US Army Corps of Engineers®
Portland District

# Willamette Basin Review Feasibility Study

## APPENDIX A

## Municipal & Industrial Demand and Supply Analyses

June 2019

# Table of Contents

1 Background ... 1
1.1 Organization of the Document ... 1
2 Study Area ... 3
2.1.1 M&I Water Suppliers Identification Step 1: Water Rights ... 5
2.1.2 M&I Water Suppliers Identification Step 2: System Planning Documents ... 5
2.2 Characteristics of Study Area M&I Systems ... 6
2.2.1 Service Area Populations ... 8
2.2.2 Primary Raw Water Source ... 8
2.2.3 M&I Water Supply Coalitions and Consortiums ... 9
2.2.4 M&I System Water Conservation ... 9
2.2.5 Unaccounted-for Water ... 9
3 Population Projections ... 11
3.1 Office of Economic Analysis Population Forecasts to 2050 ... 11
3.2 Regional Water Providers Consortium Population Forecasts to 2045 ... 12
3.3 Population Forecasts Adopted for Demand Analysis ... 13
4 M&I System Water Use Metrics ... 15
4.1 Customer Class Use Percentages ... 15
4.2 M&I System Unaccounted-for Water ... 16
4.3 Average Daily Demand and Average Gallons Per Capita Day ... 17
4.3.1 Residential and Non-Residential Sectors Average GPCD ... 18
4.3.2 Average GPCD Assuming Goal of 10 Percent Unaccounted-for Water Met ... 19
4.4 Maximum Daily Demand (MDD) and Peak Gallons Per Capita Day ... 20
4.4.1 Residential and Non-Residential Sectors Peak GPCD ... 21
4.4.2 Peak GPCD Assuming Goal of 10 Percent Unaccounted-for Water Met ... 22
4.5 Average Peak Season Use ... 23
5 M&I System Demand Projections ... 24
5.1 Demand Estimates Shown in the Summary Table and Detailed Tables ... 25
5.2 Annual M&I System Demand Projections ... 27
5.2.1 Annual M&I System Demand Projections by Sector ... 28
5.3 Peak Season M&I System Demand Projection – Peak GPCD Use ... 30
5.3.1 Peak Season (Peak GPCD) M&I System Demand Projections by Sector ... 31

5.4 Peak Season M&I System Demand Projection – Average Peak Season Use .................. 33
5.4.1 Peak Season (Average Peak Season Use) M&I System Demand Projections by Sector ........................................................................................ 34
6 Reliable Peak Season Supply Evaluation for M&I Systems .............................................. 36
6.1 Reliable Peak Season Supply Overview ........................................................................ 36
6.2 Mainstem Willamette Surface Water Permits – Peak Season Reliability ......................... 36
6.2.1 Extended Permits Peak Season Reliability Limitations ......................................... 36
6.2.2 Permits Issued Post-BiOp Peak Season Reliability Limitations ............................. 37
6.2.3 Permits Junior to MPSFs Peak Season Reliability Limitations ............................. 37
6.3 Willamette Major Tributary Permits – Peak Season Supply Reliability Limitations ....... 38
6.3.1 Extended Permits Peak Season Reliability Limitations ......................................... 38
6.3.2 Permits Junior to MPSFs Peak Season Reliability Limitations ............................. 38
6.4 Permits with Undeveloped Infrastructure ........................................................................ 38
6.5 Groundwater Permits ........................................................................................................ 38
6.6 Combined Reported Permits ............................................................................................. 38
6.7 Results of Analysis ........................................................................................................... 38
7 M&I Reliable Supply Deficits and Source Redundancy ..................................................... 40
7.1 Peak Season Supply Deficits – Peak GPCD ...................................................................... 40
7.2 Peak Season Supply Deficits – Peak Season Average Use .............................................. 41
7.2.1 M&I System Single Source Redundancy Needs .................................................... 42
8 Self-Supplied Industrial Demand ......................................................................................... 44
8.1 Estimating Future SSI Demand ......................................................................................... 44
9 M&I Demands for WVP Stored Water ................................................................................. 46
9.1 Summary Tables of M&I Demand for WVP Stored Water ............................................. 46
10 M&I Demands for Willamette Valley Project Stored Water Distributed Among Contract Reaches ........................................................................................................................... 49
11 Impacts of Climate Change: M&I Demand for WVP Stored Water .................................. 53
11.1 Climate Change Impact on M&I Water Supply ............................................................. 53
11.2 Climate Change Impact on M&I Water Demand ........................................................... 60
11.2.1 Combined Impact of Climate Change on Supply and Demand .............................. 63
12 Sensitivity Analysis ............................................................................................................. 66
12.1 M&I Systems Supply Deficit Sensitivity to Population Projections ............................... 66
12.2 M&I Systems Supply Deficit Sensitivity to the Peak GPCD Use Metric ........................ 66

