Appendix A Production Data

A.1 Fairfax Water[1]

	2005	2006	2007	2008	2009	2010	2011	2012	2013	Ave.
Ave. annual production, MGD	152	159	167	145	141	157	150	151	144	152
Monthly ave. production, MGD										
January	127	132	132	131	124	131	129	128	128	129
February	123	129	128	122	120	129	126	123	125	125
March	126	134	127	121	120	133	126	130	124	127
April	140	147	137	134	132	145	132	148	137	139
May	153	170	183	145	134	163	149	158	149	156
June	180	192	207	167	138	194	191	184	158	179
July	175	189	221	176	187	207	206	202	168	192
August	184	220	210	191	172	183	184	181	164	188
September	197	164	204	158	159	190	153	165	170	173
October	154	149	175	144	142	149	140	142	148	149
November	135	137	139	124	130	127	132	127	129	131
December	133	136	132	122	128	130	127	125	125	129
Peak 1-day production, MGD										
January	142	141	139	141	138	140	138	138	134	139
February	137	139	140	130	141	139	135	134	137	137
March	137	146	137	131	129	143	135	136	137	137
April	159	165	168	151	170	162	146	189	152	162
May	174	223	225	172	154	191	189	176	183	187
June	219	239	239	198	171	235	225	251	183	218
July	201	240	255	207	217	259	239	244	198	229
August	212	250	251	214	214	217	227	204	186	220
September	222	182	235	193	185	223	175	178	198	199
October	218	168	211	169	163	175	160	162	181	179
November	143	145	158	136	136	137	139	137	138	141
December	143	156	144	130	134	141	137	134	135	139
Ave. Jul.-Oct. production, MGD	177	181	202	167	165	182	171	173	162	176

[1] Includes water sold to Loudoun Water. See A.4 – Loudoun Water (Purchased).

A.2 Aqueduct

	2005	2006	2007	2008	2009	2010	2011	2012	2013	Ave.
Ave. annual production, MGD	164	159	165	158	158	156	146	138	134	153
Monthly ave. production, MGD										
January	155	143	137	150	159	147	145	132	124	144
February	159	149	160	146	150	150	142	128	126	146
March	148	151	150	144	145	144	134	133	123	141
April	156	152	150	146	150	148	137	137	127	145
May	153	157	170	153	157	154	144	135	135	151
June	176	169	184	168	167	174	162	147	144	166
July	187	183	191	184	181	184	172	160	151	177
August	179	193	192	179	187	167	168	157	145	174
September	181	159	178	169	164	165	154	144	144	162
October	161	154	170	156	154	149	134	130	131	149
November	155	150	152	146	144	142	131	132	128	142
December	154	148	145	150	140	145	129	118	123	139
Peak 1-day production, MGD										
January	193	166	158	175	193	172	163	146	137	167
February	190	187	187	161	172	174	165	138	148	169
March	179	195	167	159	167	161	167	153	132	164
April	176	170	181	185	177	175	152	157	141	168
May	176	189	206	184	177	170	176	151	150	175
June	202	192	209	202	185	200	198	189	159	193
July	220	221	224	202	206	234	210	189	179	209
August	205	225	232	220	218	205	190	187	159	205
September	197	182	201	204	177	191	176	162	168	184
October	185	182	192	177	176	165	158	149	154	171
November	178	172	165	159	186	184	144	167	137	166
December	197	210	217	209	163	169	146	129	143	176
Ave. Jul.-Oct. production, MGD	177	172	183	172	171	166	157	148	143	165

A.3 WSSC

	2005	2006	2007	2008	2009	2010	2011	2012	2013	Ave.
Ave. annual production, MGD	172	169	172	163	163	175	169	164	159	167
Monthly ave. production, MGD										
January	161	156	150	154	160	162	164	154	153	157
February	162	156	163	152	150	165	159	151	153	157
March	161	157	156	151	152	160	158	151	149	155
April	165	163	158	154	155	163	163	162	153	160
May	173	175	183	162	159	172	173	168	159	169
June	188	185	189	177	167	194	194	181	167	182
July	184	187	202	178	185	199	201	189	173	189
August	187	205	194	185	182	193	182	178	167	186
September	192	171	188	173	170	195	168	169	169	177
October	170	165	174	161	161	169	161	159	157	164
November	161	156	155	154	156	163	155	153	152	156
December	160	153	156	151	157	165	153	151	151	155
Peak 1-day production, MGD										
January	187	178	163	169	210	181	218	190	181	186
February	173	165	181	165	166	176	173	162	183	172
March	176	170	168	168	166	179	166	163	179	171
April	182	181	178	167	179	180	177	184	169	178
May	188	221	212	193	178	189	200	190	181	195
June	226	219	222	251	183	229	216	216	186	216
July	202	219	223	197	207	233	225	226	206	215
August	203	225	219	213	201	217	206	203	180	207
September	213	186	213	193	186	223	183	179	189	196
October	204	181	195	177	186	182	176	171	185	184
November	188	167	169	172	166	176	173	165	168	171
December	177	167	178	189	187	184	160	161	163	174
Ave. Jul.-Oct. production, MGD	183	182	189	174	174	189	178	174	166	179

A.4 Loudoun Water (Purchased)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	Ave.
Ave. annual production, MGD	18	19	22	21	20	22	21	23	22	21
Monthly ave. production, MGD										
January	14	15	15	16	16	17	17	17	18	16
February	14	15	16	16	16	17	17	17	17	16
March	14	15	16	16	16	17	17	18	18	16
April	16	18	18	20	20	22	17	23	22	20
May	18	22	27	22	19	24	20	25	24	22
June	22	23	31	27	22	30	32	30	26	27
July	22	26	34	29	29	31	34	33	28	29
August	24	30	30	30	28	27	29	28	27	28
September	26	20	28	25	24	28	21	25	28	25
October	19	17	19	21	19	20	19	21	22	20
November	16	16	16	17	17	17	17	18	19	17
December	15	13	16	16	16	17	17	17	18	16
Peak 1-day production, MGD										
January	15	17	20	17	18	18	19	18	19	18
February	15	16	19	17	18	19	18	18	19	17
March	17	18	20	17	21	19	18	19	21	19
April	19	21	23	23	26	26	21	30	26	24
May	24	31	38	27	23	28	30	28	31	29
June	29	30	38	34	28	35	38	38	31	34
July	24	33	40	35	36	43	39	38	34	36
August	29	35	37	35	35	33	36	32	31	34
September	29	24	32	30	28	33	26	31	33	30
October	28	21	26	24	23	24	21	31	29	25
November	20	18	17	19	19	19	19	19	21	19
December	17	16	17	17	20	18	18	18	20	18
Ave. Jul.-Oct. production, MGD	23	23	27	26	25	27	26	27	26	26

A.5 CO-OP System[2]

	2005	2006	2007	2008	2009	2010	2011	2012	2013	Ave.
Ave. annual production, MGD	488	487	504	465	462	487	465	453	436	472
Monthly ave. production, MGD										
January	443	431	419	435	444	441	437	414	405	430
February	444	435	451	420	420	444	427	402	404	428
March	435	442	433	416	417	436	418	414	396	423
April	461	462	445	434	437	456	433	447	417	444
May	479	502	536	460	451	488	466	461	443	476
June	544	545	580	512	471	561	547	511	468	527
July	546	558	614	539	552	590	579	551	493	558
August	550	618	596	554	541	542	534	516	476	548
September	569	494	570	500	493	550	475	478	484	512
October	485	468	518	461	457	468	435	431	436	462
November	450	443	446	424	429	432	418	413	409	429
December	447	436	433	423	425	440	410	393	399	423
Peak 1-day production, MGD										
January	488	449	452	464	531	476	496	448	441	472
February	484	466	472	442	454	474	455	416	441	456
March	462	494	451	444	450	461	449	427	427	451
April	514	498	502	488	513	507	469	530	447	496
May	535	612	638	519	489	525	562	515	502	544
June	630	625	656	591	528	656	618	645	518	607
July	600	662	694	603	617	697	671	652	568	640
August	611	696	686	620	602	620	618	561	517	615
September	595	535	628	580	542	605	511	505	544	560
October	587	531	586	508	525	503	479	465	511	522
November	485	474	492	458	480	465	439	446	427	463
December	490	489	503	479	441	469	425	409	418	458
Ave. Jul.-Oct. production, MGD	537	535	575	514	511	537	506	494	472	520

[2] Includes water provided to Loudoun Water by Fairfax Water.

Appendix B Calculating the Annual Demand Forecast

This appendix details the methods and data used to calculate past and forecasted unit use rates and describes how these rates were used to generate the average annual demand forecast as discussed in Chapter 3. The general steps for the annual demand forecast were as follows:

Past Unit Use (Section B.1 and B.2)

1. Gather past billing data (2008-2013) by end user category (single family household, multi-family household, employee). If needed, make assumptions to approximate use by the needed categories.
2. Calculate or estimate each utility's unmetered use rate by dividing the amount billed to customers by the amount produced or purchased for the period 2008-2013.
3. Use a geographic information system to determine the number of households and employees in the Metropolitan Washington Council of Governments (MWCOG) Round 8.3 data that are in each utility's service area.
4. Calculate 2010 and 2015 dwelling unit ratios (DUR) for each utility, based on the jurisdiction(s) they serve, using data on the number of single family households (SFH) and multi-family households (MFH). Data from the jurisdictions were used when available. If local data were not available, data from the U.S. Census Bureau were used.
5. Use DURs to divide 2010 and 2015 MWCOG household data for each service area into SFH and MFH.
6. Pull the number of SFH and MFH in 2005 from the 2010 demand study.
7. Use the number of SFH and MFH in 2005, 2010, and 2015 to interpolate the number of households in 2008 and 2009 and 2011 through 2013.
8. Divide each supplier's water use by category by the number of single family households, multi-family households, and employees in their service area. This generates the unit use factors for each supplier in each year between 2008 and 2013.

Unit Use Forecast (Section B.3)

9. Calculate unit use rates for the beginning of the forecast period (2015). The average of the unit use rates between 2008 and 2013 were used, thus minimizing decreases due to the recession.
10. Estimate future changes in water use behavior to calculate end use savings for SFH and MFH and employees (EMP).
11. Apply future end use savings to the estimated 2015 unit use rates to estimate rates through 2040.

Annual Demand Forecast (Section B.4)

12. Use a geographic information system to determine the number of households and employees in the MWCOG Round 8.3 forecast that are in each utilities' projected service area, through 2040.
13. Estimate future DURs based on data and information from local jurisdictions or the U.S. Census Bureau, in five-year increments through 2040.
14. Use forecasted DURs to divide MWCOG household data for each service area into single family and multi-family households.

15. Multiply the future unit use rates by the estimates of single family households, multi-family households, and employees for each water supplier and forecast year. This yields annual water use by customer category in each forecast year.
16. Estimate the amount of unmetered water use in each forecast year. If the average of the unmetered rates between 2008 and 2013 was higher than ten percent, this rate was used. If the average was less than ten percent, the unmetered use rate was assumed to be ten percent.
17. Sum the total amount of single family household, multi-family household, employee, unmetered use, and sales to wholesale customers for each supplier in each forecast year to calculate the annual demand forecast.

Completing these steps required data from multiple sources. The data sources for the annual demand forecast are billing data and service area extents from the water suppliers, including the wholesale customers; demographic information from MWCOG; and additional demographic data from local jurisdictions and the U.S. Census (Figure B-1).

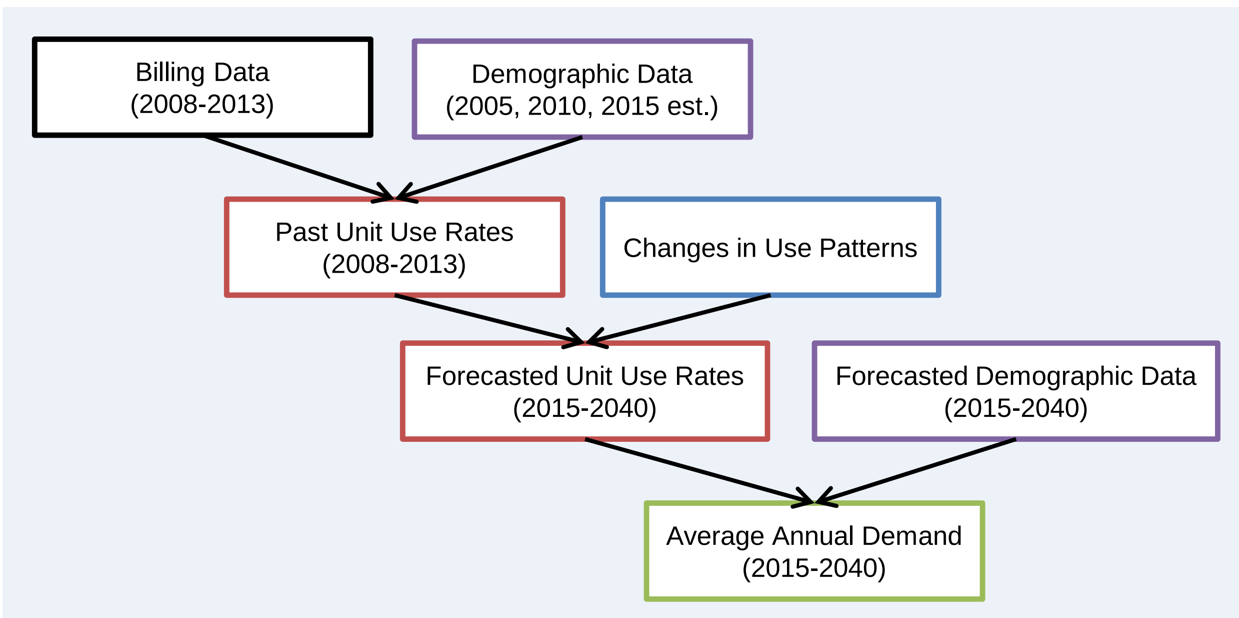

Figure B-1: Data requirements for the annual demand forecast.

The following sections detail the data received and any assumptions made to calculate the annual demand forecast for each supplier.

B.1 Dwelling Unit Ratios

Dwelling unit ratios (DUR) are calculated as the number of single family households divided by the number of multi-family households. Households are occupied housing units. County and municipal planning agencies were asked for the current and forecasted number of single family and multi-family households by traffic analysis zone (TAZ), the planning unit in the MWCOG forecasts. Few jurisdictions had these exact data and many assumptions had to be made for the DUR calculations.

Once calculated, the DURs were applied to the MWCOG household data to estimate the number of single family households (SFH) and multi-family households (MFH), since MWCOG reports only a combined figure. To determine the number of total households in each service area, the MWCOG Round 8.2 TAZs were clipped to the service area shapefiles within ESRI's ArcMap. From this, the percent of each TAZ within the corresponding service area was calculated. This percent was then applied to the number of households, employees, and the population in the given TAZ. This results in a better demographic estimate for each service area.

A review of the TAZ percentages was done for WSSC to determine if there was a benefit to a more detailed analysis of the adjusted TAZs. To do this, the service areas and TAZs were viewed using Google Earth. Here, the area-based percentage could be adjusted based on the location of buildings within the TAZ. For instance, there may be a TAZ that is 50 percent in the service area and 50 percent outside the service area. When viewing the aerial photography it may be clear that while the TAZ area is divided equally, all of the buildings fall in the portion of the TAZ outside of the service area. Therefore, the 50 percent would be adjusted to zero.

This detailed review of the TAZs on the border of WSSC's service area was completed. The adjusted percentages were applied to the demographic data. When comparing the demographic numbers after applying the original and the adjusted percentages, the differences in the total household, employment, and population figures were less than or equal to one percent. Given this small difference, it was determined not to be significant enough to impact the study's results. The original area-based percentages were used.

The data received and the assumptions made to calculate the DURs are detailed below. Typically, the jurisdictions provided the number of SFH and MFH, and CO-OP calculated the DUR. Common assumptions that had to be made were:

- If a jurisdiction does not track the number of households, but only the number of housing units, the vacancy rate had to be applied to estimate the number of households.
- If projections were not available, the most recent DUR was assumed for all future years.
- Attached single family homes, townhouses, etc. were aggregated into the SFH category. Any household type with more than one unit was categorized as MFH.

Montgomery, Prince George's, and Prince William counties provided household data by TAZ. This allowed the DUR to be calculated specifically by service area, instead of for an entire jurisdiction. This was not needed for those water suppliers whose service area matches a jurisdiction's boundaries: District of Columbia, Arlington County, City of Alexandria, Dale City, Herndon, Vienna, and Rockville. Other service areas lie wholly or partially within a larger jurisdiction and the DUR for the whole jurisdiction was applied to the smaller service area (Dulles Airport, Ft. Myer, Ft. Belvoir). Brief descriptions of the data available and assumptions for each jurisdiction are below. The DURs used for each water supplier appear in the data tables in the next section.

Fairfax County and the Town of Vienna, Virginia – Fairfax County produces Annual Demographic Reports (Fairfax County, 2015) containing the number of single family detached, single family attached, and multi-family housing units, as well as the county-wide vacancy rate. Each report provides estimates of the future number of housing units by unit type. These reports were used to gather data for 2010. The Fairfax County forecasts for 2015 through 2040 were taken from the 2013 Annual Demographic Report.

While the total number of households was available, the number of households by unit type was not. Therefore, the housing unit data, described above, was the starting point for analysis. A household estimate was calculated by applying the county vacancy rate to the number of single family and multi-family housing units. From these estimates, the DUR was calculated. This was based on data for the entire county; no adjustments were made to match the extent of the Fairfax Water service area.

For the forecast years a vacancy rate estimate was not available for Fairfax County. An estimated vacancy rate was calculated for each forecast year from the forecasted number of households and housing units provided in the 2013 report. Once this was calculated, the estimates of SFH and MFH were made.

The annual demographic reports do not contain current data for the City of Fairfax or the City of Falls Church; Herndon and Vienna figures are included. There were no forecasts specific to the Town of Vienna or Herndon. The Vienna DURs were calculated from the county dataset. Herndon-specific data were available through the town and were used to calculate the DURs.

The Herndon and Vienna housing unit and household numbers were not subtracted from the county totals when estimating the county-wide DUR. This was not done because there were no forecasts specific to the towns for single family or multi-family housing units. Therefore, for consistency, the county-wide data were used for the Fairfax County DUR.

For Herndon and Vienna, single family and multi-family housing units by type and the total number of households for the report year (2008 through 2014) were available. No forecasts for Herndon or Vienna were available so the future years' DURs were set equal to the 2013 value. Again, only Vienna numbers from this dataset were used. Herndon DURs were calculated using data from the town, as discussed below.

While Falls Church and the City of Fairfax are also within the county boundaries, they are independent jurisdictions and do their own demographic forecasts. See below for their demographic information.

The county's DURs were used for the Dulles Airport and Ft. Belvoir service areas.

Dulles International Airport, Virginia – Dulles is partially within Fairfax County. Fairfax County's DUR was applied to the Dulles service area households.

Ft. Belvoir, Virginia – Fairfax County's DUR was used for Ft. Belvoir.

Herndon, Virginia – Each year Herndon produces the Annual Population Estimate Memo for population and housing units as of January 1 of that year. The memo includes a vacancy rate that can be used to calculate the number of households. The memo also includes a total housing unit projection for 2020 and 2030, but does not have estimates for SFH or MFH. The DUR from 2014 is assumed for all forecast years.

Loudoun County, Virginia – At the time of the data request from the county, data from the 2010 Census has not yet been analyzed so the number of 2010 housing units by TAZ was not available (Kaneff, personal communication, 2014). Using the data compiled for MWCOG Round 8.3, Loudoun County provided the number of single family and multi-family households by the county's Planning Sub Areas by applying the vacancy rate to the number of housing units. Estimates were provided for 2010 through 2014 and forecasts in five-year increments between 2015 and 2040.

The Planning Sub Areas used for the Loudoun Water service area were: Potomac, Sterling, Dulles, and Ashburn (Kaneff, personal communication, 2014). The eastern portion of the Leesburg planning area is also in the service area. This area was excluded from the analysis since it includes the Town of Leesburg, which is outside the CO-OP system.

Prince William County, Virginia – MWCOG Round 8.2 SFH and MFH forecasts from 2010 to 2040 by TAZ were received from the county. Single family and townhouse units were combined into one SFH category. PWCSA service area ratios were applied to the county data to get estimate of households in service area.

City of Alexandria, Virginia – The Alexandria Department of Planning and Zoning provided the estimated number of single family and multi-family households from 2008 through 2040. These estimates were based on the forecasts done by the city for MWCOG in 2013.

Dale City, Virginia – Dale City household information was included in the data received from Prince William County. Since the data were provided by TAZ, only the data in Dale City TAZs were pulled out to calculate the DUR. The method used to calculate the Prince William County DURs, was used for Dale City.

District of Columbia – Housing unit and household data were available from the U.S. Census American Community Survey (U.S. Census Bureau, American Community Survey (d, e)). ACS has estimates of the number of housing units by unit type and the overall vacancy rate. Data from the ACS were assumed to be for the middle year of the period (data in the 2009-2011 ACS were used for this study's 2010 DUR calculation). Data for 2010 were the total number of housing units and the percentages of houses by unit type. Both datasets had information on the number of occupied housing units, allowing for the calculation of the number of households.

Data for projections of the future number of single-family versus multi-family households were unavailable. It was assumed that all future years (2015-2040) had the same DUR as in 2012.

Arlington County, Virginia – Single family and multi-family housing unit data, as well as the vacancy rates, for the county were available online for 2010 (Arlington County Government, 2015a and 2015b). Forecasts were available through 2040. Arlington's DURs were also used for the Ft. Myer service area.

Ft. Myer, Virginia – Ft. Myer is within Arlington County; Arlington's DUR was used for the service area.

City of Falls Church, Virginia – The City of Falls Church provided the total number of households from 2010 to 2040, and the number of additional households by unit type expected between 2005 and 2040. Since an initial number of households by unit type was not available, American Community Survey data had to be used. The 2006-2010 ACS (U.S. Census Bureau, American Community Survey (a)) survey for the city was used to estimate the percentage of single family and multi-family households in 2010. These percentages were applied to the 2010 total household number from Falls Church and the number of households by type was estimated through 2040, and the DUR was calculated.

For the purposes of the demand forecast, Falls Church households after 2014 are included with Fairfax Water retail area.

Town of Vienna, Virginia – See Fairfax County, Virginia.

Montgomery County, Maryland – The county provided SFH and MFH by TAZ from the county's submission to the MWCOG Round 8.3 forecast.

Prince George's County, Maryland – The county provided MWCOG Round 8.3 projections of single family and multi-family housing units by TAZ. The vacancy rate in 2010 was 7.4 percent according to the 2010 Census. This rate was applied to 2010 MWCOG data and the entire forecast period, across all TAZs. The percent of each TAZ in the WSSC service area was calculated for the current service area. WSSC predicts no change in the Prince George's County portion of the service area in the future so the percent values were the same for each TAZ in the forecast years. The percent was applied to the number of single family and multi-family households in the service area and the DUR was calculated.

Rockville, Maryland – Rockville supplied the historic number of single family and multi-family households using the U.S. Census' Censtats Building Permits Database (http://censtats.census.gov). This database has the annual number of new residential building permits. Data were given for 2008 through 2013. The number of 2005 households is used as the base year. Since the data provided by Rockville were for housing units and not households, data from the American Community Survey had to be used instead (U.S. Census Bureau, American Community Survey (c)). The ACS three-year period data were used to estimate the number of households. The ACS has estimates of the number of housing units by unit type and the overall vacancy rate. Data from the ACS were assumed to be for the middle year of the period (data in the 2009-2011 ACS were used for this study's 2010 DUR calculation).

For the forecasted numbers of SFH and MFH, the estimated number of additional housing units by type for each forecast year was provided by Rockville. The base year for these data is 2010 housing units. The vacancy rate from the 2009-2012 ACS was applied to the number of housing units to estimate the number of households. Once the number of single family and multi-family households was estimated for 2010, the additional number of households for each forecast year was added and the DUR calculated.

B.2 Water Supplier Data and Unit Use Calculations

The data requested from the water suppliers were the:

- amount of water produced at the water treatment plant(s) or purchased from another supplier,
- amount sold to other utilities, if applicable,
- customer billing records by end user category,
- calculations or estimates of unmetered (unaccounted/non-revenue) water use, and
- current and forecasted service area extent.

The data were requested by calendar year for the period 2008-2013. Not all suppliers were able to provide this information, or the exact data requested. Summaries of the information provided and any assumptions made for each supplier are below. Each supplier's summary table also includes the demographic data used to calculate the unit use rates and the resulting rates. For display purposes, numbers were rounded to fewer digits than were used in the analysis.

Data shown for each utility are what was supplied. There are some discrepancies between the amount wholesale suppliers (Fairfax Water, Washington Aqueduct, WSSC) report selling to wholesale customers and the amount the customers report purchasing. If there was a difference, the data reported by the wholesale customer was used.

B.2.1 Fairfax Water

Fairfax Water provided the requested data by calendar year for the period 2008-2013. In addition to providing water to their retail customers, Fairfax Water also supplied water to the following wholesale customers:

- Dulles International Airport
- Fort Belvoir
- Town of Herndon
- Loudoun Water
- Prince William County Service Authority
- Virginia American, City of Alexandria
- Virginia American, Dale City

The customer billing information for the retail area and each wholesale customer is detailed below.

B.2.1.1 Fairfax Water – Retail

- Service Area: Current and future service area maps were provided that included the service areas of wholesale customers.
- Produced: Provided for 2008-2013 by calendar year.
- Unmetered: Calculated.
- Billing: Fairfax Water's billing data were reported in the following categories:
    - Single Family
    - Townhouse
    - Apartment
    - Commercial and Industrial
    - Municipal and Institutional

The categories were grouped into the three categories needed for this study:

- SFH: Single Family, Townhouse
- MFH: Apartment
- EMP: Commercial and Industrial, Municipal and Institutional

Table B- 1: Data for unit use calculations and results – Fairfax Water - Retail.

			Historic Data					
			2008	**2009**	**2010**	**2011**	**2012**	**2013**
Produced (MGD)			145.08	140.61	156.95	149.69	151.6	143.92
Demand (MGD)	**Retail Sales**	**Single Family Household**	45.14	43.95	46.16	44.65	43.07	41.81
		Multi-Family Household	12.95	13.10	13.22	13.81	13.07	13.74
		Employee	17.32	16.57	17.28	17.04	16.06	14.79
	Wholesale Sales		61.68	61.56	65.90	65.13	65.77	63.68
	Unmetered		7.99	5.43	14.39	9.06	13.63	9.90
	Percent Unmetered		6%	4%	9%	6%	9%	7%
	Total		145.08	140.61	156.95	149.69	151.60	143.92
Demographics	**Population**		837,377	845,395	853,414	861,433	869,451	877,470
	Employees		420,196	422,736	425,276	427,816	430,356	432,895
	Households		303,489	305,277	307,065	308,853	310,641	312,428
	DUR				2.76			
	Single Family Households		224,174	224,783	225,391	225,999	226,608	227,216
	Multi-Family Households		79,315	80,495	81,674	82,853	84,033	85,212
Unit Use (gpd)	**Single Family Household**		201.4	195.5	204.8	197.6	190.1	184
	Multi-Family Household		163.3	162.7	161.9	166.7	155.5	161.2
	Employee		41.2	39.2	40.6	39.8	37.3	34.2

Notes: Wholesale sales reported in this table are also reported as "purchased" for each of Fairfax Water's wholesale customers in the tables that follow.

B.2.1.2 Fairfax Water – Dulles International Airport

- Service Area: Provided by Fairfax Water.
- Purchased: Fairfax Water provided the amount sold to Dulles in 2008 through 2013 by calendar year.
- Unmetered: Assumed ten percent.
- Billing: No billing data were obtained from Dulles.
- Unit use assumptions: Assumed the SFH and MFH rates were the same as Fairfax Water. These rates were multiplied by the number of households in the Dulles service area from the MWCOG data. The total amount of household use was summed and this was subtracted from the amount Fairfax Water reported selling to them. Ten percent of this was assumed to be unmetered use. The remaining amount was assumed to be the total amount of employee water use. This total amount was divided by the number of employees reported by MWCOG to estimate the EMP unit use rate.

Table B-2: Data for unit use calculations and results – Fairfax Water - Dulles.

			Historic Data					
			2008	**2009**	**2010**	**2011**	**2012**	**2013**
Purchased (MGD)			0.76	0.76	0.79	0.82	0.79	0.81
Demand (MGD)	**Retail Sales**	**Single Family Household**	0.01	0.01	0.01	0.01	0.01	0.01
		Multi-Family Household	0.002	0.002	0.002	0.002	0.002	0.002
		Employee	0.68	0.67	0.70	0.73	0.70	0.72
	Unmetered		0.07	0.08	0.08	0.08	0.08	0.08
	Percent Unmetered		9%	11%	10%	10%	10%	10%
	Total		0.76	0.76	0.79	0.82	0.79	0.81
Demographics	**Population**		92	103	115	126	137	149
	Employees		18,143	19,281	20,420	20,887	21,354	21,822
	Households		37	42	47	52	56	61
	DUR				2.76			
	Single Family Households		28	31	35	39	42	46
	Multi-Family Households		10	11	12	13	14	15
Unit Use (gpd)	**Single Family Household**		(201.4)	(195.5)	(204.8)	(197.6)	(190.1)	(184.0)
	Multi-Family Household		(163.3)	(162.7)	(161.9)	(166.7)	(155.5)	(161.2)
	Employee		37.5	34.9	34.4	34.8	32.9	32.9

Notes: Fairfax Water's DUR was assumed for 2010. Unit use rates in parenthesis are assumptions.

B.2.1.3 Fairfax Water – Ft. Belvoir

- Service Area: Provided by Fairfax Water.
- Purchased: Fairfax Water provided the amount sold to Ft. Belvoir in 2008 through 2013 by calendar year. Purchased information from Ft. Belvoir was not obtained.
- Unmetered: Assumed ten percent.
- Billing: No billing data were obtained from Ft. Belvoir.
- Unit use assumptions: Assumed the SFH and MFH rates were the same as Fairfax Water. These rates were multiplied by the number of households in the Ft. Belvoir service area from the MWCOG data. The total amount of household use was summed and this was subtracted from the amount Fairfax Water reported selling to them. Ten percent of this was assumed to be unmetered use. The remaining amount was assumed to be the total amount of employee water use. This total amount was divided by the number of employees reported by MWCOG to estimate the EMP unit use rate.

Table B-3: Data for unit use calculations and results – Fairfax Water - Ft. Belvoir.

			Historic Data					
			2008	2009	2010	2011	2012	2013
Purchased (MGD)			1.72	1.62	1.82	1.83	1.95	1.66
Demand (MGD)	**Retail Sales**	**Single Family Household**	0.11	0.13	0.15	0.14	0.14	0.13
		Multi-Family Household	0.04	0.04	0.04	0.05	0.04	0.05
		Employee	1.40	1.29	1.44	1.45	1.57	1.32
	Unmetered		0.17	0.16	0.18	0.18	0.20	0.17
	Percent Unmetered		10%	10%	10%	10%	10%	10%
	Total		1.72	1.62	1.82	1.83	1.95	1.66
Demographics	**Population**		5,026	6,304	7,582	7,588	7,593	7,599
	Employees		24,265	26,395	28,525	30,341	32,157	33,972
	Households		783	890	996	998	1,000	1,001
	DUR				2.76			
	Single Family Households		567	650	732	729	726	724
	Multi-Family Households		216	240	264	269	273	278
Unit Use (gpd)	**Single Family Household**		(201.4)	(195.5)	(204.8)	(197.6)	(190.1)	(184)
	Multi-Family Household		(163.3)	(162.7)	(161.9)	(166.7)	(155.5)	(161.2)
	Employee		57.5	48.9	50.5	47.9	48.9	38.7

Notes: Fairfax Water's DUR was assumed for 2010. Unit use rates in parenthesis are assumptions.

B.2.1.4 Fairfax Water – Herndon

- Service Area: Provided by Fairfax Water.
- Purchased: Fairfax Water provided the amount sold to Herndon in 2008 through 2013 by calendar year. Herndon supplied amount purchased; numbers are very similar. The numbers Herndon provided were used.
- Unmetered: No assumptions needed.
- Billing: Herndon tracks billing data by fiscal year (July 1 - June 30). For the requested period, the following was available: July through December of 2009, 2010, 2011, 2012, and January through June of 2013. Herndon re-grouped these data by calendar year and used typical consumption ratios to fill in the missing months of data (Barnes, personal communication, 2015). The billing data were grouped into two categories: residential and commercial. They were categorized for this study as:
  - Residential (combined SFH and MFH use): Residential
  - EMP: Commercial
- Unit use assumptions: The Residential use category was used instead of SFH and MFH unit use.

Table B-4: Data for unit use calculations and results – Fairfax Water - Herndon.

			Historic Data					
			2008	**2009**	**2010**	**2011**	**2012**	**2013**
Purchased (MGD)			2.31	2.11	2.16	2.12	2.14	1.97
Demand (MGD)	**Retail Sales**	**Residential**	1.19	1.11	1.14	1.09	1.05	0.93
		Employee	1.06	0.99	1.04	1.03	0.97	0.98
	Unmetered		0.06	0.01	-0.02	0.00	0.12	0.06
	Percent Unmetered		3%	0%	0%	0%	6%	3%
	Total		2.31	2.11	2.16	2.12	2.14	1.97
Demographics	**Population**		20,944	20,481	20,019	20,212	20,405	20,597
	Employees		21,432	21,253	21,074	21,245	21,415	21,586
	Households		7,213	7,162	7,111	7,178	7,246	7,313
	DUR				2.11			
	Single Family Households		4,891	4,857	4,824	4,876	4,928	4,980
	Multi-Family Households		2,323	2,305	2,287	2,302	2,318	2,333
Unit Use (gpd)	**Residential**		165.0	155.0	160.3	151.9	144.9	127.2
	Employee		49.5	46.6	49.3	48.5	45.3	45.4

B.2.1.5 Fairfax Water – Loudoun Water

- Service Area: Provided by Fairfax Water.
- Purchased: Fairfax Water provided the amount sold to Loudoun Water. Loudoun Water reported the same amounts as purchased. Loudoun Water also reported a small amount purchased from the City of Fairfax.
- Unmetered: No assumptions needed.
- Billing: Loudoun Water's billing data was reported in the following categories:
    - Single family attached (townhouses) and detached residences
    - Multi-family residences
    - Non-residential (e.g. office, retail, data centers, commercial, etc.) customers
    - Contractors (not directly contracted with Loudoun Water), landscaping companies, swimming pool contractors, etc. The metered values are reported and billed on a monthly or quarterly basis. Also referred to as fire hydrant meters.
    - Contractors constructing water mains on behalf of developers (not contracted directly with Loudoun Water). These quantities of water are estimated (not metered) by field personnel and billing is based on the estimated values.
    - Water used at Loudoun Water owned and operated facilities such as offices and treatment plants; includes an estimate for water main flushing.

  The categories were grouped into the three categories needed for this study:
    - SFH: Single family attached and detached residences
    - MFH: multi-family residences
    - EMP: non-residential, all contractors, Loudoun Water facilities

Table B-5: Data for unit use calculations and results – Fairfax Water - Loudoun Water.