12.3 Sensitivity to Reliable Rights Yield ........ 67

# List of Tables

Table 1-1 Willamette River Basin Counties ........ 3
Table 2-1 Population Size Characteristics of Study Area M&I Water Suppliers ........ 8
Table 2-2 Primary Raw Water Source of Study Area M&I Water Suppliers ........ 8
Table 3-1 Regional Water Providers Consortium Study Area Members ........ 13
Table 3-2 Adopted Population Projection & OEA Method Population Projection ........ 14
Table 3-3 Study Area Population Projections for the Period of Analysis ........ 14
Table 4-1 Median Values of Percent Residential and Non-Residential Water Use Observed ........ 15
Table 4-2 Median Values of Unaccounted-for Water Observed ........ 16
Table 4-3 Study Area Descriptive Statistics: Unaccounted-for Water ........ 17
Table 4-4 Median Values of Average GPCD Observed ........ 18
Table 4-5 Study Area Descriptive Statistics: Average GPCD ........ 18
Table 4-6 Study Area Descriptive Statistics: Residential Sector Average GPCD ........ 19
Table 4-7 Study Area Descriptive Statistics: Non-Residential Sector Average GPCD ........ 19
Table 4-8 Study Area Descriptive Statistics: Residential Sector Average GPCD at 10 Percent Unaccounted-for Water Goal ........ 20
Table 4-9 Study Area Descriptive Statistics: Non-Residential Sector Average GPCD at 10 Percent Unaccounted-for Water Goal ........ 20
Table 4-10 Median Values of Peak GPCD Observed ........ 21
Table 4-11 Study Area Descriptive Statistics: Peak GPCD ........ 21
Table 4-12 Study Area Descriptive Statistics: Residential Sector Peak GPCD ........ 22
Table 4-13 Study Area Descriptive Statistics: Non-Residential Sector Peak GPCD ........ 22
Table 4-14 Study Area Descriptive Statistics: Residential Sector Peak GPCD at 10 Percent Unaccounted-for Water Goal ........ 23
Table 4-15 Study Area Descriptive Statistics: Non-Residential Sector Peak GPCD at 10 Percent Unaccounted-for Water Goal ........ 23
Table 4-16 Median Values of Peak Season Use as Percent of Annual Use Observed ........ 24
Table 4-17 Study Area Descriptive Statistics: Peak Season Use Percent of Annual Use ........ 24
Table 5-1 Summary of M&I System Peak Season Water Demand Scenarios (acre-feet) ........ 26

Table 5-2 Annual M&I System Demand Projection (acre-feet) .................................................. 27
Table 5-3 Annual M&I System Demand Projection (acre-feet) at 10 Percent Unaccounted-for Water Goal ........................................................................ 27
Table 5-4 Annual Residential M&I System Demand Projection (acre-feet) ................................ 28
Table 5-5 Annual Non-Residential M&I System Demand Projection (acre-feet) ........................ 28
Table 5-6 Annual Residential M&I System Demand Projection (acre-feet) at 10 Percent Unaccounted-for Water Goal ........................................................................ 29
Table 5-7 Annual Non-Residential M&I System Demand Projection (acre-feet) at 10 Percent Unaccounted-for Water Goal ........................................................... 29
Table 5-8 Peak Season M&I System Demand Projection – Peak GPCD Use (acre-feet) ............ 30
Table 5-9 Peak Season (Peak GPCD) M&I System Demand Projection (acre-feet) at 10 Percent Unaccounted-for Water Goal ........................................................... 30
Table 5-10 Peak Season Residential M&I System Demand Projection Based on Peak GPD (acre-feet) ......................................................................................... 31
Table 5-11 Peak Season Non-Residential M&I System Demand Projection Based on Peak GPCD (acre-feet) ............................................................................... 31
Table 5-12 Peak Season Residential M&I System Demand Projection (acre-feet) Based on Peak GPCD at 10 Percent Unaccounted-for Water Goal ........................................ 32
Table 5-13 Peak Season Non-Residential M&I System Demand Projection (acre-feet) Based on Peak GPCD at 10 Percent Unaccounted-for Water Goal ............................ 32
Table 5-14 Peak Season M&I System Demand Projection – Average Peak Season Use (acre-feet) ........................................................................................................ 33
Table 5-15 Peak Season (Average Peak Season Use) M&I System Demand Projection (acre-feet) at 10 Percent Unaccounted-for Water Goal ................................................. 33
Table 5-16 Peak Season Residential M&I System Demand Projection Based on Average Peak Season Use (acre-feet) .......................................................... 34
Table 5-17 Peak Season Non-Residential M&I System Demand Projection Based on Average Peak Season Use (acre-feet) .......................................................... 34
Table 5-18 Peak Season Residential M&I System Demand Projection (acre-feet) Based on Average Peak Season Use at 10 Percent Unaccounted-for Water Goal ................. 35
Table 5-19 Peak Season Non-Residential M&I System Demand Projection (acre-feet) Based on Average Peak Season Use at 10 Percent Unaccounted-for Water Goal ........................................................................................................ 35
Table 6-1 Median Values of Reliable Peak Season Rights to Unrestricted Rights Ratio Observed ........................................................................................................ 39
Table 6-2 Study Area Descriptive Statistics: Peak Season Rights to Unrestricted Rights Ratio ........................................................................................................ 39

Table 7-1 M&I Peak Season Supply Deficit Projections (Peak GPCD Use, units: acre-feet) ... 41

Table 7-2 M&I Peak Season Supply Deficit Projections Unaccounted-for Goal of 10 Percent Met (Peak GPCD Use, units: acre-feet) ... 41

Table 7-3 M M&I Peak Season Supply Deficit Projections (Peak Season Average Use, units: acre-feet) ... 42

Table 7-4 M&I Peak Season Supply Deficit Projections Unaccounted-for Goal of 10 Percent Met (Peak Season Average Use, units: acre-feet) ... 42

Table 7-5 M&I System Single Source Redundancy Needs (acre-feet) ... 43

Table 8-1 SSI Peak Season Supply Deficits (new Permits) for the Period of Analysis ... 46

Table 9-1 Total M&I Peak Season WVP Stored Water Needs (Peak GPCD basis used for M&I Systems Demand) ... 47

Table 9-2 Total M&I Peak Season WVP Stored Water Needs Unaccounted-for Water Goal of 10 Percent Met (Peak GPCD basis used for M&I Systems Demand) ... 48

Table 9-3 Total M&I Peak Season WVP Stored Water Needs (Average Peak Season Use basis used for M&I Systems Demand) ... 48