			Historic Data					
			2008	2009	2010	2011	2012	2013
Purchased (MGD)			21.39	20.74	21.83	21.91	22.17	22.23
Demand (MGD)	Retail Sales	Single Family Household	11.79	11.48	12.53	11.96	12.46	12.22
		Multi-Family Household	1.86	1.91	2.00	2.02	2.07	2.19
		Employee	5.23	4.83	5.58	5.43	6.20	5.72
	Unmetered		2.51	2.52	1.72	2.50	1.44	2.10
	Percent Unmetered		12%	12%	8%	11%	6%	9%
	Total		21.39	20.74	21.83	21.91	22.17	22.23
Demographics	Population		190,707	200,654	210,601	219,910	229,219	238,529
	Employees		103,613	107,250	110,887	114,170	117,453	120,735
	Households		64,973	67,708	70,444	73,533	76,622	79,711
	DUR				4.17			
	Single Family Households		53,139	54,978	56,817	59,202	61,588	63,973
	Multi-Family Households		11,834	12,730	13,627	14,331	15,034	15,738
Unit Use (gpd)	Single Family Household		221.9	208.8	220.5	202.0	202.3	191.0
	Multi-Family Household		157.2	150.0	146.8	141.0	137.7	139.2
	Employee		50.5	45.0	50.3	47.6	52.8	47.4

Loudoun Water notes that water use between 2008 and 2013 was low compared to other years (Lipinski, personal communication, June 8, 2015). Higher use rates are expected in the coming years related to summertime outdoor water use, especially during years with little rainfall.

B.2.1.6 Fairfax Water – Prince William County Service Authority

- Service Area: Provided by Fairfax Water.
- Purchased: Fairfax Water provided the amount sold to PWCSA by calendar year. The PWCSA Finance Department provided the amount purchased by fiscal year for 2008 through 2013. The data for 2008 through 2011 were estimates as the data were not readily available (Guerra, personal communication, 2014). PWCSA also purchases water from the City of Manassas. Therefore, the amount they report as purchased is higher than the amount Fairfax Water reported selling to them. Not accounted for in this amount is the water supplied to customers from groundwater wells. Since this is a small portion of the service area, it is not thought to have a significant impact on the unit use calculations. The numbers reported here, and for the purpose of calculating the unit use rates, are from PWCSA.
- Unmetered: The PWCSA Finance Department provided the amount of unmetered water by fiscal year for 2008 through 2013. The data for 2008 through 2011 were estimates as the data were not readily available (Guerra, personal communication, 2014). Ten percent was assumed in calculations to be conservative.

- Sold: PWSCA reported selling a small amount of water (0.1 MGD) to other utilities in 2011 through 2013.
- Billing: PWSCA provided data for residential and commercial water usage for 2013 and the first six months of 2014.
- Unit use assumptions: Since billing data were limited, assumed the SFH and MFH rates were the same as Loudoun Water. These rates were multiplied by the number of households for the PWCSA service area from the MWCOG data. The total amount of household use was summed and this was subtracted from the amount PWCSA reported purchasing from Fairfax Water and the City of Manassas. Ten percent of this was assumed to be unmetered use. The remaining amount was assumed to be the total amount of employee water use. This total amount was divided by the number of employees reported by MWCOG to estimate the EMP unit use rate.

Table B-6: Data for unit use calculations and results – Fairfax Water - PWCSA.

			Historic Data					
			2008	**2009**	**2010**	**2011**	**2012**	**2013**
Purchased (MGD)			25.80	26.10	26.40	26.60	26.90	25.30
Demand (MGD)	**Retail Sales**	**Single Family Household**	16.36	16.01	17.55	16.32	16.57	15.87
		Multi-Family Household	2.72	2.65	2.65	2.80	2.98	3.27
		Employee	4.14	4.83	3.56	4.82	4.65	3.63
	Wholesale Sales		0.00	0.00	0.00	0.00	0.10	0.10
	Unmetered		2.58	2.58	2.61	2.64	2.56	2.59
	Percent Unmetered		10%	10%	10%	10%	10%	10%
	Total		25.80	25.80	26.10	26.40	26.60	26.90
Demographics	**Population**		271,100	282,801	294,501	302,627	310,753	318,879
	Employees		80,321	81,093	81,865	85,127	88,388	91,650
	Households		91,003	94,335	97,667	100,630	103,593	106,557
	DUR				4.41			
	Single Family Households		73,728	76,670	79,612	80,767	81,921	83,076
	Multi-Family Households		17,275	17,665	18,055	19,864	21,672	23,481
Unit Use (gpd)	**Single Family Household**		(221.9)	(208.8)	(220.5)	(202.0)	(202.3)	(191.0)
	Multi-Family Household		(157.2)	(150.0)	(146.8)	(141.0)	(137.7)	(139.2)
	Employee		51.6	59.6	43.4	56.7	52.6	39.6

Notes: Unit use rates in parenthesis are assumptions.

B.2.1.7 Fairfax Water – Virginia American Water, City of Alexandria

- Service Area: Provided by Fairfax Water.
- Purchased: Fairfax Water provided the amount sold to them.
- Unmetered: Assumed ten percent.
- Billing: No data were received from Virginia American Water.
- Unit use assumptions: Assumed the SFH and MFH rates were the same as Fairfax Water. These rates were multiplied by the number of households in the Alexandria service area from the MWCOG data. The total amount of household use was summed and this was subtracted from the amount Fairfax Water reported selling to them. Ten percent of this was assumed to be unmetered use. The remaining amount was assumed to be the total amount of employee water use. This total amount was divided by the number of employees reported by MWCOG to estimate the EMP unit use rate.

Table B-7: Data for unit use calculations and results – Fairfax Water - Virginia American Water, Alexandria.

			Historic Data					
			2008	**2009**	**2010**	**2011**	**2012**	**2013**
Purchased (MGD)			15.46	15.02	15.79	15.47	15.57	14.90
Demand (MGD)	**Retail Sales**	**Single Family Household**	4.10	3.93	4.06	3.92	3.77	3.66
		Multi-Family Household	7.68	7.76	7.82	8.19	7.77	8.18
		Employee	2.13	1.84	2.33	1.81	2.48	1.57
	Unmetered		1.55	1.49	1.58	1.55	1.55	1.49
	Percent Unmetered		10%	10%	10%	10%	10%	10%
	Total		15.46	15.01	15.79	15.47	15.57	14.90
Demographics	**Population**		138,316	139,137	139,958	141,669	143,380	145,091
	Employees		104,065	103,480	102,895	104,366	105,836	107,307
	Households		67,413	67,772	68,131	68,966	69,801	70,636
	DUR				0.41			
	Single Family Households		20,372	20,093	19,814	19,833	19,853	19,872
	Multi-Family Households		47,041	47,679	48,317	49,133	49,948	50,764
Unit Use (gpd)	**Single Family Household**		(201.4)	(195.5)	(204.8)	(197.6)	(190.1)	(184.0)
	Multi-Family Household		(163.3)	(162.7)	(161.9)	(166.7)	(155.5)	(161.2)
	Employee		20.5	17.7	22.6	17.4	23.4	14.7

Notes: Unit use rates in parenthesis are assumptions.

B.2.1.8 Fairfax Water – Virginia American Water, Dale City

- Service Area: Provided by Fairfax Water.
- Purchased: Fairfax Water provided the amount sold to them.
- Unmetered: Assumed ten percent.
- Billing: No data were received from Virginia American Water.
- Unit use assumptions: Assumed the SFH and MFH rates were the same as Fairfax Water. These rates were multiplied by the number of households in the Dale City service area from the MWCOG data. The total amount of household use was summed and this was subtracted from the amount Fairfax Water reported selling to them. Ten percent of this was assumed to be unmetered use. The remaining amount was assumed to be the total amount of employee water use. This total amount was divided by the number of employees reported by MWCOG to estimate the EMP unit use rate.

Table B-8: Data for unit use calculations and results – Fairfax Water - Virginia American Water, Dale City.

			Historic Data					
			2008	2009	2010	2011	2012	2013
Purchased (MGD)			5.77	4.83	4.95	4.77	4.87	4.60
Demand (MGD)	**Retail Sales**	**Single Family Household**	3.56	3.59	3.90	3.79	3.68	3.59
		Multi-Family Household	0.54	0.45	0.35	0.36	0.34	0.36
		Employee	1.09	0.32	0.21	0.14	0.36	0.19
	Unmetered		0.58	0.48	0.49	0.48	0.49	0.46
	Percent Unmetered		10%	10%	10%	10%	10%	10%
	Total		5.77	4.83	4.95	4.78	4.87	4.60
Demographics	**Population**		64,944	65,801	66,658	67,247	67,837	68,426
	Employees		9,371	9,424	9,477	9,806	10,135	10,463
	Households		20,979	21,099	21,219	21,384	21,549	21,715
	DUR				8.76			
	Single Family Households		17,680	18,363	19,045	19,202	19,358	19,515
	Multi-Family Households		3,298	2,736	2,174	2,183	2,191	2,200
Unit Use (gpd)	**Single Family Household**		(201.4)	(195.5)	(204.8)	(197.6)	(190.1)	(184.0)
	Multi-Family Household		(163.3)	(162.7)	(161.9)	(166.7)	(155.5)	(161.2)
	Employee		116.2	33.5	21.8	14.2	35.7	18.5

Notes: Unit use rates in parenthesis are assumptions.

B.2.2 Washington Aqueduct

Aqueduct provided the amount of water produced and the amount sold to wholesale customers between 2004 and 2013 by calendar year.

B.2.2.1 Washington Aqueduct – DC Water

- Service area: The service area is the boundary of the District of Columbia. There have been no changes since the 2010 study.
- Purchased: Washington Aqueduct supplied the amount sold to DC Water by calendar year between 2004 and 2013.
- Unmetered: No assumption. Note that these rates are high because of how fire hydrant use is accounted for.
- Billing: Data provided by DC Water was by fiscal year (October 1 – September 30). To estimate the amount billed for this study, data from fiscal years 2008 through 2011 were used. The numbers reported represent the net amount billed to customers after corrections and does not include fire hydrant use (Preston, personal communication, 2014).

  DC Water's billing data were reported in the following categories:
  - Commercial
  - Exempt – meters exempt from billing (This is the first time this has been used, this previously was in the municipal category.)
  - Federal
  - Housing – DC Housing Authority
  - Municipal – DC Government, excluding housing
  - Multi-family – buildings with 4 or more dwelling units
  - Residential – buildings with one to three dwelling units
  - WASA – DC Water's own use
  - Washington Aqueduct

  The DC Water categories were grouped into the categories needed for this study:
  - SFH: Residential
  - MFH: Housing, Multi-family
  - EMP: Commercial, exempt, federal, municipal
  - Other : DC Water and Washington Aqueduct

Table B-9: Data for unit use calculations and results – Washington Aqueduct - DC Water.

			Historic Data					
			2008	**2009**	**2010**	**2011**	**2012**	**2013**
Purchased (MGD)			114.87	110.72	104.43	102.96	99.46	95.50
Demand (MGD)	**Retail Sales**	**Single Family Household**	17.61	16.90	16.99	16.82	16.03	15.65
		Multi-Family Household	19.46	18.62	18.31	17.91	17.10	16.86
		Employee	45.06	42.99	42.51	43.43	42.37	39.22
		Other	1.70	1.77	1.60	1.28	1.05	0.37
	Unmetered		31.04	30.44	25.02	23.52	22.91	23.4
	Percent Unmetered		27%	27%	24%	23%	23%	25%
	Total		114.87	110.72	104.43	102.96	99.46	95.50
Demographics	**Population**		593,924	597,844	601,764	613,517	625,270	637,022
	Employees		770,180	776,820	783,460	789,357	795,255	801,152
	Households		261,376	264,041	266,707	270,788	274,869	278,950
	DUR		0.63	0.64	0.59	0.61	0.59	0.59
	Single Family Households		100,570	99,768	98,966	100,481	101,996	103,510
	Multi-Family Households		160,806	164,274	167,741	170,307	172,873	175,440
Unit Use (gpd)	**Single Family Household**		175.1	169.4	171.7	167.4	157.2	151.2
	Multi-Family Household		121.0	113.3	109.2	105.2	98.9	96.1
	Employee		58.5	55.3	54.3	55.0	32.9	32.9

B.2.2.2 Washington Aqueduct – Arlington County DES

- Service Area: No change from 2010 service area boundary.
- Purchased: Provided by Washington Aqueduct for calendar year 2004 through 2013. Arlington also provided amount purchased from Washington Aqueduct. The two sets of numbers matched.
- Sold: Provided the amount sold to Ft. Myer from 2008 through 2013.
- Unmetered: Provided an approximation of unaccounted for water. Since the unaccounted for numbers sent by Arlington were an estimate using rounded numbers, the numbers shown below are ones calculated by subtracting the amount sold to retail customers and Fort Myer from the amount purchased from Washington Aqueduct.
- Billing: Provided the actual amount billed to customers by calendar year from 2008 to 2013. The billing data was reported in the following categories:
    - Residential: single family homes
    - Commercial and large apartments: commercial and large apartments, county agencies
    - Apartments: multifamily duplexes and apartment buildings

  The categories were grouped into the three categories needed for this study:
    - SFH: Residential
    - MFH: Apartments
    - EMP: Commercial

Table B-10: Data for unit use calculations and results – Washington Aqueduct - Arlington County DES.

			Historic Data					
			2008	2009	2010	2011	2012	2013
Purchased (MGD)			23.15	23.20	23.78	22.46	22.76	22.15
Demand (MGD)	Retail Sales	Single Family Household	5.77	5.76	5.65	5.50	5.40	5.27
		Multi-Family Household	5.65	5.42	5.65	5.57	5.49	5.50
		Employee	8.27	8.56	8.86	8.31	8.19	8.30
	Wholesale Sales		0.35	0.30	0.30	0.26	0.28	0.55
	Unmetered		3.11	3.16	3.32	2.82	3.4	2.53
	Percent Unmetered		13%	14%	14%	13%	15%	11%
	Total		23.15	23.20	23.78	22.46	22.76	22.15
Demographics	Population		202,626	204,625	206,624	209,676	212,727	215,779
	Employees		207,560	212,495	217,430	222,589	227,748	232,908
	Households		95,489	96,682	97,875	99,403	100,932	102,460
	DUR				0.59			
	Single Family Households		36,502	36,411	36,320	36,275	36,229	36,184
	Multi-Family Households		58,987	60,271	61,555	63,129	64,703	66,276
Unit Use (gpd)	Single Family Household		158.1	158.2	155.6	151.6	149.1	145.6
	Multi-Family Household		95.8	89.9	91.8	88.2	84.8	83.0
	Employee		39.8	40.3	40.7	37.3	36.0	35.6

Notes: The wholesale values are also reported in the Ft. Myer table as “purchased” since they are a wholesale customer of Arlington.

B.2.2.3 Washington Aqueduct – Arlington – Ft. Myer

- Service Area: No change from 2010 service area boundary.
- Purchased: Arlington reported the amount sold to Ft. Myer between 2008 and 2013.
- Unmetered: Assumed ten percent.
- Unit use assumptions: Assumed the SFH and MFH rates were the same as Fairfax Water. These rates were multiplied by the number of households in the Ft. Myer service area from the MWCOG data. The total amount of household use was summed and this was subtracted from the amount Arlington reported selling to them. Ten percent of this was assumed to be unmetered use. The remaining amount was assumed to be the total amount of employee water use. This total amount was divided by the number of employees reported by MWCOG to estimate the EMP unit use rate.

Table B-11: Data for unit use calculations and results – Washington Aqueduct - Arlington - Ft. Myer.

			Historic Data					
			2008	**2009**	**2010**	**2011**	**2012**	**2013**
Purchased (MGD)			0.35	0.30	0.30	0.26	0.28	0.55
Demand (MGD)	**Retail Sales**	**Single Family Household**	0.02	0.02	0.01	0.01	0.01	0.01
		Multi-Family Household	0.02	0.02	0.02	0.02	0.02	0.02
		Employee	0.27	0.24	0.24	0.20	0.22	0.47
	Unmetered		0.03	0.03	0.03	0.02	0.03	0.05
	Percent Unmetered		10%	10%	10%	10%	10%	10%
	Total		0.35	0.30	0.30	0.26	0.28	0.54
Demographics	**Population**		1,639	1,321	1,003	1,003	1,003	1,003
	Employees		4,349	5,091	5,834	5,514	5,194	4,874
	Households		227	201	175	175	175	175
	DUR				0.59			
	Single Family Households		88	76	65	64	63	62
	Multi-Family Households		139	125	110	111	112	113
Unit Use (gpd)	**Single Family Household**		(201.4)	(201.4)	(204.8)	(197.6)	(190.1)	(184.0)
	Multi-Family Household		(163.3)	(163.3)	(161.9)	(166.7)	(155.5)	(161.2)
	Employee		63.0	63.0	41.0	36.6	42.9	95.6

Notes: Arlington County’s DUR was assumed for 2010. Unit use rates in parenthesis are assumptions.

B.2.2.4 Washington Aqueduct – Falls Church

- Service Area: Provided by Fairfax Water.
- Purchased: Washington Aqueduct provided the amount sold to them in calendar year 2004 through 2013. Fairfax Water provided the amount sold to them in 2008 through 2013 by calendar year. Purchased information from Falls Church was not available.
- Unmetered: Assumed ten percent.
- Billing: Limited data were available for 2008 and 2009; detailed data were available for 2013.
- Unit use assumptions: Assumed the SFH and MFH rates were the same as Fairfax Water. These rates were multiplied by the number of households in the Falls Church service area from the MWCOG data. The total amount of household use was summed and this was subtracted from the amount Washington Aqueduct and Fairfax Water reported selling to them. Ten percent of this was assumed to be unmetered use. The remaining amount was assumed to be the total amount of employee water use. This total amount was divided by the number of employees reported by MWCOG to estimate the EMP unit use rate.

  Estimates for 2011 through 2013 could not be made because household estimates were not available. The estimates could not be calculated because the area served by Falls Church became part of Fairfax Water's retail area in 2014, so there are no households or employees for Falls Church in 2015, which is the year used to estimate 2011 through 2014 demographics for the utilities.

Table B-12: Data for unit use calculations and results – Washington Aqueduct - Falls Church.

			Historic Data		
			2008	**2009**	**2010**
Purchased (MGD)			17.25	16.70	16.65
Demand (MGD)	**Retail Sales**	**Single Family Household**	7.01	6.97	7.48
		Multi-Family Household	2.50	2.40	2.29
		Employee	6.01	5.66	5.21
	Unmetered		1.73	1.66	1.66
	Percent Unmetered		10%	10%	10%
Demographics	**Population**		128,179	129,631	131,082
	Employees		127,738	128,042	128,346
	Households		50,123	50,413	50,704
	DUR				1.5
	Single Family Households		34,817	35,675	36,533
	Multi-Family Households		15,306	14,738	14,171
Unit Use (gpd)	**Single Family Household**		(201.4)	(195.5)	(204.8)
	Multi-Family Household		(163.3)	(162.7)	(161.9)
	Employee		47.1	44.2	40.6

Notes: Unit use rates in parenthesis are assumptions.

B.2.2.5 Washington Aqueduct – Falls Church – Vienna

- Service Area: Provided by Fairfax Water.
- Purchased: Fairfax Water provided the amount sold to Vienna which is only a portion of the total amount they used. Before 2013, Vienna also purchased water from Falls Church. Since no data were available from Falls Church, the total amount purchased could not be calculated. The amount Vienna purchased from Falls Church in 2008 (2.12 MGD) was available from the 2010 Demand Study.
- Unmetered: Assumed ten percent.
- Unit use assumptions: Estimates of water use by customer category could only be made for 2008. This is because this was the only year for which the amount of water purchased by Vienna from Falls Church was known. The 2008 estimate assumed the SFH and MFH rates were the same as Fairfax Water. These rates were multiplied by the number of households in the Vienna service area from the MWCOG data. The total amount of household use was summed and this was subtracted from the amount Fairfax Water and Falls Church reported selling to them. Ten percent of this was assumed to be unmetered use. The remaining amount was assumed to be the total amount of employee water use. This total amount was divided by the number of employees reported by MWCOG to estimate the EMP unit use rate.

Table B-13: Data for unit use calculations and results – Washington Aqueduct - Falls Church - Vienna.

			Historic Data
			2008
Purchased (MGD)			2.25
Demand (MGD)	**Retail Sales**	**Single Family Household**	1.70
		Multi-Family Household	0.14
		Employee	0.19
	Unmetered		0.23
	Percent Unmetered		10%
	Total		2.25
Demographics	**Population**		26,836
	Employees		13,390
	Households		9,288
	DUR		8.82
	Single Family Households		8,439
	Multi-Family Households		849
Unit Use (gpd)	**Single Family Household**		(201.4)
	Multi-Family Household		(163.3)
	Employee		13.9

Notes: Unit use rates in parenthesis are assumptions.

B.2.3 WSSC

- Service area: The map of the current service area is based on the existing pipes.
- Produced: WSSC provided the amount produced from 2008 through 2013 by calendar year.
- Unmetered: Provided the *2013 Water Loss Reduction Plan* as submitted to the Maryland Department of the Environment. This report says that for fiscal year 2012, the unaccounted for water losses were 17.4 percent. The calculated unmetered use rate (production minus retail and wholesale sales) was used in analysis.
- Sold: The amount sold to wholesale customers was provided for 2010 to 2012 by fiscal year for Rockville, DC Water, Bowie, Howard County, and Charles County. Daily average consumption (DAC), or a rolling average of consumption, values were also provided for Rockville, DC Water, Howard County, and Charles County by calendar year for 2008 through 2013. Since the 2010 Demand Study used the DAC to estimate the wholesale sales, it was also used in this report for consistency.
- Billing: Retail billing data were also provided as the DAC. To calculate the annual use, an average of the DAC over 12 months was taken.

Table B-14: Data for unit use calculations and results – WSSC.

			Historic Data					
			2008	2009	2010	2011	2012	2013
Produced (MGD)			163.18	162.95	174.92	169.36	164.32	158.63
Demand (MGD)	**Retail Sales**	**Single Family Household**	76.22	69.84	70.85	69.52	68.39	67.83
		Multi-Family Household	30.07	29.87	30.39	29.87	26.44	27.88
		Employee	31.34	29.31	30.59	31.44	35.56	32.37
	Wholesale Sales		1.07	2.34	6.69	5.67	4.43	3.39
	Unmetered		24.48	31.59	36.4	32.86	29.5	27.16
	Percent Unmetered		15%	19%	21%	19%	18%	17%
	Total		163.18	162.95	174.92	169.36	164.32	158.63
Demographics	**Population**		1,680,764	1,693,115	1,705,466	1,717,929	1,730,392	1,742,855
	Employees		783,457	814,957	759,727	766,099	772,471	778,842
	Households		612,106	614,603	617,100	623,748	630,395	637,043
	DUR - Montgomery County				2.02			
	DUR - Prince George's County				2.51			
	Single Family Households		417,538	421,827	426,116	429,321	432,525	435,730
	Multi-Family Households		194,569	192,776	190,984	194,427	197,870	201,313
Unit Use (gpd)	**Single Family Household**		182.5	165.6	166.3	161.9	158.1	155.7
	Multi-Family Household		154.5	154.9	159.1	153.6	133.6	138.5
	Employee		40.0	36.0	40.3	41.0	46.0	41.6

B.2.4 Rockville

- Service area: Provided by Rockville.
- Produced: The amount produced was estimated by subtracting the amount purchased from WSSC from the amount conveyed to customers (Lish, personal communication, 2014).
- Purchased: The amount purchased was provided by Rockville by calendar year for 2008 through 2013.
- Unmetered: Rockville supplied water audit reports for 2010, 2011, and 2012. Assumed ten percent.
- Billing: No billing data were available for 2008 and were very limited for 2009. Only 2010 and 2013 were used in the study. Rockville's billing data were reported in the following categories:
    - Residential: single family households
    - Commercial: business as well as apartments and condos
    - Tax exempt category: church, schools, and government buildings

  The categories were grouped into the three categories needed for this study:
    - SFH: residential
    - MFH_ EMP: commercial and tax exempt
- Unit use assumptions: Reduced SFH unit use by ten percent to estimate MFH unit use. This use rate was then multiplied by the number of multi-family households in Rockville to get the total multi-family use. This and the total single family use were subtracted from the total water purchased and produced, minus ten percent for the unmetered water assumption, to estimate the employee use. The employee use was then divided by the number of employees to estimate an employee unit use rate.

Table B-15: Data for unit use calculations and results – Rockville.

			Historic Data		
			2010	2011	2012
Produced (MGD)			3.48	4.65	4.87
Purchased (MGD)			1.56	0.01	0.12
Demand (MGD)	Retail Sales	Single Family Household	1.91	1.89	1.80
		Multi-Family Household	1.04	1.05	1.02
		Employee	1.59	1.25	1.67
	Unmetered		0.51	0.47	0.50
	Percent Unmetered		10%	10%	10%
	Total		5.05	4.66	4.99
Demographics	Population		47,556	47,824	48,091
	Employees		61,234	61,706	62,178
	Households		19,435	19,561	19,688
	DUR		1.65		
	Single Family Households		12,102	12,090	12,078
	Multi-Family Households		7,333	7,472	7,610
Unit Use (gpd)	Single Family Household		157.8	156.3	149.0
	Multi-Family Household		142.0	140.7	134.2
	Employee		25.9	20.3	26.9

B.3 End Use Savings

The end use savings model used in this study attempted to more accurately account for the reduction in water use that can be attributed to low flow appliances and fixtures. Previous CO-OP studies only looked at toilets and showerheads. In addition to those, this study considers savings from clothes washers, dishwashers, and faucets. A simple estimate is also made for savings from low-flow toilets in commercial buildings.

Also different from previous studies is the additional assumption about the market share for conventional, low flow (EPAct), and high efficiency (WaterSense or Energy Star) fixtures and appliances. The tables below summarize the assumptions used for the flow rates, natural replacement rates (non-incentivized), frequency of household use, and market share (Table B-16 through Table B-21). This method is adapted from information and the method described in a 2013 study completed for Tampa Bay Water on demand management (see Hazen and Sawyer, 2013).

Table B-16: Mechanical efficiency ratings (flow rates) compiled from EPAct and WaterSense information, and from Hazen and Sawyer (2013).

Fixture	Unit	Flow Rate		
		Conventional (average)	Low Flow	High Efficiency
Residential Toilets	Gallon per flush (gpf)	4.25	1.6	1.28
Commercial Toilets	Gallon per flush (gpf)	3.5	1.6	1.28
Showerheads	Gallon per minute (gpm)		2.2	1.15
Faucets	Gallon per minute (gpm)		2.2	1.15
Washing machines	Gallon/cycle/ft^3	40.0 – 15.1		29.7 – 12.7
Dishwasher	Gallon/load	8.7 – 6.0		4.5

Notes: Flow rate ranges indicate that efficiency ratings are expected to change over time due to changing standards and specifications. Showerheads and faucets rates are difficult to estimate since the user can adjust the flow during use.

Table B-17: Natural replacement rate of fixtures (Hazen and Sawyer, 2013).

Fixture	Expected Life (Years)	Natural Replacement Rate (1/expected life)
Residential Toilets	25	4.0%
Commercial Toilets	30	3.3%
Showerheads	8	12.5%
Residential faucets	8	12.5%
Washing machines	12	8.3%
Dishwasher	8	12.5%

Table B-18: Frequency of fixture and appliance use (Hazen and Sawyer, 2013).

Fixture	Event	Event Frequencies	Total Use
Residential Toilets	flushes/person/day	5.05	11.4 total flushes
Commercial Toilets	flushes/employee/day	3.0	n/a
Showerheads	minutes/person/day	6.1	13.8 total minutes
Faucets	minutes/person/day	8.1	18.3 total minutes
Washing machines	loads/person/day	0.37	0.8 total loads
Dishwasher	loads/person/day	0.23	0.5 total loads

Note: Assumes 2.26 people per household.

Table B-19: Percent market share of EPAct and WaterSense-rated toilets (McNeil, 2008).

Year	WaterSense	EPAct
2015	13%	87%
2020	28%	72%
2025	47%	53%
2030	66%	34%
2035	70%	30%
2040	87%	13%

Notes: Gray values were extrapolated. These rates were also assumed for commercial toilets.

Table B-20: Percent market share of EPAct and WaterSense-rated faucets (Michael McNeil, 2008).

Year	WaterSense	EPAct
2015	24%	76%
2020	44%	56%
2025	64%	36%
2030	84%	16%
2035	99%	1%
2040	99%	1%

Notes: Gray values were extrapolated. These rates were also assumed for showerheads.

Table B-21: Percent of market share of conventional and high efficiency clothes washers (Hazen and Sawyer, 2013).

Year	Conventional	High Efficiency
2015	47%	53%
2020	33%	67%
2025	30%	70%
2030	30%	70%
2035	30%	70%
2040	30%	70%

Notes: Gray values were extrapolated. These rates were also assumed for dishwashers.

The results from the model used for each fixture or appliance are in Table B-22. The end use savings rates applied to the 2015 unit use rates are in Table B-23.

Table B-22: Estimated household fixture and appliance water use (gallons/household/day).

	Water Use					
Year	**Toilets**	**Clothes Washers**	**Dishwashers**	**Faucets**	**Showerheads**	**Total**
2015	29.2	12.7	3.6	34.0	24.9	104.4
2020	26.6	12.4	3.3	29.7	20.9	92.8
2025	24.5	12.3	3.2	27.3	19.4	86.6
2030	22.7	12.3	3.2	26.0	18.7	82.9
2035	21.4	12.3	3.2	25.3	18.5	80.6
2040	20.4	12.3	3.2	24.8	18.4	79.1

Table B-23: Savings applied to 2015 unit use rates to estimate the unit use rate in the given forecast year (gallons/day).

Year	SFH and MFH Savings	EMP Savings
2015	--	--
2020	12	1
2025	18	1
2030	21	1
2035	24	2
2040	25	2

B.4 Annual Demand Forecast by Supplier

This section summarizes the data used for each supplier's annual demand forecast calculation. This includes the forecasted unit use rates, demographics, and unmetered use. Unmetered use is the average of the past year's unmetered rates, if equal to or greater than ten percent. If less than ten percent, the rate was assumed to be ten percent. These instances are identified in the table notes.

Note the following changes in service areas and wholesale customers that occurred between 2013 and 2014:

- Falls Church is no longer a wholesale customer of Washington Aqueduct, it became part of Fairfax Water's retail area in 2014;
- The City of Fairfax became part of Fairfax Water's retail area in 2014, it previously supplied its own water and was not included in the demand studies; and
- Vienna became a wholesale customer of Fairfax Water in 2013.

Table B-24: Unit use, demographic, and average annual demand forecasts – Fairfax Water - Retail.

			Forecasts					
			2015	2020	2025	2030	2035	2040
Demand (MGD)	Retail Sales	Single Family Household	53.55	50.56	50.04	50.24	50.20	50.76
		Multi-Family Household	18.01	19.01	20.97	22.89	24.76	26.86
		Employee	24.03	25.63	27.62	29.45	29.85	30.93
	Wholesale Sales		83.35	87.35	92.02	96.56	99.17	102.80
	Unmetered		9.56	9.52	9.86	10.26	10.48	10.86
	Percent Unmetered		10%	10%	10%	10%	10%	10%
	Total		186.30	190.06	198.42	207.29	212.36	220.15
Demographics	Population		1,067,578	1,106,090	1,165,195	1,218,248	1,269,738	1,320,451
	Employees		620,932	679,872	732,721	781,229	813,420	842,821
	Households		384,996	402,143	427,478	450,189	472,106	493,749
	DUR		2.51	2.22	1.97	1.8	1.65	1.53
	Single Family Households		273,767	275,355	281,749	287,741	292,565	297,515
	Multi-Family Households		111,229	126,788	145,729	162,448	179,541	196,234
Unit Use (gpd)	Single Family Household		195.6	183.6	177.6	174.6	171.6	170.6
	Multi-Family Household		161.9	149.9	143.9	140.9	137.9	136.9
	Employee		38.7	37.7	37.7	37.7	36.7	36.7

Notes: Wholesale sales reported in this table are also reported as "purchased" for each of Fairfax Water's wholesale customers in the tables that follow. Assumed 10% unmetered use rate.

Table B-25: Unit use, demographic, and average annual demand forecasts – Fairfax Water - Dulles.

			Forecasts					
			2015	**2020**	**2025**	**2030**	**2035**	**2040**
Demand (MGD)	**Retail Sales**	**Single Family Household**	0.01	0.03	0.04	0.04	0.05	0.05
		Multi-Family Household	0.003	0.01	0.01	0.02	0.02	0.02
		Employee	0.79	0.88	0.98	1.04	1.05	1.08
	Unmetered		0.08	0.09	0.10	0.11	0.11	0.12
	Percent Unmetered		10%	10%	10%	10%	10%	10%
	Total		0.88	1.00	1.13	1.21	1.23	1.27
Demographic	**Population**		171	499	650	805	955	1,058
	Employees		22,756	26,065	29,074	31,011	32,164	33,223
	Households		70	207	276	346	416	460
	DUR		2.51	2.22	1.97	1.8	1.65	1.53
	Single Family Households		53	155	195	234	275	296
	Multi-Family Households		17	52	81	112	141	164
Unit Use (gpd)	**Single Family Household**		195.6	183.6	177.6	174.6	171.6	170.6
	Multi-Family Household		161.9	149.9	143.9	140.9	137.9	136.9
	Employee		34.6	33.6	33.6	33.6	32.6	32.6

Notes: Assumed Fairfax Water's forecasted DURs.

Table B-26: Unit use, demographic, and average annual demand forecasts – Fairfax Water - Ft. Belvoir.

			Forecasts					
			2015	**2020**	**2025**	**2030**	**2035**	**2040**
Demand (MGD)	**Retail Sales**	**Single Family Household**	0.14	0.13	0.13	0.13	0.13	0.14
		Multi-Family Household	0.05	0.05	0.05	0.06	0.07	0.07
		Employee	1.83	1.97	2.24	2.50	2.45	2.46
	Unmetered		0.21	0.22	0.25	0.27	0.27	0.27
	Percent Unmetered		10%	10%	10%	10%	10%	10%
	Total		2.22	2.37	2.67	2.97	2.92	2.94
Demographic	**Population**		7,610	7,704	7,882	8,039	8,194	8,343
	Employees		37,604	41,278	46,876	52,476	52,544	52,615
	Households		1,005	1,046	1,119	1,187	1,253	1,316
	DUR		2.51	2.22	1.97	1.8	1.65	1.53
	Single Family Households		718	721	744	765	779	798
	Multi-Family Households		287	325	375	422	474	518
Unit Use (gpd)	**Single Family Household**		195.6	183.6	177.6	174.6	171.6	170.6
	Multi-Family Household		161.9	149.9	143.9	140.9	137.9	136.9
	Employee		48.7	47.7	47.7	47.7	46.7	46.7

Note: Assumed Fairfax Water's forecasted DURs.

Table B-27: Unit use, demographic, and average annual demand forecasts – Fairfax Water - Herndon.

			Forecasts					
			2015	**2020**	**2025**	**2030**	**2035**	**2040**
Demand (MGD)	**Retail Sales**	**Residential**	1.12	1.04	1.01	1.00	0.98	0.99
		Employee	1.04	1.07	1.11	1.15	1.16	1.20
	Unmetered		0.32	0.32	0.32	0.32	0.32	0.32
	Percent Unmetered		15%	15%	15%	15%	15%	15%
	Total		2.49	2.42	2.44	2.47	2.47	2.52
Demographics	**Population**		20,983	21,112	21,332	21,533	21,733	21,935
	Employees		21,927	22,986	23,895	24,750	25,563	26,471
	Households		7,448	7,501	7,593	7,678	7,766	7,851
	DUR		2.15	2.15	2.15	2.15	2.15	2.15
	Single Family Households		5,084	5,120	5,182	5,240	5,300	5,359
	Multi-Family Households		2,364	2,381	2,411	2,438	2,466	2,492
Unit Use (gpd)	**Residential**		150.7	138.7	132.7	129.7	126.7	125.7
	Employee		47.4	46.4	46.4	46.4	45.4	45.4

Note: Assumed 15% unmetered use rate.