Table 9-4 Total M&I Peak Season WVP Stored Water Needs Unaccounted-for Water Goal of 10 Percent Met (Average Peak Season Use basis used for M&I Systems Deficits) ... 49

Table 10-1 Total M&I Peak Season WVP Stored Water Needs (Peak GPCD basis used for M&I Systems Demand) by Reclamation Contract Reach ... 51

Table 10-2 Total M&I Peak Season WVP Stored Water Needs Unaccounted-for Water Goal of 10 Percent Met (Peak GPCD basis used for M&I Systems Demand) by Reclamation Contract Reach ... 51

Table 10-3 Total M&I Peak Season WVP Stored Water Needs (Average Peak Season Use basis used for M&I Systems Demand) by Reclamation Contract Reach ... 52

Table 10-4 Total M&I Peak Season WVP Stored Water Needs Unaccounted-for Water Goal of 10 Percent Met (Average Peak Season Use basis for M&I Systems Deficits) By Reclamation Contract Reach ... 52

Table 11-1 Climate Impact Group Sites: Willamette River Basin ... 53

Table 11-2 Projected Average Daily Flow Volumes at Salem Year 2020 (abridged) ... 57

Table 11-3 Projected Average Daily Flow Volumes at Salem Year 2080 (abridged) ... 57

Table 11-4 Example Calculation – Change from 2020 to 2080 ... 58

Table 11-5 Climate Change Impact to M&I Demands for WVP Stored Water (Peak GPCD Basis, Supply Impact Only) ... 59

Table 11-6 Climate Change Impact to M&I Demands for WVP Stored Water (Average Peak Season Use, Supply Impact Only) ... 59

Table 11-7 Climate Change Impact to M&I Demands (Supply Deficits) for WVP Stored Water (Peak GPCD Basis for Deficits, Demand Impact Only) .................................. 62

Table 11-8 Climate Change Impact to M&I Demands (Supply Deficits) for WVP Stored Water (Average Peak Season Use Basis, Demand Impact Only) ............................... 63

Table 11-9 Climate Change Impact to M&I Demands (Supply Deficits) for WVP Stored Water (Peak GPCD Basis, Combined Demand and Supply Impact).......................... 64

Table 11-10 Climate Change Impact to M&I Demands (Supply Deficits) for WVP Stored Water (Average Peak Season Use Basis, Combined Demand and Supply Impact) ........................................................................................................ 65

Table 12-1 Sensitivity of M&I Deficit Forecast to Variations in Population Forecasts............... 68

Table 12-2 Sensitivity of M&I Deficit Forecast to Variations in Peak GPCD Use ..................... 69

Table 12-3 Sensitivity of M&I Deficit Forecast to Variations in Reliable Rights Yield ............ 70

## List of Figures

Figure 1-1 Willamette River Basin Overview .................................................................... 4

Figure 2-1 Geographic Distribution of Study Area M&I Systems ................................................. 7

Figure 10-1 U.S. Bureau of Reclamation Contract Reaches ...................................................... 50

Figure 12-1 Sensitivity of M&I Deficit Forecast to Variations in Population Forecasts ............. 68

Figure 12-2 Sensitivity of M&I Deficit Forecast to Variations in Peak GPCD Use .................... 69

Figure 12-3 Sensitivity of M&I Deficit Forecast to Variations in Reliable Rights Yield ............ 70

# Municipal & Industrial Demand and Supply Analyses for the Willamette Basin Review Feasibility Study

## 1 Background

This document provides a description of the analyses conducted to develop municipal and industrial (M&I) and self-supplied industrial (SSI) water demand forecasts, water supply deficits, and demand for Willamette Valley Project (WVP) stored water during the months of June through September. The period of analysis used in this evaluation is 2020 through 2070.

### 1.1 Organization of the Document

This document is organized into ten sections, and has one attachment.

**Section 2: Study Area Refinement** - provides a description of analyses used to refine the definition of the study area so that demand for WVP stored water would not be overstated. Also includes overall characteristics of the M&I systems within the refined study area.

**Section 3: Population Projections -** provides a description of analyses conducted in order to estimate the population of study area M&I systems.

**Section 4: M&I System Water Use Metrics** - provides a description of M&I system water use and performance metrics obtained from study area M&I system planning documents. Also describes the methodology used to assign water use and performance metrics to M&I systems for which planning documents could not be obtained.

**Section 5: M&I System Demand Projections** - provides M&I system demand projections based on the population projections developed in Section 3 and the M&I system water use metrics developed in Section 4.

**Section 6: Supply Evaluation for M&I Systems** - provides a description of analyses undertaken to evaluate the reliable peak season supply of water for study area M&I systems.

**Section 7: M&I Reliable Supply Deficits and Source Redundancy** - provides an analysis of M&I water supply deficits over the period of analysis using M&I system demand projections developed in Section 5 and reliable peak season supply of water for M&I systems developed in Section 6. Also included in this section is an estimate of M&I needs for redundant, or a back-up, reliable supply of water during peak season.

**Section 8: Self-Supplied Industrial Demand** - provides a description of analyses undertaken to estimate current self-supplied industrial demand, an estimate of the demand for new permits required for future new self-supplied industrial demand, and an estimate water demanded by the new permit holders.

**Section 9: M&I Demands for Willamette Valley Project Stored Water** - consolidates the results provided in Sections 7 and 8 to estimate total M&I and SSI demand for WVP stored water.

**Section 10: Summary of M&I and SSI Demands for Willamette Valley Project Stored Water Distributed Among Contract Reaches** - introduces the organizational element of the contract reach and provides the results shown in Section 9 distributed among the 15 contract reaches.

**Section 11: Impacts of Climate Change on M&I Peak Season Supply Deficits** – evaluates the effect of climate-induced changes in river flow and quantity of water demanded on M&I demands for WVP stored water.

**Section 12: Sensitivity Analysis** – evaluates the sensitivity of M&I peak season supply deficits (calculated using the Peak GPCD basis) to changes in input parameters.

# 2 Study Area

The study area was initially defined broadly as the geographic boundaries of the Willamette River basin, which lies entirely within the state of Oregon. Using this initial definition, the geographic boundaries of the Willamette River basin includes the 12 counties shown below in Table 1-1 and on Figure 1-1.

**Table 1-1**
**Willamette River Basin Counties**

| | |
|---|---|
| Benton | Linn |
| Clackamas | Marion |
| Columbia | Multnomah |
| Klamath | Polk |
| Lane | Washington |
| Lincoln | Yamhill |

Because the Willamette Basin Review Feasibility Study is focused on the reallocation of WVP conservation storage, the study area for M&I system demand was limited to the M&I systems that draw water (either by surface draw or through wells) from the Willamette River or its tributaries. This refinement of the study area ensured that M&I demand for WVP stored water[1] would not be overstated.

Given this distinction, several M&I systems located within the basin (though not using the Willamette River or its tributaries as a water source) were removed from the analysis so that water supply needs could be calculated only for M&I systems that rely on the Willamette River and its tributaries for water supply. For example, at the outset of the study, it was known that the City of Portland (with a current population of 632,500 persons) lies entirely within the Willamette River basin. However, through the analyses outlined later in this section, it was determined that the City of Portland's M&I system, Portland Water Bureau (PWB), obtains its water from the Bull Run Watershed and the Columbia South Shore Well Field. Both of these sources lie within the Columbia River Basin (and outside of the Willamette Basin), which led to the exclusion of Portland from the refined study area.

Systems were excluded ONLY if their source of water supply is located outside of the Willamette River basin. Several other systems of varying sizes also were excluded on the basis of this rationale, including those systems whose sole source of supply is the wholesale purchase of water from PWB.

[1] WVP stored water is the water held in WVP conservation storage.

**Figure 1-1**
**Willamette River Basin Overview**

### 2.1.1 M&I Water Suppliers Identification Step 1: Water Rights

The set of M&I systems used in this analysis was developed through an examination of Oregon water rights for M&I water supply within the Willamette River basin. Data used in this analysis was obtained from the Oregon Water Resources Department (OWRD) – the state's agency charged with administration of the laws governing surface and ground water resources. As such, OWRD maintains extensive databases that house information about water rights. Their main tool is the Water Rights Information System (WRIS), a warehouse of information pertaining to water right applications, permits, certificates, transfers, leases and other related information. Among the files of WRIS are ArcGIS geodatabases that provide information on:

- Spatial identification of Points of Diversion and Points of Use
- A hyperlink to the water right that can be viewed in pdf form;
- Source type (e.g., well, stream, spring, etc.);
- Entity name;
- Use description (e.g., municipal, recreation, livestock, nursery, etc.);
- Water right priority date;
- Authorized rate of withdrawal; and
- Source stream (relevant for groundwater sources, as well).

WRIS holds over 52,000 records that represent individual wells, surface intakes, reservoirs, and other points of diversion within the Willamette River basin– each tied to a specific water right. The water right provides detailed information on the source of water (i.e., by stream code), which identifies the name of the stream and the parent river from which permitted water can be drawn.

These 52,000 records consolidate to roughly 27,000 records that represent individual water rights for various purposes throughout the basin. Of the 27,000 individual water rights, approximately 500 rights are classified for use as "Municipal Purposes", which corresponds to the use classification for M&I systems. The 500 water rights are owned by 102 M&I systems.

### 2.1.2 M&I Water Suppliers Identification Step 2: System Planning Documents

Many M&I systems are required to submit planning documents to OWRD and to the Oregon Health Authority (OHA). Generally, suppliers serving over 1,000 people are required submit a Water Management and Conservation Plan (WMCP) to the OWRD, and a Water System Master Plan[2] (WSMP) to the OHA. Both documents describe the water system and its needs, identify its sources of water, and explain how the water supplier will manage those supplies to meet present and future needs. WMCPs also focus on water curtailment plans and long-term conservation, and WSMPs provide an additional focus on the physical condition of system facilities and plans for rehabilitation or expansion.

Included in the plans are descriptions of:

- water rights held by the service provider;
- authorized and feasible diversion rates for each water right;

[2] Also referred to as a Water Master Plan, or WMP.

- dates during the year each water right can be used;
- average day & peak day water use;
- service area population & forecast;
- interconnections with other water systems;
- system water loss rates;
- conservation plan (WMCP only); and
- plans to meet future needs

Planning documents for all 102 M&I systems were requested, though 35 planning documents were unavailable for use in this analysis[3]. Each of the available documents were reviewed to determine whether or not the M&I system identified through the water rights examination used raw water obtained from the Willamette River or its tributaries. In addition, internet sites of all systems for which a planning document was not obtained were investigated for pertinent information regarding raw water supply. After a review of all available information, 12 of the 102 M&I water suppliers were removed from the study area because information revealed that their source of raw water was not the Willamette River or its tributaries.