Table B-28: Unit use, demographic, and average annual demand forecasts – Fairfax Water - Loudoun Water.

			Forecasts					
			2015	**2020**	**2025**	**2030**	**2035**	**2040**
Demand (MGD)	**Retail Sales**	**Single Family Household**	14.29	14.96	14.99	14.78	14.59	14.52
		Multi-Family Household	2.49	2.98	3.53	3.97	4.13	4.17
		Employee	6.23	7.49	8.56	9.54	9.93	10.47
	Unmetered		2.22	2.22	2.46	2.62	2.73	2.77
	Percent Unmetered		10%	10%	10%	10%	10%	10%
	Total		25.22	27.88	29.69	31.02	31.42	31.98
Demographics	**Population**		257,147	293,205	313,105	322,144	327,161	328,469
	Employees		127,301	156,382	178,695	199,062	211,614	223,269
	Households		85,889	98,720	106,650	111,043	113,463	114,101
	DUR		4.01	3.42	2.85	2.48	2.33	2.29
	Single Family Households		68,744	76,393	78,956	79,136	79,388	79,417
	Multi-Family Households		17,145	22,327	27,694	31,907	34,075	34,684
Unit Use (gpd)	**Single Family Household**		207.8	195.8	189.8	186.8	183.8	182.8
	Multi-Family Household		145.3	133.3	127.3	124.3	121.3	120.3
	Employee		48.9	47.9	47.9	47.9	46.9	46.9

Note: The method used to develop the forecasts may not be as well suited for Loudoun Water as for the other suppliers. In 2008, a water use study was conducted for their center service area that showed that over two-thirds of the homes had been constructed after 1994 and, therefore, likely already have low flow appliances and fixtures installed (Lipinski, personal communication, June 8, 2015). This could mean that the end use savings applied between 2015 and 2040 lead to an underestimate of forecasted demand. The next iteration of the demand study may want to consider varying the model to account for this.

Table B-29: Unit use, demographic, and average annual demand forecasts – Fairfax Water - PWCSA.

			Forecasts					
			2015	2020	2025	2030	2035	2040
Demand (MGD)	Retail Sales	Single Family Household	17.74	17.64	17.87	18.27	18.65	19.19
		Multi-Family Household	3.94	4.75	5.52	6.20	6.65	7.01
		Employee	4.97	5.63	6.36	7.16	7.82	8.67
	Wholesale Sales		0.1	0.10	0.10	0.10	0.10	0.10
	Unmetered		2.67	2.67	2.80	2.98	3.16	3.31
	Percent Unmetered		10%	10%	10%	10%	10%	10%
	Total		29.41	30.91	32.83	34.89	36.53	38.46
Demographics	Population		335,131	369,944	400,188	427,080	450,319	469,536
	Employees		98,173	113,563	128,230	144,261	160,853	178,394
	Households		112,483	125,666	137,530	147,684	156,303	163,242
	DUR		3.15	2.53	2.17	1.96	1.85	1.8
	Single Family Households		85,385	90,066	94,147	97,800	101,466	104,949
	Multi-Family Households		27,098	35,600	43,383	49,884	54,837	58,293
Unit Use (gpd)	Single Family Household		207.8	195.8	189.8	186.8	183.8	182.8
	Multi-Family Household		145.3	133.3	127.3	124.3	121.3	120.3
	Employee		50.6	49.6	49.6	49.6	48.6	48.6

Table B-30: Unit use, demographic, and average annual demand forecasts – Fairfax Water - Virginia American, Alexandria.

			Forecasts					
			2015	**2020**	**2025**	**2030**	**2035**	**2040**
Demand (MGD)	**Retail Sales**	**Single Family Household**	3.90	3.74	3.75	3.67	3.74	3.83
		Multi-Family Household	8.48	8.49	8.67	8.98	9.40	9.92
		Employee	2.14	2.15	2.41	2.75	2.74	2.92
	Unmetered		1.45	1.44	1.48	1.54	1.59	1.67
	Percent Unmetered		10%	10%	10%	10%	10%	10%
	Total		15.97	15.81	16.31	16.94	17.47	18.33
Demographics	**Population**		148,513	158,102	167,085	174,030	184,741	194,890
	Employees		110,248	116,812	131,152	149,552	157,405	167,598
	Households		72,306	76,978	81,352	84,717	89,941	94,890
	DUR		0.38	0.36	0.35	0.33	0.32	0.31
	Single Family Households		19,911	20,372	21,089	21,020	21,806	22,456
	Multi-Family Households		52,395	56,606	60,263	63,697	68,135	72,434
Unit Use (gpd)	**Single Family Household**		195.6	183.6	177.6	174.6	171.6	170.6
	Multi-Family Household		161.9	149.9	143.9	140.9	137.9	136.9
	Employee		19.4	18.4	18.4	18.4	17.4	17.4

Table B-31: Unit use, demographic, and average annual demand forecasts – Fairfax Water - Virginia American Water, Dale City.

			Forecasts					
			2015	2020	2025	2030	2035	2040
Demand (MGD)	Retail Sales	Single Family Household	3.88	3.77	3.76	3.80	3.84	3.91
		Multi-Family Household	0.36	0.34	0.33	0.33	0.33	0.33
		Employee	0.28	0.30	0.34	0.38	0.41	0.45
	Unmetered		0.45	0.44	0.44	0.45	0.46	0.47
	Percent Unmetered		10%	10%	10%	10%	10%	10%
	Total		4.96	4.85	4.87	4.96	5.03	5.16
Demographics	Population		69,605	72,007	74,049	75,972	77,878	79,710
	Employees		11,121	12,773	14,369	16,113	17,937	19,873
	Households		22,045	22,774	23,450	24,079	24,711	25,321
	DUR		8.94	9.07	9.2	9.33	9.48	9.66
	Single Family Households		19,828	20,511	21,148	21,749	22,356	22,943
	Multi-Family Households		2,217	2,263	2,302	2,330	2,355	2,378
Unit Use (gpd)	Single Family Household		195.6	183.6	177.6	174.6	171.6	170.6
	Multi-Family Household		161.9	149.9	143.9	140.9	137.9	136.9
	Employee		24.7	23.7	23.7	23.7	22.7	22.7

Table B-32: Unit use, demographic, and average annual demand forecasts – Fairfax Water - Vienna.

			Forecasts					
			2015	**2020**	**2025**	**2030**	**2035**	**2040**
Demand (MGD)	**Retail Sales**	**Single Family Household**	1.66	1.58	1.58	1.59	1.61	1.64
		Multi-Family Household	0.15	0.14	0.14	0.14	0.14	0.15
		Employee	0.19	0.18	0.18	0.18	0.17	0.17
	Unmetered		0.20	0.19	0.19	0.19	0.19	0.20
	Percent Unmetered		10%	10%	10%	10%	10%	10%
	Total		2.20	2.09	2.09	2.11	2.12	2.16
Demographics	**Population**		27,429	27,888	28,757	29,510	30,311	31,072
	Employees		13,504	13,822	14,045	14,233	14,377	14,509
	Households		9,152	9,304	9,592	9,839	10,102	10,358
	DUR		8.81	8.81	8.81	8.81	8.81	8.81
	Single Family Households		8,218	8,356	8,614	8,835	9,072	9,302
	Multi-Family Households		934	948	978	1,004	1,030	1,056
Unit Use (gpd)	**Single Family Household**		201.4	189.4	183.4	180.4	177.4	176.4
	Multi-Family Household		163.3	151.3	145.3	142.3	139.3	138.3
	Employee		13.9	12.9	12.9	12.9	11.9	11.9

Notes: Assumed 10% unmetered use rate. Vienna became a wholesale customer of Fairfax Water in 2013. Prior to 2013, Vienna was a wholesale customer of Washington Aqueduct.

Table B-33: Unit use, demographic, and average annual demand forecasts – Washington Aqueduct - DC Water.

			Forecasts					
			2015	**2020**	**2025**	**2030**	**2035**	**2040**
Demand (MGD)	**Retail Sales**	**Single Family Household**	17.61	17.38	17.67	18.22	18.71	19.30
		Multi-Family Household	19.38	18.31	18.15	18.47	18.70	19.19
		Employee	44.17	45.85	48.19	50.23	50.79	52.30
		Other	1.29	1.29	1.29	1.29	1.29	1.29
	Unmetered		20.15	20.15	20.25	20.86	21.59	21.90
	Percent Unmetered		25%	25%	25%	25%	25%	25%
	Total		102.61	103.09	106.16	109.80	111.40	114.63
Demographics	**Population**		660,528	715,494	764,267	808,718	852,428	883,568
	Employees		814,957	861,814	905,846	944,096	972,955	1,001,814
	Households		287,112	305,550	323,191	340,307	356,923	370,758
	DUR		0.59	0.59	0.59	0.59	0.59	0.59
	Single Family Households		106,540	113,379	119,922	126,271	132,442	137,575
	Multi-Family Households		180,572	192,171	203,269	214,036	224,481	233,183
Unit Use (gpd)	**Single Family Household**		165.3	153.3	147.3	144.3	141.3	140.3
	Multi-Family Household		107.3	95.3	89.3	86.3	83.3	82.3
	Employee		54.2	53.2	53.2	53.2	52.2	52.2

Note: The “Other” category is forecasted to be an average of the values report for 2008-2013.

Table B-34: Unit use, demographic, and average annual demand forecasts – Washington Aqueduct - Arlington County DES.

			Forecasts					
			2015	**2020**	**2025**	**2030**	**2035**	**2040**
Demand (MGD)	**Retail Sales**	**Single Family Household**	5.52	5.12	4.91	4.81	4.74	4.70
		Multi-Family Household	6.17	5.82	5.73	5.76	5.68	5.86
		Employee	9.32	10.15	10.74	11.15	10.95	11.06
	Wholesale Sales		0.29	0.28	0.28	0.28	0.27	0.27
	Unmetered		2.80	2.81	2.85	2.90	2.85	2.88
	Percent Unmetered		13%	13%	13%	13%	13%	13%
	Total		24.10	24.18	24.50	24.89	24.49	24.77
Demographics	**Population**		221,882	235,080	247,679	257,726	265,370	275,041
	Employees		243,226	272,047	287,844	298,810	301,736	304,596
	Households		105,517	112,036	117,157	121,198	124,232	128,420
	DUR		0.52	0.48	0.45	0.43	0.42	0.40
	Single Family Households		36,093	36,332	36,357	36,445	36,747	36,692
	Multi-Family Households		69,424	75,704	80,800	84,753	87,485	91,728
Unit Use (gpd)	**Single Family Household**		153.0	141.0	135.0	132.0	129.0	128.0
	Multi-Family Household		88.9	76.9	70.9	67.9	64.9	63.9
	Employee		38.3	37.3	37.3	37.3	36.3	36.3

Note: Wholesale sales reported in this table are also reported as “purchased” in the Ft. Myer table that follows.

Table B-35: Unit use, demographic, and average annual demand forecasts – Washington Aqueduct - Arlington County DES - Ft. Myer.

			Forecasts					
			2015	**2020**	**2025**	**2030**	**2035**	**2040**
Demand (MGD)	**Retail Sales**	**Single Family Household**	0.01	0.01	0.01	0.01	0.01	0.01
		Multi-Family Household	0.02	0.02	0.02	0.02	0.02	0.02
		Employee	0.23	0.23	0.23	0.23	0.22	0.22
	Unmetered		0.03	0.03	0.03	0.03	0.03	0.03
	Percent Unmetered		10%	10%	10%	10%	10%	10%
	Total		0.29	0.28	0.28	0.28	0.27	0.27
Demographics	**Population**		1,003	1,003	1,003	1,031	1,031	1,031
	Employees		4,234	4,234	4,234	4,234	4,234	4,234
	Households		175	175	175	185	185	185
	DUR		0.52	0.48	0.45	0.43	0.42	0.40
	Single Family Households		60	56	55	55	55	52
	Multi-Family Households		115	119	120	130	130	133
Unit Use (gpd)	**Single Family Household**		195.6	183.6	177.6	174.6	171.6	170.6
	Multi-Family Household		161.9	149.9	143.9	140.9	137.9	136.9
	Employee		54.2	53.2	53.2	53.2	52.2	52.2

Note: Assumed Arlington's forecasted DURs.

Table B-36: Unit use, demographic, and average annual demand forecasts – WSSC.

			Forecasts					
			2015	**2020**	**2025**	**2030**	**2035**	**2040**
Demand (MGD)	**Retail Sales**	**Single Family Household**	72.95	69.48	68.30	67.98	67.41	67.48
		Multi-Family Household	31.02	30.99	31.91	33.96	35.32	36.73
		Employee	32.30	33.45	35.59	37.73	39.19	42.12
	Wholesale Sales		6.4	6.4	6.4	6.4	6.4	6.4
	Unmetered		32.30	33.45	35.59	37.73	39.19	42.12
	Percent Unmetered		18%	18%	18%	18%	18%	18%
	Total		174.97	173.76	177.79	183.79	187.50	194.85
Demographics	**Population**		1,767,781	1,828,060	1,892,751	1,954,173	2,003,729	2,040,426
	Employees		791,586	840,321	894,240	947,967	1,009,951	1,085,632
	Households		650,338	680,298	708,220	737,349	760,639	778,192
	DUR - Montgomery County		1.88	1.74	1.61	1.44	1.34	1.27
	DUR - Prince George's County		2.45	2.38	2.34	2.31	2.26	2.21
	Single Family Households		442,139	454,110	464,631	472,062	478,090	481,981
	Multi-Family Households		208,199	226,188	243,589	265,287	282,549	296,211
Unit Use (gpd)	**Single Family Household**		165	153	147	144	141	140
	Multi-Family Household		149	137	131	128	125	124
	Employee		40.8	39.8	39.8	39.8	38.8	38.8

Note: Wholesale sales are estimated for Howard and Charles counties. Separate demand forecasts were not developed.

Table B-37: Unit use, demographic, and average annual demand forecasts – Rockville.

			Forecasts					
			2015	**2020**	**2025**	**2030**	**2035**	**2040**
Demand (MGD)	**Retail Sales**	**Single Family Household**	1.84	1.67	1.58	1.55	1.51	1.51
		Multi-Family Household	1.12	1.21	1.30	1.43	1.55	1.70
		Employee	1.55	1.57	1.67	1.81	1.85	1.95
	Unmetered		0.45	0.45	0.45	0.46	0.48	0.49
	Percent Unmetered		10%	10%	10%	10%	10%	10%
	Total		4.96	4.89	5.01	5.27	5.41	5.67
Demographics	**Population**		48,894	51,564	53,884	56,843	59,764	62,806
	Employees		63,593	67,114	71,549	77,462	82,639	86,857
	Households		20,067	21,358	22,469	23,803	25,204	26,675
	DUR		1.50	1.24	1.09	0.97	0.87	0.79
	Single Family Households		12,041	11,822	11,717	11,719	11,729	11,772
	Multi-Family Households		8,026	9,536	10,752	12,084	13,475	14,903
Unit Use (gpd)	**Single Family Household**		153.1	141.1	135.1	132.1	129.1	128.1
	Multi-Family Household		139.0	127.0	121.0	118.0	115.0	114.0
	Employee		24.4	23.4	23.4	23.4	22.4	22.4

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Appendix C Stationarity of Monthly Production Factors

The set of 12 average monthly production factors implies that monthly demand remains proportionally constant throughout the forecast period. In the 2010 and 2000 demand studies it was shown that August production factors for the CO-OP system were increasing slightly over time. A new linear trend analysis concluded that during the time period from 1990 to 2013 there is no linear trend in the water supply production factors for this study. However, there are anecdotal reports from water suppliers in the Northern Virginia suburbs that outdoor summer water use is increasing in some areas. Potential trends in monthly production factors for summer months should continue to be monitored in future WMA water supply studies.

A linear trend analysis was performed for each month by fitting a linear regression equation to a set of 14 production factors for that month and their respective years (1990-2013). A statistical analysis was then performed on the slope coefficient for each regression equation in the form of the following null hypothesis (H_0) and the two-sided alternative hypothesis (H_A):

$$H_0:\ \beta_1 = 0 \qquad \text{(C-1a)}$$
$$H_A:\ \beta_1 \neq 0 \qquad \text{(C-1b)}$$

in which β_1 is the slope coefficient of the linear regression. The null hypothesis (H_0) is tested for significance using the *t* statistics reported in Table C-1 through Table C-3. For a five percent level of significance and 22 degrees of freedom, the critical *t* value is 2.074. Therefore, the alternative hypothesis for the two-sided test is accepted if *t* is less than -2.074 or *t* is greater than 2.074. Most slope coefficients for all three water suppliers are insignificant. The slope coefficients that are significant occur in November for Fairfax Water and February and October for Aqueduct.

Table C-1: Fairfax Water linear regression coefficients and statistics for the production factor trend analysis.