## 2.2 Characteristics of Study Area M&I Systems

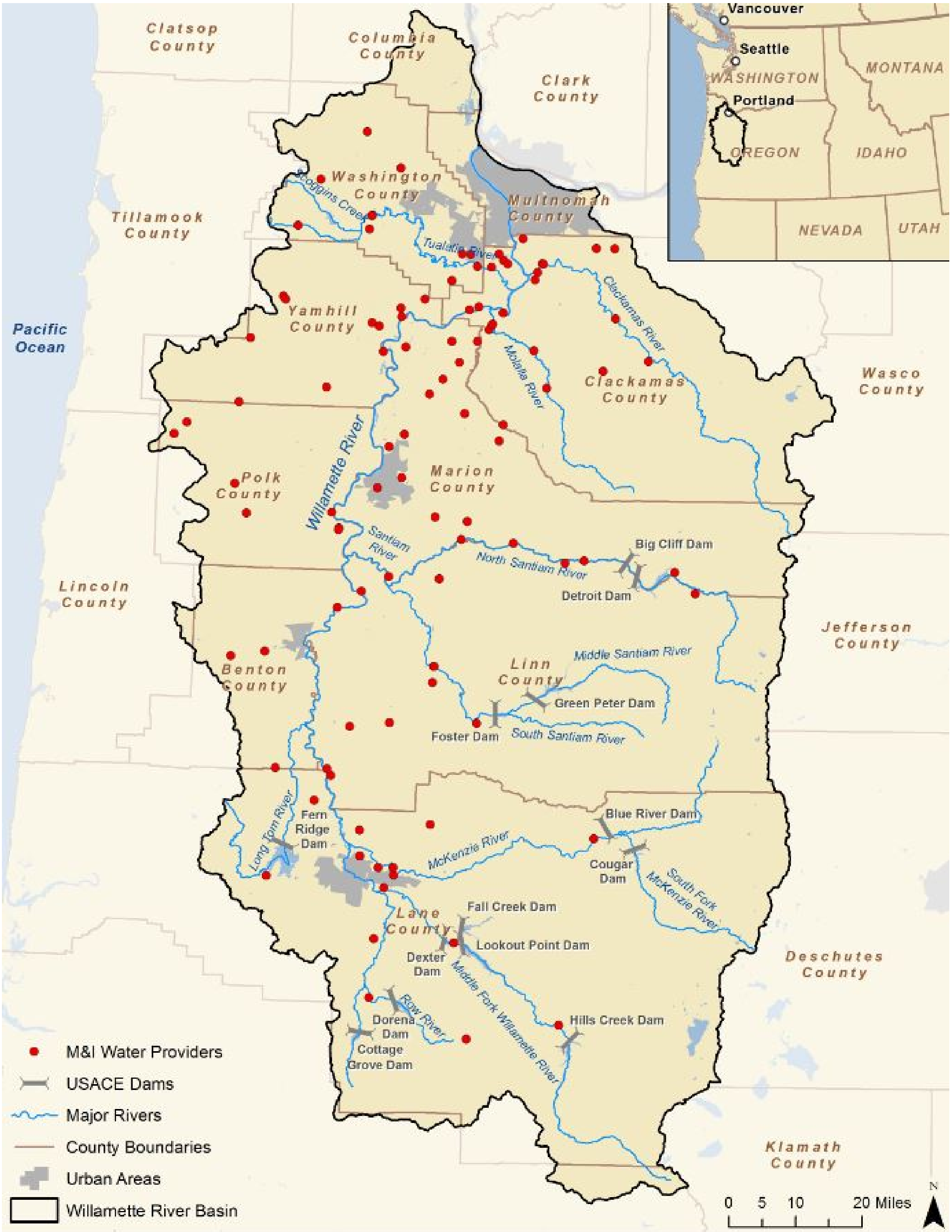
The 90 remaining M&I water suppliers in the study area are distributed throughout the basin as shown on Figure 2-1. OHA maintains a database of public water systems, which mainly includes data on drinking water quality performance, violations, enforcements, public notices, and basic system information. Current 2015 population also is available through the database, and was used as baseline service area population for each M&I system in this analysis.

The M&I systems serve a total population of approximately 1.62 million persons[4] (62 percent of the entire basin-wide population of 2.6 million persons). It is important to note that the Portland Water Bureau serves a population of approximately 970 thousand, which is <u>not</u> included in the service area population of 1.62 million. However, the basin-wide population of 2.6 million is reconciled by the sum of the study area and the Portland Water Bureau service area (1.62 million + 0.97 million = 2.59 million).

[3] It should be noted that both types of planning documents typically are submitted as part of certain permit requirements - when systems are seeking a long term permit extension and must demonstrate a need for increased diversions of water, or when an M&I system is undertaking a major system expansion. It can be presumed that recent permit extensions or major expansions of those 35 systems that would have triggered submission of a planning document have not taken place.

[4] Service area population obtained through the OHA database of public water systems.

**Figure 2-1**
**Geographic Distribution of Study Area M&I Systems**



### 2.2.1 Service Area Populations

The 90 study area M&I systems are of varying service area population sizes. For the purposes of this analysis, seven population size categories were developed, and are shown on Table 2-1 along with the number of systems within each size category, and the total service area population for each size category. As shown on the table, 62 of the 90 systems (69 percent of all systems) serve a population of 10,000 persons or fewer, though the total population served by these 62 systems amounts to only about 163,000 persons (about 10 percent of the total study area population). The remaining 28 M&I systems serve 90 percent of the study area population, and three of the largest systems serve 35 percent of the study area population.

**Table 2-1**
**Population Size Characteristics of Study Area M&I Water Suppliers**

| Population Category | Number of Systems | Total Population |
|---|---|---|
| Under 1,000 | 24 | 11,800 |
| 1,000 to 5,000 | 28 | 72,300 |
| 5,000 to 10,000 | 10 | 79,000 |
| 10,000 to 25,000 | 11 | 197,600 |
| 25,000 to 50,000 | 7 | 235,000 |
| 50,000 to 100,000 | 7 | 449,700 |
| Over 100,000 | 3 | 573,700 |
| TOTAL | 90 | 1,619,100 |

### 2.2.2 Primary Raw Water Source

In general terms, the primary water source for the study area M&I systems is depicted in Table 2-2. As shown in the table, smaller M&I systems rely on groundwater and surface water for a raw water source at a roughly 50/50 basis, though the larger systems rely heavily (if not entirely) on surface water as a supply source.