	Intercept				Slope			
Month	**Coefficients**	**SE**	***t***	**p-value**	**Coefficients**	***SE***	***t***	**p-value**
Jan	3.63	1.98	1.83	8.02e-2	-1.38e-3	9.89e-4	-1.39	1.77e-1
Feb	4.56	2.18	2.09	4.83e-2	-1.85e-3	1.09e-3	-1.70	1.03e-1
Mar	4.40	2.12	2.08	4.97e-2	-1.77e-3	1.06e-3	-1.67	1.09e-1
Apr	2.83	2.49	1.14	2.68e-1	-9.47e-4	1.24e-3	-7.63e-1	4.54e-1
May	1.99	3.01	0.66	5.17e-1	-4.77e-4	1.51e-3	-3.16e-1	7.55e-1
Jun	1.29	5.24	0.25	8.07e-1	-6.92e-5	2.62e-3	-2.64e-2	9.79e-1
Jul	-6.80	5.02	-1.35	1.89e-1	4.01e-3	2.51e-3	1.60	1.24e-1
Aug	-6.31	5.54	-1.14	2.67e-1	3.75e-3	2.77e-3	1.35	1.90e-1
Sep	-5.02	4.50	-1.11	2.77e-1	3.06e-3	2.25e-3	1.36	1.88e-1
Oct	-0.10	2.42	-0.04	9.66e-1	5.44e-4	1.21e-3	4.50e-1	6.57e-1
Nov	6.60	2.64	2.50	2.03e-2	-2.85e-3	1.32e-3	-2.16	4.20e-2
Dec	5.25	2.26	2.32	3.00e-2	-2.18e-3	1.13e-3	-1.93	6.63e-2

Table C-2: WSSC linear regression coefficients and statistics for the production factor trend analysis.

	Intercept				Slope			
Month	**Coefficients**	***SE***	***t***	**p-value**	**Coefficients**	***SE***	***t***	**p-value**
Jan	0.48	2.32	0.21	0.84	2.33e-4	1.16e-3	2.02e-1	8.42e-1
Feb	-1.66	1.86	-0.89	0.38	1.30e-3	9.28e-4	1.40	1.76e-1
Mar	-0.47	1.27	-0.37	0.72	6.97e-4	6.36e-4	1.10	2.84e-1
Apr	-0.05	1.37	-0.04	0.97	5.01e-4	6.84e-4	7.32e-1	4.72e-1
May	1.42	2.12	0.67	0.51	-1.99e-4	1.06e-3	-1.88e-1	8.53e-1
Jun	3.46	2.84	1.22	0.24	-1.18e-3	1.42e-3	-8.32e-1	4.14e-1
Jul	3.14	3.38	0.93	0.36	-1.01e-3	1.69e-3	-5.96e-1	5.58e-1
Aug	1.34	3.11	0.43	0.67	-1.19e-4	1.55e-3	-7.68e-2	9.39e-1
Sep	1.02	2.45	0.42	0.68	1.34e-5	1.23e-3	1.09e-2	9.91e-1
Oct	1.27	1.13	1.12	0.27	-1.44e-4	5.64e-4	-2.55e-1	8.01e-1
Nov	2.00	1.16	1.73	0.10	-5.31e-4	5.79e-4	-9.16e-1	3.69e-1
Dec	-0.16	1.36	-0.12	0.91	5.44e-4	6.78e-4	8.02e-1	4.31e-1

Table C-3: Aqueduct linear regression coefficients and statistics for the production factor trend analysis.

	Intercept				Slope			
Month	**Coefficients**	***SE***	***t***	**p-value**	**Coefficients**	***SE***	***t***	**p-value**
Jan	-0.54	2.93	-0.18	0.86	7.41e-4	1.46e-3	5.06e-1	6.18e-1
Feb	-4.12	2.12	-1.95	0.06	2.53e-3	1.06e-3	2.39	2.60e-2
Mar	-0.48	1.34	-0.36	0.72	6.99e-4	6.67e-4	1.05	3.06e-1
Apr	0.35	1.11	0.31	0.76	2.99e-4	5.56e-4	5.38e-1	5.96e-1
May	0.88	1.98	0.45	0.66	5.16e-5	9.91e-4	5.21e-2	9.59e-1
Jun	1.55	2.14	0.72	0.48	-2.36e-4	1.07e-3	-2.21e-1	8.27e-1
Jul	1.12	2.33	0.48	0.64	1.47e-5	1.16e-3	1.26e-2	9.90e-1
Aug	0.17	2.63	0.06	0.95	4.80e-4	1.32e-3	3.65e-1	7.19e-1
Sep	3.44	2.22	1.55	0.14	-1.18e-3	1.11e-3	-1.07	2.97e-1
Oct	5.00	1.61	3.10	0.01	-2.00e-3	8.05e-4	-2.49	2.09e-2
Nov	2.78	1.92	1.44	0.16	-9.17e-4	9.61e-4	-9.55e-1	3.50e-1
Dec	1.46	1.95	0.75	0.46	-2.74e-4	9.77e-4	-2.81e-1	7.82e-1

However, the regression equations themselves are poor as shown in Table C-4 and therefore not much weight can be put on the significance of these slope coefficients. The regression equations were evaluated using the following criteria: (1) the correlation coefficient (*R*); (2) the standard error of estimate (*SE*). The square of the correlation coefficient (R^2) equals the percentage of the variance in the criterion variable explained by the predictor variable. The range of R^2 calculated for the analysis showed that only 0 to 22 percent of the variance in the monthly factors can be explained by time. The *SE* can be compared to the standard deviation (*SY*) of the monthly factors. The *SE/SY* values for all regressions were near one indicating that the regression has not improved the reliability of the prediction from simply assuming the mean of the monthly factors.

Table C-4: Goodness-of-fit statistics for the production factor trend analysis for the three water suppliers.

	Fairfax Water			**WSSC**			**Aqueduct**		
Month	R^2	***SE***	***SE/SY***	R^2	***SE***	***SE/SY***	R^2	***SE***	***SE/SY***
Jan	0.08	0.03	0.98	0.00	0.04	1.02	0.01	0.05	1.02
Feb	0.12	0.04	0.96	0.08	0.03	0.98	0.21	0.04	0.91
Mar	0.11	0.04	0.96	0.05	0.02	1.00	0.05	0.02	1.00
Apr	0.03	0.04	1.01	0.02	0.02	1.01	0.01	0.02	1.02
May	0.00	0.05	1.02	0.00	0.04	1.02	0.00	0.03	1.02
Jun	0.00	0.09	1.02	0.03	0.05	1.01	0.00	0.04	1.02
Jul	0.10	0.09	0.97	0.02	0.06	1.01	0.00	0.04	1.02
Aug	0.08	0.09	0.98	0.00	0.05	1.02	0.01	0.04	1.02
Sep	0.08	0.08	0.98	0.00	0.04	1.02	0.05	0.04	1.00
Oct	0.01	0.04	1.02	0.00	0.02	1.02	0.22	0.03	0.90
Nov	0.17	0.04	0.93	0.04	0.02	1.00	0.04	0.03	1.00
Dec	0.15	0.04	0.95	0.03	0.02	1.01	0.00	0.03	1.02

Appendix D Upstream Consumptive Use

This appendix provides a description of Potomac River basin population growth projections and of water withdrawals in the upper Potomac basin by water use category. The upper Potomac basin is defined as the portion of the Potomac River drainage area upstream of the Washington metropolitan area water supply intakes. It also includes summaries of the assumptions used to estimate current and future consumptive use (CU).

D.1 Growth Projections

Assumed growth for many water use sectors considered in this study are based on projected increases in population. Current and projected population for Potomac basin counties were obtained from the following sources:

- the Maryland Department of Planning's Maryland State Data Center, at http://www.mdp.state.md.us/msdc/s3_projection.shtml (accessed on 12/8/2014);
- Pennsylvania county 2010 populations and population projections and information on the methodology used are available at the Pennsylvania Department of Environmental Protection website at: http://www.pawaterplan.dep.state.pa.us/docs/TechnicalDocuments/2010_2040PopulationProjections.pdf and http://www.pawaterplan.dep.state.pa.us/docs/TechnicalDocuments/2012_PopProjectionProcedure.pdf (accessed on 12/1/2014);
- the University of Virginia's Weldon Cooper Center for Public Service – Demographics Research Group, at http://www.coopercenter.org/demographics (accessed on 1/12/2015); and
- "West Virginia Population Projection by Age-Group, Sex, and County", by Christiadi, Bureau of Business and Economic Research, College of Business and Economics, West Virginia University, 2009.

To estimate future growth in the upper Potomac basin area adjustment factors were applied to county population figures, based on the fraction of the county lying within the upper Potomac basin. Estimates of the population served by the WMA suppliers – Fairfax Water, Aqueduct, WSSC, City of Rockville, and Loudoun Water – were removed from the population estimates. Separate growth estimates were made for counties bordering the mainstem of the Potomac River or the North Branch of the Potomac River (Allegheny, Frederick, Garrett, Montgomery, and Washington in Maryland; Fairfax and Loudoun in Virginia; and Berkeley, Hampshire, Jefferson, Mineral, and Morgan in West Virginia), and counties not bordering the mainstem. The population growth rate between 2010 and 2040 was estimated to be 38 percent for mainstem counties and 31 percent for non-mainstem counties. The growth rate for all basin counties was estimated to be 35 percent.

D.2 Withdrawal and Consumptive Use by Water Use Sector

The withdrawal and consumptive use data referenced below is from the following sources:

- ICPRB's database of historical withdrawals and estimated CU for the upper Potomac River basin, Version 2.1, which includes a compilation of mean monthly withdrawal data time series provided by basin state agencies. (See Section 6.1 of the main report for information on the sources of the state withdrawal data.)
- The USGS's datasets of annual average withdrawals, by county, for the years 1985, 1990, 1995, 2000, 2005, and 2010, available via the USGS's website (http://water.usgs.gov/watuse/data).

Aquaculture (AQU) The largest aquaculture user in the upper Potomac basin, accounting for over a third of the annual withdrawals in the AQU category in the 2005-2008 time period, was Lilipons Water Gardens in Frederick County, Maryland, which raises and sells fish, shellfish, and aquatic plants. Operations in Lilipons' current 250-acre tract adjacent to Bennett Creek began in 1925. The next three largest users, based on average withdrawals over the period in which data are available, were the Maryland Department of Natural Resources Albert M. Powell State Fish Hatchery in Washington County, and the West Virginia Department of Natural Resources' Spring Run Hatchery in Grant County and Reeds Creek Hatchery in Pendleton County.

Consistent with Steiner (2000), it is assumed that use of water for aquaculture will not grow in the upper Potomac basin over the forecast period. Steiner argued that the best sites for aquaculture are already in use. In addition, the largest users, with the exception of Lilipons, are state agencies, which are unlikely to experience significant growth due to funding constraints. CU of AQU withdrawals was computed using average monthly CU coefficients computed by Shaffer (2009) from 1995-2004 withdrawal and return flow data from Ohio (see Table 6-2 of the current study).

Commercial self-supplied (COM) Commercial self-supplied users in the upper Potomac basin include schools, churches, restaurants, hotels, campgrounds, resorts, and retail stores. There are some gaps in the understanding of the COM sector, since no monthly COM withdrawal data are available for West Virginia, and the last year the USGS included COM data in its county datasets was 1995. In addition, ICPRB did not have the resources to make estimates of commercial self-served withdrawals for users below the various state reporting thresholds. Fortunately, the COM water use sector appears to account for a relatively small portion of withdrawals and CU in the Potomac basin, and inaccuracies in COM water sector estimates will not have much of an impact on our understanding of upstream CU.

Based on analyses of Maryland and Virginia data, which provide relatively long time series of monthly COM withdrawals, water use by commercial establishments is sensitive to dry conditions. Therefore, the default values for COM CU coefficients used in the current study were the 75th percentile values reported by Shaffer (2009), computed from 1995-2004 withdrawal and return flow data from Ohio (see Table 6-2). In addition, a "dry factor" of 1.65 was applied to total monthly upstream COM withdrawals and CU calculated by the database, for the months of May, June, July, August, September, and October. This factor is based on the ratio of combined Maryland and Virginia average withdrawals during these months for the dry years, 1999, 2002, 2007, and 2010, to average withdrawals for these months over the period, 2005-2008.

A number of individual withdrawal sites in the COM sector were assigned site specific CU coefficients. These were withdrawals by ski resorts, which use water primarily for snow-making. Consumptive loss associated with snow-making was estimated to be 30 percent, based on data in Mills *et al.* (1986).

Withdrawals and CU for the COM water use sector were assumed to grow in proportion to population growth in the upper basin, that is, at a rate of 35 percent over the thirty-year period, 2010-2040. This assumption was consistent with that used by Steiner (2000).

<u>Industrial self-supplied (IND)</u> The largest consumptive user in the self-supplied industrial category is a paper mill in the town of Luke, in Allegany County, Maryland, which has been operating since the late 1800s. The mill is currently owned by the NewPage Corporation (formerly Luke Paper Company, then Westvaco Corporation). The mill withdraws water from the North Branch of the Potomac River, approximately half a mile downstream of the USGS stream gage at Luke. Wastewater from the plant is treated by the Westernport Wastewater Treatment Facility, which is operated by the Upper Potomac River Commission (UPRC), which also treats municipal sewage from the adjacent communities of Luke and Westernport, Maryland, and Piedmont, West Virginia. The UPRC wastewater treatment plant discharges effluent at a point approximately two miles downstream of the mill. Mean monthly withdrawals by the mill have ranged from 27 to 51 MGD over the period, 1985-2012. A noticeable change in facility's withdrawals occurred circa 2006. Withdrawals averaged 46 MGD in the period from 1985 through 2005, and averaged 35 MGD over the period, 2006 through 2012. A site-specific CU factor of 45 percent was computed for this facility, based on available discharge data, which is for the year 2010, and corresponding withdrawal data. For other withdrawals in the IND category, CU was computed using average monthly CU coefficients computed by Shaffer (2009) from 1995-2004 withdrawal and return flow data from Ohio (see Table 6-2).

Consistent with time trends in the historical state data and with Steiner (2000), it is assumed that use of water for self-supplied industrial users will not grow in the upper Potomac basin over the forecast period.

<u>Irrigation – agricultural (IRRA)</u> Annual total upstream withdrawals for agricultural irrigation from ICPRB's database averaged 2.4 MGD for the years 2005 through 2008. No agricultural irrigation data were available for West Virginia. Annual total upstream IRRA withdrawals in 2010 from the USGS's county dataset is 7.9 MGD. This value was computed by applying land area weighting factors to the IRRA withdrawal values for the individual counties from the USGS dataset. The USGS's upstream IRRA withdrawal total, which is 3.35 times the value obtained from ICPRB's database, is considered to be more accurate because the USGS dataset is based on agricultural census data and includes water use that was below the state reporting limits.

To obtain estimates of total upstream monthly CU for the IRRA sector, monthly CU estimates were first computed using ICPRB's state withdrawal data and the IRRA CU coefficients which appear in Table 6-2. Then an adjustment factor of 3.35, described above, was applied to create a set of monthly CU values associated with withdrawals that had an annual average of 7.9 MGD, consistent with the value computed using the 2010 USGS data. It should be noted that 2010 was a dry year in the Potomac basin, so no dry factor was applied.

For the current study, the preliminary assumption has been made that withdrawals for agricultural irrigation will not increase in the upper Potomac basin over the forecast horizon. Maryland is the only state in ICPRB's database with a long-term time series of IRRA withdrawal data, and visual inspection and linear regression analyses indicated that there are no significant time trends. The USGS's county water use datasets combined agricultural and golf irrigation withdrawals until 2010, so these data cannot be used to examine time trends. The preliminary no growth assumption for upstream IRRA withdrawals and CU may be revised when ICPRB receives the USDA's new projections for agriculture in the Chesapeake Bay watersheds, scheduled for the spring of 2015.

Irrigation for golf courses (IRRG) All four basin states' withdrawal datasets include data for golf courses. Withdrawals originally categorized by the states as commercial or unspecified irrigation were re-categorized in ICPRB's database as IRRG withdrawals if information in state database description fields indicated that water was being withdrawn by a golf course.

Based on analyses of Maryland and Virginia data, which provide relatively long time series of monthly IRRG withdrawals, water use by golf courses is sensitive to dry conditions. Therefore, the default values for IRRG CU coefficients used in the current study are the 75th percentile values reported by Shaffer (2009) (see Table 6-2). In addition, a "dry factor" of 1.14 was applied to total monthly upstream IRRG withdrawals and CU calculated by the database, for the months of May through October, based on the ratio of combined Maryland and Virginia average withdrawals during these months for the dry years, 1999, 2002, 2007, and 2010, to average withdrawals for these months over the period, 2005-2008.

Withdrawals and CU for the IRRG water use sector were assumed to grow in proportion to population growth in the upper basin, that is, at a rate of 35 percent over the 30-year period from 2010 to 2040.

Livestock (LIV) ICPRB's database has little historical withdrawal data in the LIV category, with total reported withdrawals in the upper Potomac basin averaging just 0.23 MGD over the period 2005 through 2008. However, the USGS county datasets provide estimates of LIV withdrawals based on agricultural census data, which are available at the county level. For this study, combined upstream LIV withdrawals were assumed to be 16.3 MGD throughout the year, based on 2010 USGS data for Potomac basin counties. USGS county LIV withdrawal values were distributed to the upper Potomac basin using land use areas from the Chesapeake Bay Program. For a given county, the upper Potomac LIV withdrawal was estimated to be the total LIV withdrawal for the county, times the fraction of the county's animal feeding operations land use type that lies within the upper Potomac basin. CU associated with LIV withdrawals was computed using the constant coefficient of 76 percent for all months, from Shaffer (2009).

Withdrawals and CU for the LIV water use sector were assumed to grow in proportion to population growth in the upper basin, that is, at a rate of 35 percent over the 30-year period from 2010-2040. This assumption was consistent with that used by Steiner (2000). This assumption may be revised when ICPRB receives the USDA's new projections for agriculture in the Chesapeake Bay watersheds, scheduled to be available in the spring of 2015.

Mining (MIN) Withdrawals in the MIN use category in the upper Potomac basin are primarily associated with quarrying and cement manufacturing. There are also withdrawals at the Mettiki coal mine in Garrett County, Maryland, though the largest of these is for mine dewatering. To compute CU for the MIN sector, withdrawals identified as dewatering, pit sump discharge, and water table lowering were assigned site-specific monthly CU coefficients of zero. For all other MIN withdrawals, default CU coefficients were used (Table 6-2). The default coefficients are the average of coefficients for the MIN sector computed by Shaffer (2009) from 1995-2004 withdrawal and return flow data from Ohio.