**Table 2-2**
**Primary Raw Water Source of Study Area M&I Water Suppliers**

| Population Category | Primary Water Source | | Total |
|---|---|---|---|
| | Groundwater | Surface Water | |
| Under 1,000 | 14 | 10 | 24 |
| 1,000 to 5,000 | 15 | 13 | 28 |
| 5,000 to 10,000 | 4 | 6 | 10 |
| 10,000 to 25,000 | 3 | 8 | 11 |
| 25,000 to 50,000 | 1 | 6 | 7 |
| 50,000 to 100,000 | | 7 | 7 |
| Over 100,000 | | 3 | 3 |
| TOTAL | 37 | 53 | 90 |

### 2.2.3 M&I Water Supply Coalitions and Consortiums

Water supply coalitions and consortiums serve as collaborative and coordinating organizations to improve the planning and management of municipal water supplies. M&I system members work together to prepare for, respond to, and recover from emergency events. Many other M&I systems in study area share intergovernmental agreements with neighboring systems and have constructed emergency interconnections. Coalition and Consortium members are committed to protecting the best interests of their communities by working together to secure water rights, investigate water treatment options and monitor water quality.

The largest consortiums in the study area are described below.

- **South Fork Water Board (SFWB)** is a wholesale water supplier that is equally owned by the Cities of Oregon City and West Linn. The SFWB operates an intake and pumping station just to the north of Oregon City, which delivers raw water to the SFWB treatment plant.
- **Clackamas River Water (CRW)** was formed in 1995 when the Clackamas Water District and the Clairmont Water District consolidated. CRW's history dates from 1926 when the Clackamas Water District was formed, and includes multiple mergers with other districts through the years. CRW's service area is located in Clackamas County, south of Portland and east of the Willamette River, in primarily unincorporated areas both inside and outside of the urban growth boundaries of the Portland Metropolitan Area and Oregon City.
- **The Willamette River Water Coalition (WRWC)** was created in 1997 and is comprised of four local governments that have united together in order to preserve access to the Willamette River as a potential municipal and industrial water source for their communities. WRWC members include the cities of Tigard, Tualatin, and Sherwood, as well as the Tualatin Valley Water District. The coalition holds the water rights to 130 million gallons of water per day from the Willamette River.

### 2.2.4 M&I System Water Conservation

Many Oregon M&I systems offer incentives and/or assistance to foster water conservation. Examples include give-away programs for low-flow showerheads, low-flow faucet aerators, and water gauges for lawn irrigation, and cost-share programs for purchases of low-flow toilets or other water saving devices and appliances inside the home, and for purchases of more efficient sprinkler system components such as water-saving spray nozzles, and weather-based irrigation controllers.

Building codes help ensure the installation of low-flow appliances in new construction. Generally, these conservation efforts are implemented gradually and, once fully implemented, cannot further reduce water demand without changes in social practices. Cultural connections between municipal water use and the health of the local watershed have grown in Oregon, in part, to ongoing efforts made by Oregon's municipal water suppliers to provide public education that encourages efficient water use and low water use landscaping to conserve water. Future changes in social preferences and connections to watersheds may continue to influence per capita demands.

### 2.2.5 Unaccounted-for Water

Some M&I systems have a large amount of unaccounted-for water that artificially increases their reported per capita demands. For example, an M&I system may use 1 million gallons per day, but may only be able to bill for 800,000 gallons based on meter readings. The water provider would have 20 percent unaccounted-for water that may be lost through leaks in the system and/or unmetered usage. Municipal water providers constantly work to reduce the amount of unaccounted-for water in their systems through leak detection, pipe repair and replacement, metering of source diversions and service connections, and regularly monitoring and auditing water use, all of which can help reduce their per capita demands.

# 3 Population Projections

Future M&I demand WVP stored water is estimated for the 50-year period of analysis, from 2020 to 2070. After the study area was fully defined (as discussed above), population forecasts were developed for each of the study area M&I systems. Sources of population projections used in the analysis are:

- Oregon Office of Economic Analysis (OEA) Population Forecasts to 2050; and
- Regional Water Providers Consortium Population Forecasts to 2045.

The period of analysis extends through the year 2070, though population projections for either of the forecast sources do not extend through 2070. The methodology used to extend the population projections through the end of the period of analysis was to project the growth rate calculated for the last five-year increment provided in the population projection, and continue that growth rate to the year 2070. For example, population forecasts taken from the OEA Population Forecasts to 2050, the projected population growth observed from the year 2045 through 2050 was extended to each of the five-year periods through the year 2070.

## 3.1 Office of Economic Analysis Population Forecasts to 2050

The Oregon Office of Economic Analysis (OEA) provides objective forecasts[5] of the state's economy, revenue, and population. The current long-term population forecasts for Oregon and its counties are developed using the widely used cohort-component projection procedure. This forecasting model "survives" the initial population distribution by age and sex to the future years. The population is subjected to projected age-sex-specific birth and survival rates to determine the number of births and deaths during a given period. A separate assumption is made for the migration estimates and they are subjected to the same vital rates. In the current forecast, the July 1, 2010 population by five-year age group and five-year time period is projected subject to specific assumptions about vital events and migrations.

### Births

Number of births is calculated by applying age-specific fertility rates (ASFR) to the women in corresponding age groups. The Census Bureau's national ASFR trend and projection and Oregon's historical ASFR were evaluated for Oregon's future fertility rates. The historical ASFRs for Oregon counties were computed for an individual county or for a group of counties if the rates were distorted by smaller number of births. The projections of county rates were determined based on the county's rate in relation to Oregon's and U.S. rates.