Withdrawals and CU for the MIN water use sector were assumed to grow in proportion to population growth in the upper basin, at a rate of 35 percent over the 30-year period, 2010-2040, since both quarrying and cement manufacturing are related to the building industry.

Thermoelectric power generation (PP) Thermoelectric power facilities are responsible for more water withdrawals in the upper Potomac basin than any other water use sector. ICPRB's database includes withdrawal information for four facilities in the upper Potomac basin, listed in Table D-1.

Table D-1: Thermoelectric power generating facilities in the upper Potomac basin.

Owner	Plant Name	Fuel Type	Capacity (MW)
AES Enterprise[1]	Warrior Run	Coal	229
Allegheny Energy Supply[1]	R.P. Smith	Coal	110
NRG (formerly Mirant)[1]	Dickerson	Coal/Natural Gas	930
Dominion	Mount Storm	Coal	1600

[1] Information from MD DNR (2014).

[2] From Dominion's website (https://www.dom.com/corporate/what-we-do/electricity/generation/fossil-fueled-power-stations/mount-storm-power-station).

Two facilities account for almost all of the PP withdrawals: Dominion's Mount Storm Power Station in Grant County, West Virginia, and NRG's Dickerson Generating Station in Montgomery County, Maryland. The Mount Storm facility's consumptive use is not considered in this study, because this facility is located upstream of Jennings Randolph Reservoir and its consumptive demand from the North Branch of the Potomac River is mitigated by water quality releases from Jennings Randolph and Savage River reservoirs to meet flow targets at Luke, as discussed in Chapter 6.

New reductions of emissions from coal-burning power generating facilities are being required under federal Clean Air Act and Maryland Healthy Air Act regulations (MD DNR, 2014). Owners have decommissioned or have stated that they plan to decommission two facilities in the upper Potomac basin: the R.P. Smith plant and the Dickerson plant, due to the cost of complying with new regulations. However, the long-term future of these facilities is unknown.

There is uncertainty regarding the response of the owners of coal-powered generating facilities to new Federal and state air emissions requirements, the siting of new gas-powered plants, and the rate at which solar and wind generation will grow in the Potomac basin. In addition, regulation in both Maryland and Virginia require power facilities to take measures to reduce or mitigate the impact of their consumptive use in the upper Potomac basin during low flow periods (Code of Maryland Regulation, 26.17.07; Code of Virginia: 62:1-44.15:5.02). In this study it is assumed that PP withdrawals remain constant in the upper Potomac basin over the next 30 years, but that CU increases by a factor of 1.5 due to a changeover from once-through cooling systems to closed-cycle systems (MD DNR, 2014). Closed-cycle systems significantly reduce fish kills due to impingement and entrainment. The PP CU coefficient used in this study is two percent, which is the 75th percentile of the annual average coefficients computed for Ohio facilities with once-through cooling systems from Shaffer (2009).

Public water supply (PWS) Monthly consumptive use coefficients for Potomac basin public water suppliers were calculated in this study using the winter base rate method. Available data for public water suppliers is discussed in Chapter 6 of this report.

Monthly consumptive use coefficients for public water supply systems upstream of the WMA intakes are given in the fourth and fifth column of Table 6-3. These values were computed in five steps:

1) summing all Potomac River basin PWS withdrawals within each upstream county, by month and by year;
2) computing the winter base rate for each county by year;
3) computing the consumptive use for each county, by month and by year;
4) computing the total upstream PWS consumptive use of all counties, by month and by year; and
5) computing the set of monthly coefficients for total upstream PWS consumptive use, by year.

All data were discarded for any county for which July or August withdrawals were less than the winter base rate, following Shaffer (2009), who discarded data for years in which July withdrawals were less than the winter base rate. The coefficients for upstream Potomac River basin counties in Table 6-3 reflect coefficients for the total PWS consumptive use in all of the upstream counties, averaged over the period 1990-2012, and over the dry years, 1991, 1999, 2002, 2007, and 2010.

Withdrawals in the PWS sector were assumed to increase in proportion to population growth. However, separate estimates for future PWS consumptive use were made for mainstem counties, that is, the counties bordering the Potomac River or its North Branch, and for non-mainstem counties. In these two areas, PWS withdrawals were assumed to increase in line with population growth rates estimated for the period 2010-2040: a 38 percent average increase for counties bordering the Potomac River and a 31 percent average increase for counties not bordering the Potomac River. The counties that border the Potomac River and the North Branch have access to an ample supply of water during droughts relative to their potential needs due to the river's large drainage area and the regulation of low flows by Jennings Randolph and Savage reservoirs. Many municipalities without access to the river found their supplies stressed during recent droughts. It was assumed that the consumptive use coefficients of mainstem counties would, over the course of the forecast period, transition to values similar to those of the CO-OP suppliers. It was assumed that the consumptive use patterns of counties not bordering the Potomac River would not change from their estimated present values.

Self-served domestic (SSD) The amount of water withdrawn from individual residential wells is computed based on the "self-supplied" population of basin counties in 2010, reported in the USGS's county withdrawal datasets. To estimate CU for the SSD sector, withdrawals are assumed to be 75 gallons per capita day. It is assumed that the resulting wastewater is treated by individual septic systems, and that the CU coefficient is 16 percent. Both of these values are taken from a study of water use in New Hampshire by Horn *et al.* (2008). No monthly or dry year factors were applied to the CU estimates, since no model is currently available in the Potomac basin to determine the amount of time required for variations in residential well use to affect stream flows.

Withdrawals and CU for the SSD water use sector were assumed to grow in proportion to population growth in the upper basin, at a rate of 35 percent over the 30-year period, 2010-2040.

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Appendix E Climate Change Results

Table E-1: PRRISM results for stream flow percent change of 30, given 2040 demands.[1]

	1929-2013		1930		1966	
	Ave.	**(Sd.)**	**Ave.**	**(Sd.)**	**Ave.**	**(Sd.)**
Percentage of years (or days[2]) with no Potomac deficits, %	100.0	(0.0)	100.0	(0.0)	100.0	(0.0)
Max. No. of days in a row of Potomac deficits	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
No. of Potomac deficits	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Max. amount of deficit in a single day, MGD	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Total amount of deficit in full simulation period, MG	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
No. of Patuxent shortfalls	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
No. of Occoquan shortfalls	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
No. of days with Patuxent production < 33 MGD	2121.4	(34.7)	131.8	(2.0)	184.2	(34.4)
Percentage of years (or days[2]) with voluntary restrictions, %	3.6	(0.0)	34.2	(0.2)	7.5	(0.7)
Percentage of years (or days[2]) with mandatory restrictions, %	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Percentage of years (or days[2]) with emergency restrictions, %	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Little Seneca Reservoir min. storage, BG	2.6	(0.4)	3.3	(0.1)	2.6	(0.4)
Jennings Randolph water supply min. storage, BG	5.0	(0.1)	5.3	(0.1)	5.0	(0.1)
Jennings Randolph water quality min. storage, BG	3.0	(0.0)	5.6	(0.0)	3.7	(0.0)
Patuxent Reservoir min. storage, BG	1.2	(0.0)	1.5	(0.0)	2.3	(0.0)
Occoquan Reservoir min. storage, BG	2.6	(0.1)	2.9	(0.0)	3.1	(0.2)
Savage Reservoir min. storage, BG	0.6	(0.0)	0.7	(0.0)	0.7	(0.0)
Loudoun Water Quarry min. storage, BG	0.8	(0.0)	0.9	(0.0)	0.8	(0.0)
Jennings Randolph water supply and Little Seneca Reservoir min. storage, BG	7.6	(0.4)	8.6	(0.2)	7.6	(0.4)
Jennings Randolph water supply and Little Seneca, Occoquan, and Patuxent Reservoirs min. storage, BG	13.4	(0.2)	13.4	(0.2)	15.6	(0.6)
COOP max. average annual demands, MGD	538.7	(3.2)	524.1	(8.6)	523.3	(7.7)
Loudoun Water max. average annual demands, MGD	32.9	(0.2)	32.3	(0.4)	32.2	(0.4)
Min. average late summer flow at Little Falls with no WMA impact, MGD	808.9	(0.0)	890.5	(0.0)	808.9	(0.0)
Min. average fall flow at Little Falls with no WMA impact, MGD	659.7	(0.0)	659.7	(0.0)	4507.0	(0.0)
Min. average late summer flow at Little Falls, MGD	450.4	(18.1)	523.6	(19)	450.4	(18.1)
Min. average fall flow at Little Falls, MGD	346.4	(13.8)	346.4	(13.8)	4122.8	(14.7)

[1] This table reports averages (standard deviations) of results from 20 model runs, where each run covers the 84-year historical period from 1929-2013.
[2] All values that reference percentage of years (*i.e.*, percentage of years with no Potomac deficits, and percentage of years with voluntary, mandatory, and emergency restrictions) are in terms of percent of 365 days for the 1930 and 1966 output.

Table E-2: PRRISM results for stream flow percent change of 20, given 2040 demands.[1]

	1929-2013		1930		1966	
	Ave.	(Sd.)	Ave.	(Sd.)	Ave.	(Sd.)
Percentage of years (or days[2]) with no Potomac deficits, %	100.0	(0.0)	100.0	(0.0)	100.0	(0.0)
Max. No. of days in a row of Potomac deficits	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
No. of Potomac deficits	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Max. amount of deficit in a single day, MGD	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Total amount of deficit in full simulation period, MG	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
No. of Patuxent shortfalls	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
No. of Occoquan shortfalls	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
No. of days with Patuxent production < 33 MGD	2722.4	(228.1)	134.9	(35.4)	300.2	(27.5)
Percentage of years (or days[2]) with voluntary restrictions, %	3.6	(0.0)	36.3	(0.3)	12.1	(1.2)
Percentage of years (or days[2]) with mandatory restrictions, %	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Percentage of years (or days[2]) with emergency restrictions, %	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Little Seneca Reservoir min. storage, BG	2.1	(0.3)	2.5	(0.3)	2.1	(0.3)
Jennings Randolph water supply min. storage, BG	3.7	(0.1)	4.0	(0.2)	3.7	(0.1)
Jennings Randolph water quality min. storage, BG	2.9	(0.0)	5.5	(0.0)	3.6	(0.1)
Patuxent Reservoir min. storage, BG	0.9	(0.0)	1.5	(0.2)	2.1	(0.0)
Occoquan Reservoir min. storage, BG	2.5	(0.1)	2.9	(0.1)	3.0	(0.1)
Savage Reservoir min. storage, BG	0.6	(0.0)	0.6	(0.0)	0.7	(0.0)
Loudoun Water Quarry min. storage, BG	0.8	(0.0)	0.9	(0.0)	0.8	(0.0)
Jennings Randolph water supply and Little Seneca Reservoir min. storage, BG	5.9	(0.3)	6.4	(0.4)	5.9	(0.3)
Jennings Randolph water supply and Little Seneca, Occoquan, and Patuxent Reservoirs min. storage, BG	11.1	(0.2)	11.1	(0.2)	13.5	(0.4)
COOP max. average annual demands, MGD	540.6	(4.2)	526.4	(7.0)	524.5	(6.7)
Loudoun Water max. average annual demands, MGD	33.0	(0.2)	32.4	(0.3)	32.2	(0.3)
Min. average late summer flow at Little Falls with no WMA impact, MGD	739.4	(0.0)	810.9	(0.0)	739.4	(0.0)
Min. average fall flow at Little Falls with no WMA impact, MGD	613.3	(0.0)	613.3	(0.0)	4226.6	(0.0)
Min. average late summer flow at Little Falls, MGD	398.9	(14.2)	464.9	(16.9)	398.9	(14.2)
Min. average fall flow at Little Falls, MGD	296.0	(9.5)	296.0	(9.5)	3837.1	(11.2)

[1] This table reports averages (standard deviations) of results from 20 model runs, where each run covers the 84-year historical period from 1929-2013.

[2] All values that reference percentage of years (*i.e.*, percentage of years with no Potomac deficits, and percentage of years with voluntary, mandatory, and emergency restrictions) are in terms of percent of 365 days for the 1930 and 1966 output.

Table E-3: PRRISM results for stream flow percent change of 10, given 2040 demands.[1]

	1929-2013		1930		1966	
	Ave.	(Sd.)	Ave.	(Sd.)	Ave.	(Sd.)
Percentage of years (or days[2]) with no Potomac deficits, %	100.0	(0.0)	100.0	(0.0)	100.0	(0.0)
Max. No. of days in a row of Potomac deficits	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
No. of Potomac deficits	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Max. amount of deficit in a single day, MGD	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Total amount of deficit in full simulation period, MG	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
No. of Patuxent shortfalls	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
No. of Occoquan shortfalls	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
No. of days with Patuxent production < 33 MGD	3226.9	(237.4)	129.9	(41.1)	320.8	(8.2)
Percentage of years (or days[2]) with voluntary restrictions, %	4.8	(0.0)	10.2	(3.8)	21.9	(2.1)
Percentage of years (or days[2]) with mandatory restrictions, %	2.7	(0.6)	27.5	(4.1)	3.3	(0.4)
Percentage of years (or days[2]) with emergency restrictions, %	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Little Seneca Reservoir min. storage, BG	1.5	(0.3)	1.9	(0.5)	1.6	(0.4)
Jennings Randolph water supply min. storage, BG	2.6	(0.2)	2.8	(0.3)	2.6	(0.1)
Jennings Randolph water quality min. storage, BG	2.8	(0.0)	5.3	(0.0)	4.1	(0.1)
Patuxent Reservoir min. storage, BG	0.4	(0.0)	1.4	(0.3)	1.9	(0.0)
Occoquan Reservoir min. storage, BG	2.5	(0.0)	2.7	(0.2)	2.7	(0.1)
Savage Reservoir min. storage, BG	0.6	(0.0)	0.6	(0.0)	0.7	(0.0)
Loudoun Water Quarry min. storage, BG	0.7	(0.0)	0.7	(0.0)	0.8	(0.0)
Jennings Randolph water supply and Little Seneca Reservoir min. storage, BG	4.1	(0.4)	4.7	(0.6)	4.2	(0.5)
Jennings Randolph water supply and Little Seneca, Occoquan, and Patuxent Reservoirs min. storage, BG	9.2	(0.5)	9.2	(0.5)	10.8	(0.6)
COOP max. average annual demands, MGD	540.4	(4.5)	518.5	(8.7)	520.7	(6.8)
Loudoun Water max. average annual demands, MGD	33.0	(0.2)	32.0	(0.4)	32.0	(0.3)
Min. average late summer flow at Little Falls with no WMA impact, MGD	670.0	(0.0)	731.3	(0.0)	670.0	(0.0)
Min. average fall flow at Little Falls with no WMA impact, MGD	566.8	(0.0)	566.8	(0.0)	3946.2	(0.0)
Min. average late summer flow at Little Falls, MGD	361.4	(12.3)	408.3	(14.1)	361.4	(12.3)
Min. average fall flow at Little Falls, MGD	270.9	(9.9)	270.9	(9.9)	3563.3	(11.4)

[1] This table reports averages (standard deviations) of results from 20 model runs, where each run covers the 84-year historical period from 1929-2013.
[2] All values that reference percentage of years (*i.e.*, percentage of years with no Potomac deficits, and percentage of years with voluntary, mandatory, and emergency restrictions) are in terms of percent of 365 days for the 1930 and 1966 output.

Table E-4: PRRISM results for stream flow percent change of -10, given 2040 demands.[1]

	1929-2013		1930		1966	
	Ave.	**(Sd.)**	**Ave.**	**(Sd.)**	**Ave.**	**(Sd.)**
Percentage of years (or days[2]) with no Potomac deficits, %	98.9	(0.7)	100.0	(0.1)	100.0	(0.0)
Max. No. of days in a row of Potomac deficits	0.1	(0.4)	0.0	(0.0)	0.0	(0.0)
No. of Potomac deficits	1.0	(0.7)	0.1	(0.3)	0.0	(0.0)
Max. amount of deficit in a single day, MGD	9.1	(6.9)	0.5	(1.7)	0.0	(0.0)
Total amount of deficit in full simulation period, MG	9.9	(7.9)	0.5	(1.7)	0.0	(0.0)
No. of Patuxent shortfalls	47.2	(0.5)	0.0	(0.0)	0.0	(0.0)
No. of Occoquan shortfalls	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
No. of days with Patuxent production < 33 MGD	4731.9	(257)	143.1	(51.2)	123.0	(149.7)
Percentage of years (or days[2]) with voluntary restrictions, %	8.3	(0.7)	4.2	(0.2)	20.1	(7.0)
Percentage of years (or days[2]) with mandatory restrictions, %	7.0	(0.4)	5.3	(2.6)	17.7	(6.9)
Percentage of years (or days[2]) with emergency restrictions, %	3.9	(0.9)	30.8	(2.7)	4.1	(0.8)
Little Seneca Reservoir min. storage, BG	0.1	(0.2)	0.2	(0.3)	0.5	(0.3)
Jennings Randolph water supply min. storage, BG	0.0	(0.1)	0.2	(0.2)	0.1	(0.1)
Jennings Randolph water quality min. storage, BG	2.7	(0.0)	5.1	(0.0)	5.6	(0.0)
Patuxent Reservoir min. storage, BG	0.0	(0.0)	1.2	(0.1)	1.3	(0.1)
Occoquan Reservoir min. storage, BG	1.9	(0.5)	1.9	(0.6)	2.3	(0.1)
Savage Reservoir min. storage, BG	0.5	(0.1)	0.5	(0.1)	0.7	(0.0)
Loudoun Water Quarry min. storage, BG	0.0	(0.0)	0.0	(0.0)	0.7	(0.0)
Jennings Randolph water supply and Little Seneca Reservoir min. storage, BG	0.3	(0.3)	0.4	(0.4)	0.6	(0.4)
Jennings Randolph water supply and Little Seneca, Occoquan, and Patuxent Reservoirs min. storage, BG	3.8	(0.8)	3.8	(0.8)	5.1	(0.5)
COOP max. average annual demands, MGD	539.7	(3.9)	504.3	(7.8)	510.2	(6.5)
Loudoun Water max. average annual demands, MGD	32.9	(0.2)	31.1	(0.4)	31.4	(0.3)
Min. average late summer flow at Little Falls with no WMA impact, MGD	531.2	(0.0)	572.0	(0.0)	531.2	(0.0)
Min. average fall flow at Little Falls with no WMA impact, MGD	474.0	(0.0)	474.0	(0.0)	3385.4	(0.0)
Min. average late summer flow at Little Falls, MGD	286.1	(11.2)	314.9	(6.7)	286.1	(11.3)
Min. average fall flow at Little Falls, MGD	247.7	(7.2)	247.7	(7.2)	3006.9	(9.8)

[1] This table reports averages (standard deviations) of results from 20 model runs, where each run covers the 84-year historical period from 1929-2013.
[2] All values that reference percentage of years (*i.e.*, percentage of years with no Potomac deficits, and percentage of years with voluntary, mandatory, and emergency restrictions) are in terms of percent of 365 days for the 1930 and 1966 output.