### Deaths

Deaths are based on the historical change in life expectancies, U.S. and Oregon's life expectancies estimated for 2050 and for the intervening years. Separate life tables for Oregon's males and females for the year 2008 and past decennial census years were constructed. The life tables were adjusted to yield the previously estimated life expectancies for each of the forecast period. In the forecast model, survival rates derived from the life tables were used to estimate the number surviving and dying by age and sex during a forecast cycle. The counties were grouped based on

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[5] Available on line at http://www.oregon.gov/das/OEA/Pages/forecastdemographic.aspx

mortality characteristics and life table and survival rates were constructed for each group of counties.

### Migration

Migrations for the state through 2025 were determined based on Oregon's expected employment and income outlooks in relation to the outlook in the nation and in the neighboring states. Beyond 2025, the state-level migration was determined based on trended fertility, mortality, and overall population growth rates. Migration levels for the counties were determined based on Oregon's migration level, and the county's relation to Oregon's migration in the past. Final numbers show the smooth out trend and accommodation to the most recent trend including estimates by the Population Research Center, Portland State University.

### Application in Analysis

OEA provides population forecasts only at the county level. For this analysis, the population growth rate for each M&I system was estimated by applying the appropriate county-specific growth rate to the 2015 service area population of each M&I system. As described above, the growth rate from year 2045 to year 2050 was extended through the end of the period of analysis (year 2070).

## 3.2 Regional Water Providers Consortium Population Forecasts to 2045

The "Regional Water Providers Consortium Population, Housing Unit, and Household Forecasts 2014 to 2045" was published by Portland State University's Population Research Center in October of 2014[6]. The study was initiated to provide members of the consortium with estimates and forecasts of the total population and the number of housing units and households within their service areas. In turn, the consortium members rely on these estimates in planning for future water system needs.

Forecasts for all years were prepared based on 2013 service area boundaries for every water provider included in the study. Included in these service area boundaries are future expanded service areas. The forecasts integrate housing unit forecasts from a three-county area (Clackamas, Multnomah, and Washington), which are segmented into nearly 1,500 sub-areas, and then aggregated to each M&I service provider's service area. The forecasts were first allocated to vacant land within the service areas, followed by underdeveloped land with residential capacity, followed by existing developed multiple family parcels, and finally to land not included in the buildable land inventory.

The analysis included occupancy rates for housing units, which was held constant at the level of the 2010 Census. M&I systems in the consortium that also are included within the study area are listed in Table 3-1.

[6] Rynerson, Charles and Rancik, Kevin Christopher, "Regional Water Providers Consortium Population, Housing Unit, and Household Forecasts 2014 to 2045" (2014). Publications, Reports and Presentations. Paper 29. Portland State University

**Table 3-1**
**Regional Water Providers Consortium Study Area Members**

| Cities in the Consortium | Consolidated Water Commissions in the Consortium |
|---|---|
| City of Beaverton | Clackamas River Water District |
| City of Fairview | Rockwood Water PUD |
| City of Forest Grove | South Fork Water Board |
| City of Gladstone | Clackamas River Water |
| City of Gresham | Sunrise Water Authority |
| City of Hillsboro | Tualatin Valley Water District |
| Cherry Grove (City of Hillsboro) | |
| City of Lake Oswego | |
| City of Milwaukie | |
| City of Sherwood | |
| City of Tigard | |
| City of Tualatin | |
| City of Wilsonville | |

## 3.3 Population Forecasts Adopted for Demand Analysis

Population forecasts for all M&I systems presented in the Regional Water Providers Consortium Population Forecasts were compared to population forecasts using the OEA county-level data. The difference between the population forecasts varied from year-to-year, as did which of the forecasts showed a higher population projection in any given year.

In order to provide an estimate with a degree of conservatism (i.e., to not understate population growth over the period of analysis), the higher of the two estimates was adopted. The overall difference between the forecasts adopted and the OEA forecasts is somewhat small on a percentage basis, as shown on Table 3-2.

**Table 3-2**
**Adopted Population Projection & OEA Method Population Projection**

| Forecast Year | Adopted Population Projection | OEA Method Population Projection | Difference | Percent Difference |
|---|---|---|---|---|
| 2020 | 1,760,700 | 1,737,100 | 23,600 | 1.4% |
| 2025 | 1,883,200 | 1,863,000 | 20,200 | 1.1% |
| 2030 | 2,004,000 | 1,985,900 | 18,100 | 0.9% |
| 2035 | 2,117,900 | 2,100,000 | 17,900 | 0.9% |
| 2040 | 2,220,500 | 2,206,500 | 14,000 | 0.6% |
| 2045 | 2,325,700 | 2,307,900 | 17,800 | 0.8% |
| 2050 | 2,429,600 | 2,407,000 | 22,600 | 0.9% |
| 2055 | 2,539,000 | 2,510,600 | 28,400 | 1.1% |
| 2060 | 2,654,200 | 2,618,600 | 35,600 | 1.4% |
| 2065 | 2,774,900 | 2,731,500 | 43,400 | 1.6% |
| 2070 | 2,901,600 | 2,849,300 | 52,300 | 1.8% |

Table 3-3 shows total study area M&I system population for 2015 and population projections in 10-year increments through the end of the period of analysis in 2070. The table provides the projections by population category size as of 2015. As shown in the table, total population has been forecast to grow from a current population of 1,619,000 in 2015 to a population of 2,901,600 in 2070, which corresponds to an average annual rate of growth equal to 1.1 percent.