Table E-5: PRRISM results for stream flow percent change of -20, given 2040 demands.[1]

	1929-2013		1930		1966	
	Ave.	**(Sd.)**	**Ave.**	**(Sd.)**	**Ave.**	**(Sd.)**
Percentage of years (or days[2]) with no Potomac deficits, %	98.0	(0.6)	99.2	(0.4)	99.6	(0.4)
Max. No. of days in a row of Potomac deficits	1.1	(1.3)	0.7	(1.0)	0.8	(1.3)
No. of Potomac deficits	4.3	(2.4)	2.8	(1.6)	1.5	(1.5)
Max. amount of deficit in a single day, MGD	66.6	(33.6)	50.2	(20.6)	-40.6	(46.9)
Total amount of deficit in full simulation period, MG	152.3	(134.6)	76.9	(56.9)	-75.4	(112.6)
No. of Patuxent shortfalls	85.0	(0.0)	0.0	(0.0)	0.0	(0.0)
No. of Occoquan shortfalls	11.9	(13.2)	11.9	(13.2)	0.0	(0.0)
No. of days with Patuxent production < 33 MGD	6577.7	(176.3)	119.9	(29.2)	45.8	(75.1)
Percentage of years (or days[2]) with voluntary restrictions, %	13.2	(0.8)	4.0	(0.1)	15.5	(4.5)
Percentage of years (or days[2]) with mandatory restrictions, %	9.4	(0.4)	3.4	(0.3)	29.2	(3.5)
Percentage of years (or days[2]) with emergency restrictions, %	6.0	(0.0)	33.8	(0.4)	9.3	(0.7)
Little Seneca Reservoir min. storage, BG	0.0	(0.0)	0.0	(0.0)	0.1	(0.2)
Jennings Randolph water supply min. storage, BG	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Jennings Randolph water quality min. storage, BG	3.2	(0.0)	4.8	(0.0)	5.5	(0.0)
Patuxent Reservoir min. storage, BG	0.0	(0.0)	0.6	(0.1)	1.0	(0.1)
Occoquan Reservoir min. storage, BG	0.1	(0.3)	0.1	(0.3)	2.0	(0.3)
Savage Reservoir min. storage, BG	0.2	(0.0)	0.2	(0.0)	0.7	(0.0)
Loudoun Water Quarry min. storage, BG	0.0	(0.0)	0.0	(0.0)	0.5	(0.0)
Jennings Randolph water supply and Little Seneca Reservoir min. storage, BG	0.0	(0.0)	0.0	(0.0)	0.1	(0.2)
Jennings Randolph water supply and Little Seneca, Occoquan, and Patuxent Reservoirs min. storage, BG	0.9	(0.4)	0.9	(0.4)	3.1	(0.4)
COOP max. average annual demands, MGD	541.7	(2.5)	504.2	(6.2)	507.0	(6.3)
Loudoun Water max. average annual demands, MGD	33.0	(0.1)	31.1	(0.3)	31.1	(0.3)
Min. average late summer flow at Little Falls with no WMA impact, MGD	461.7	(0.0)	492.4	(0.0)	461.7	(0.0)
Min. average fall flow at Little Falls with no WMA impact, MGD	427.6	(0.0)	427.6	(0.0)	3105.1	(0.0)
Min. average late summer flow at Little Falls, MGD	258.4	(6.1)	284.2	(3.6)	258.4	(6.1)
Min. average fall flow at Little Falls, MGD	200.4	(12.4)	200.4	(12.4)	2713.8	(13.1)

[1] This table reports averages (standard deviations) of results from 20 model runs, where each run covers the 84-year historical period from 1929-2013.
[2] All values that reference percentage of years (*i.e.*, percentage of years with no Potomac deficits, and percentage of years with voluntary, mandatory, and emergency restrictions) are in terms of percent of 365 days for the 1930 and 1966 output.

Table E-6: PRRISM results for stream flow percent change of -30, given 2040 demands.[1]

	1929-2013		1930		1966	
	Ave.	**(Sd.)**	**Ave.**	**(Sd.)**	**Ave.**	**(Sd.)**
Percentage of years (or days[2]) with no Potomac deficits, %	96.3	(0.4)	89.8	(2.5)	95.9	(0.5)
Max. No. of days in a row of Potomac deficits	21.6	(5.9)	21.3	(6.4)	13.3	(1.9)
No. of Potomac deficits	54.8	(9.8)	37.2	(9.1)	14.8	(1.9)
Max. amount of deficit in a single day, MGD	174.1	(21.8)	112.0	(18.7)	-174.1	(21.8)
Total amount of deficit in full simulation period, MG	2997.3	(788.1)	1333.0	(566.4)	-1570.0	(465.4)
No. of Patuxent shortfalls	183.2	(5.8)	19.2	(5.8)	0.0	(0.0)
No. of Occoquan shortfalls	60.8	(5.4)	60.7	(5.5)	0.0	(0.0)
No. of days with Patuxent production < 33 MGD	9166.9	(215.2)	150.1	(9.1)	19.2	(11.2)
Percentage of years (or days[2]) with voluntary restrictions, %	16.2	(1.1)	3.8	(0.2)	13.6	(2.8)
Percentage of years (or days[2]) with mandatory restrictions, %	13.1	(0.0)	2.9	(0.2)	31.9	(3.6)
Percentage of years (or days[2]) with emergency restrictions, %	7.8	(0.6)	35.8	(0.3)	14.3	(0.4)
Little Seneca Reservoir min. storage, BG	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Jennings Randolph water supply min. storage, BG	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Jennings Randolph water quality min. storage, BG	3.1	(0.0)	4.2	(0.0)	5.0	(0.0)
Patuxent Reservoir min. storage, BG	0.0	(0.0)	0.0	(0.0)	0.7	(0.1)
Occoquan Reservoir min. storage, BG	0.0	(0.0)	0.0	(0.0)	2.1	(0.3)
Savage Reservoir min. storage, BG	0.0	(0.0)	0.0	(0.0)	0.7	(0.0)
Loudoun Water Quarry min. storage, BG	0.0	(0.0)	0.0	(0.0)	0.5	(0.0)
Jennings Randolph water supply and Little Seneca Reservoir min. storage, BG	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Jennings Randolph water supply and Little Seneca, Occoquan, and Patuxent Reservoirs min. storage, BG	0.0	(0.0)	0.0	(0.0)	2.8	(0.3)
COOP max. average annual demands, MGD	539.8	(4.1)	500.8	(7.8)	503.0	(7.8)
Loudoun Water max. average annual demands, MGD	32.9	(0.2)	30.9	(0.4)	30.9	(0.4)
Min. average late summer flow at Little Falls with no WMA impact, MGD	392.3	(0.0)	412.8	(0.0)	392.3	(0.0)
Min. average fall flow at Little Falls with no WMA impact, MGD	381.1	(0.0)	381.1	(0.0)	2824.7	(0.0)
Min. average late summer flow at Little Falls, MGD	245.9	(9.7)	263.3	(4.3)	245.9	(9.7)
Min. average fall flow at Little Falls, MGD	127.0	(13)	127.0	(13)	2410.1	(16.4)

[1] This table reports averages (standard deviations) of results from 20 model runs, where each run covers the 84-year historical period from 1929-2013.
[2] All values that reference percentage of years (*i.e.*, percentage of years with no Potomac deficits, and percentage of years with voluntary, mandatory, and emergency restrictions) are in terms of percent of 365 days for the 1930 and 1966 output.

Table E-7: PRRISM results for stream flow percent change of -40, given 2040 demands.[1]

	1929-2013		1930		1966	
	Ave.	**(Sd.)**	**Ave.**	**(Sd.)**	**Ave.**	**(Sd.)**
Percentage of years (or days[2]) with no Potomac deficits, %	93.6	(1)	77.9	(0.9)	91.6	(0.4)
Max. No. of days in a row of Potomac deficits	46.6	(3.9)	46.6	(3.9)	26.5	(0.9)
No. of Potomac deficits	136.1	(4.2)	80.6	(3.2)	30.7	(1.3)
Max. amount of deficit in a single day, MGD	271.9	(20.5)	207.6	(23)	-271.9	(20.5)
Total amount of deficit in full simulation period, MG	12868.8	(1051.3)	6742.8	(878.7)	-4784.4	(438.2)
No. of Patuxent shortfalls	442.6	(3.1)	52.6	(2.2)	26.0	(2.1)
No. of Occoquan shortfalls	80.5	(3.5)	77.9	(2.6)	0.0	(0.0)
No. of days with Patuxent production < 33 MGD	11562.3	(510.8)	187.4	(1.6)	159.4	(105.5)
Percentage of years (or days[2]) with voluntary restrictions, %	28.2	(1.5)	3.5	(0.4)	0.2	(0.9)
Percentage of years (or days[2]) with mandatory restrictions, %	23.5	(1.2)	2.7	(0.3)	63.0	(2.1)
Percentage of years (or days[2]) with emergency restrictions, %	13.8	(0.9)	37.9	(0.6)	31.1	(1.8)
Little Seneca Reservoir min. storage, BG	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Jennings Randolph water supply min. storage, BG	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Jennings Randolph water quality min. storage, BG	2.9	(0.0)	3.9	(0.0)	4.8	(0.0)
Patuxent Reservoir min. storage, BG	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Occoquan Reservoir min. storage, BG	0.0	(0.0)	0.0	(0.0)	0.3	(0.1)
Savage Reservoir min. storage, BG	0.0	(0.0)	0.0	(0.0)	0.7	(0.0)
Loudoun Water Quarry min. storage, BG	0.0	(0.0)	0.0	(0.0)	0.2	(0.0)
Jennings Randolph water supply and Little Seneca Reservoir min. storage, BG	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Jennings Randolph water supply and Little Seneca, Occoquan, and Patuxent Reservoirs min. storage, BG	0.0	(0.0)	0.0	(0.0)	0.3	(0.1)
COOP max. average annual demands, MGD	539.4	(3.2)	498.2	(5.0)	477.0	(6.4)
Loudoun Water max. average annual demands, MGD	32.9	(0.2)	30.7	(0.2)	29.4	(0.3)
Min. average late summer flow at Little Falls with no WMA impact, MGD	322.9	(0.0)	333.2	(0.0)	322.9	(0.0)
Min. average fall flow at Little Falls with no WMA impact, MGD	334.7	(0.0)	334.7	(0.0)	2544.3	(0.0)
Min. average late summer flow at Little Falls, MGD	188.8	(9.2)	217.1	(8.9)	188.8	(9.2)
Min. average fall flow at Little Falls, MGD	49.4	(10.3)	49.4	(10.3)	2127.3	(13.9)

[1] This table reports averages (standard deviations) of results from 20 model runs, where each run covers the 84-year historical period from 1929-2013.
[2] All values that reference percentage of years (*i.e.*, percentage of years with no Potomac deficits, and percentage of years with voluntary, mandatory, and emergency restrictions) are in terms of percent of 365 days for the 1930 and 1966 output.

Appendix F PRRISM Input Parameters

Model Input	2010 Study	2015 Study
General		
Potomac River historical flow time series (MGD)	Little Falls, 1929-2007	Little Falls, 1929-2013
Great Falls/Little Falls flow-bys (MGD)	300/100	300/100
Margin of safety (MOS) for Little Seneca release (MGD)	30	130
Extra MOS for Little Seneca release when Patuxent reservoirs below emergency storage level (MGD)	NA	100
Patuxent MOS (MGD)	NA	40
Occoquan MOS (MGD)	NA	-30
Little Falls 9-day future flow predictions	Mainstem regression equation using Little Falls Q, no NB, MGD	Mainstem regression equation using Little Falls Q, no NB, MGD
Load shifting to Occoquan & Patuxent	Yes	Yes
Parameters in buffer equation for balance N Br/L Seneca releases (MGD)	-150/150	-100/200
Extra additive buffer for balance N Br/L Seneca releases (MGD)	0	60
Random number seed for single runs	4426	NA, fixed file
North Branch reservoirs		
JR usable capacity, WS + WQ (MG)	12,803 + 15,929 as of year 1997	13,907 + 16,296 as of year 2013
JR dead storage below intake (MG)	16	36 as of 2013
JR sedimentation rate (MG/yr)	127 (distributed) as of year 1997	45 (distributed) as of year 2013
Savage usable capacity in 2000 (MG)	6331 as of year 2000	6331 as of year 2000
Savage sedimentation rate (MG/yr)	18	18
Savage match	Yes - 16% of JR release	Yes - 16% of JR release
Westernport withdrawal/cutbacks	1/No	3.2/Yes
North Branch Advisory Group Recommendations		
JR whitewater releases	Yes	Yes
Savage whitewater releases	Yes	Yes
Threshold for making Savage WW releases as percentage of Rule Curve B	95%	95%
Little Seneca Reservoir		
Usable capacity in (BG)	3,785 as of year 2000	3,903 as of year 2010
Sedimentation rate (MG/yr)	15	4
Occoquan Reservoir		
Occoquan Reservoir usable capacity (MG)	8,004 as of year 2005	8,004 as of year 2005
Occoquan Reservoir sedimentation rate (MG/yr)	40	40
Rule curve (MGD)	70 + UOSA; 70; 60; 50	70 + UOSA*0.7; 60 + UOSA*0.7; 50 + UOSA*0.7
Patuxent reservoirs		
Usable capacity (MG)	10,080 as of year 2004	10,300 as of year 2004

Model Input	2010 Study	2015 Study
Sedimentation rate (MG/yr)	24	24
Patuxent rule curve, MGD	30/40/60	34/40/60
Maximum treatment rate (MGD)	100	120
Production loss rate (percent)	0	3
Delta load shift (MGD)	40	60
Cut back Patuxent withdrawals Jun 1 – Jul 15?	Yes – to 27 MGD	Yes – to 34 MGD
Reset Patuxent reservoirs?	No	No
Additional Fairfax Water System Constraints		
Maximum Occoquan Production (MGD)	120 in 2010; to 140 in 2018; to 160 in 2040	120
Maximum Potomac Production (MGD)	225	225
Minimum Occoquan Production (MGD)	45	45
Minimum Potomac Production (MGD)		55
Griffith to Potomac max transfer of finished water (MGD)	35	35
Corbalis to Occoquan (West to East) max transfer of finished water	65	65
Max Occoquan Production Change (MGD)	40	75
Occoquan to Corbalis (East to West) max transfer (MGD)		10
Central to West transfer rate of finished water (MGD)		6
West to Central transfer rate of finished water (MGD)		10 fast; up to 25 with 1 week notice
Griffith treatment plant water loss rate (percent)	12%	10
Corbalis plant production loss rate (percent)	NA	3
Cut back Occoquan withdrawals Jun 1 to Jul 15?	No	NA
Reset Occoquan?	No	NA
Maximum Occoquan Production (MGD)	120 in 2010; to 140 in 2018; to 160 in 2040	120
Consumptive Use & WWTP return flows (MGD)		
Upstream consumptive use for Jun-Aug (MGD)	Based on Steiner *et al*., (2000), plus 1 MGD for Mirant Dickerson	See Table 6-4
Upstream consumptive use for Sep-May (MGD)	Based on Steiner *et al*., (2000), plus 1 MGD for Mirant Dickerson	See Table 6-4
Broad Run WWTP return flows (MGD)	Based on estimated Loudoun Water wintertime demand and consumptive use estimate (see Section 6.5)	See Table 5-7 and Table 5-8
Seneca WWTP return flows (MGD)	2010, 2015, 2020, 2025, 2030, 2035, 2040: 18.82, 20.57, 22.13, 23.49, 24.58, 26.37, 27.86	See Table 5-7 and Table 5-8
Damascus WWTP return flows (MGD)	NA	See Table 5-7 and Table 5-8
UOSA WWTP return flows (MGD)	2010, 2015, 2020, 2025, 2030, 2035, 2040: 32.15, 36.35, 40.45, 44.45, 48.45, 52.45, 56.45	See Table 5-7 and Table 5-8

Model Input	2010 Study	2015 Study
Water use restrictions		
Water use restrictions	Yes	Yes
Restriction triggers: JR and/or L Seneca storage <, Voluntary/Mandatory/Emergency	60%/25%/5%	60%/25%/5%
Assumed demand reduction, Jun-Sep, Voluntary/Mandatory/Emergency	5%/9.2%/15%	5%/9.2%/15%
Assumed demand reduction in other months, Voluntary/Mandatory/Emergency	3%/5%/15%	3%/5%/15%
Maximum change in demand reduction per time step	0.5%	0.5%
Other system constants		
Potomac water treatment plant production loss rates (for Corbalis, Dalecarlia, and WSSC Potomac Filtration plants - percent)	0	3
Luke minimum flow (MGD)		77.5
Higher Luke minimum flow (MGD)		194
Savage typical minimum release (MGD)		35.6
Savage legal minimum release (MGD)		12.9