**Table 3-3**
**Study Area Population Projections for the Period of Analysis**

| Population Category | 2015 Baseline | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| Under 1,000 | 11,800 | 12,600 | 14,300 | 15,700 | 17,100 | 18,600 | 20,200 |
| 1,000 to 5,000 | 72,300 | 77,400 | 88,400 | 98,100 | 107,000 | 116,500 | 126,800 |
| 5,000 to 10,000 | 79,000 | 84,600 | 96,600 | 107,200 | 117,200 | 127,900 | 139,600 |
| 10,000 to 25,000 | 197,600 | 217,600 | 250,400 | 278,800 | 303,700 | 331,300 | 362,200 |
| 25,000 to 50,000 | 235,000 | 261,900 | 301,300 | 332,000 | 368,400 | 408,500 | 453,500 |
| 50,000 to 100,000 | 449,700 | 488,200 | 554,500 | 614,200 | 671,500 | 732,300 | 799,200 |
| Over 100,000 | 573,700 | 618,300 | 698,500 | 774,500 | 844,800 | 919,100 | 1,000,100 |
| TOTAL | 1,619,100 | 1,760,700 | 2,004,000 | 2,220,500 | 2,429,600 | 2,654,200 | 2,901,600 |

# 4 M&I System Water Use Metrics

Extensive, high-quality system-specific data are available for many Oregon M&I systems through WMCPs and WSMPs. Because these data are available, the analysis uses a "system" approach in the analysis of M&I water demand and supply. This approach reflects the use of system-specific data in all calculations, whenever possible, and differs from broad-based M&I water demand forecasts in which general, or consolidated, water use metrics are applied to a jurisdictional population estimate in order to estimate future water demand. This section describes the compilation and assignment of data for the following M&I system water use metrics:

- sector (i.e., residential and non-residential) category percentages of water use;
- M&I system unaccounted-for water loss;
- Average Daily Demand and Average Gallons per Capita Day;
- Peak Daily Demand and Peak Daily Demand per Capita Day; and
- Average Peak Season Use.

## 4.1 Customer Class Use Percentages

The examination was initiated with the goal of identifying residential, commercial, industrial, and public customer class water use percentages. However, only 13 systems provide a water use break-out that included an "Industrial" category alone. Also, only 33 systems provide a combined "Commercial & Industrial" category, and only 16 systems provide a "Commercial & Public" category. Because the only level of consistent categorization that could be discerned from the data is "Residential" and "Non-Residential", those categories were used in this analysis.

Table 4-1 shows the median values of Residential and Non-Residential percent of water use derived from the examination of M&I system planning documents by M&I population category.

**Table 4-1**
**Median Values of Percent Residential and Non-Residential Water Use Observed**

| Population Category | Number of Systems in Statistic | MEDIAN Residential Percent Use | MEDIAN Non-Residential Percent Use | Number of Systems Median Assigned |
|---|---|---|---|---|
| Under 1,000 | 7 | 83% | 17% | 17 |
| 1,000 to 5,000 | 14 | 85% | 15% | 14 |
| 5,000 to 10,000 | 4 | 61% | 39% | 6 |
| 10,000 to 25,000 | 8 | 76% | 24% | 3 |
| 25,000 to 50,000 | 6 | 78% | 22% | 1 |
| 50,000 to 100,000 | 7 | 59% | 41% | 0 |
| Over 100,000 | 3 | 69% | 31% | 0 |
| Overall | 49 | 78% | 22% | 41 |

The column named "Number of Systems in Statistic" represents the number of study area systems for which actual data were obtained through examination of the planning documents. Median values shown in the table are based on data from these systems. The column named "Number of

Systems Median Assigned" represents the number of study area systems for which a median value was assigned because actual data were not available. As such, if an M&I system provided data in a planning document that describes customer class use, (i.e., one of the 49 listed in the statistical totals above), the actual customer class use percentages were used in all analyses. For the remaining 41 M&I systems, the median values of customer class use percentages corresponding to the appropriate population size category was used in all analyses.

## 4.2 M&I System Unaccounted-for Water

Unaccounted-for water represents the difference between "net production" (the volume of water delivered into a distribution network) and "consumption", the volume of water that can be accounted for by legitimate consumption. M&I water suppliers show varying levels of unaccounted-for water, and each M&I system strives for a reduction to an industry-accepted goal of no more than 10 percent unaccounted-for water. The systems work to reduce the amount of unaccounted-for water in their systems through leak detection, pipe repair and replacement, metering of source diversions and service connections, and regularly monitoring and auditing water use. Through implementation of these programs, each M&I system could reduce its per capita demands.

Table 4-2 shows median values by M&I Population category of Unaccounted-for Water percentages derived from the examination of M&I system planning documents.

**Table 4-2**
**Median Values of Unaccounted-for Water Observed**

| Population Category | Number of Systems in Statistic | MEDIAN | Number of Systems Median Assigned |
|---|---|---|---|
| Under 1,000 | 7 | 16% | 17 |
| 1,000 to 5,000 | 18 | 14% | 10 |
| 5,000 to 10,000 | 4 | 18% | 6 |
| 10,000 to 25,000 | 8 | 10% | 3 |
| 25,000 to 50,000 | 6 | 8% | 1 |
| 50,000 to 100,000 | 7 | 12% | 0 |
| Over 100,000 | 3 | 7% | 0 |
| Overall | 53 | 13% | 37 |

The column named "Number of Systems in Statistic" represents the number of study area M&I systems for which actual data were obtained through examination of the planning documents. Median values shown in the table are based on data from these systems. The column named "Number of Systems Median Assigned" represents the number of study area systems for which a median value was assigned because actual data were not available. As such, if an M&I system provided data in a planning document that describes an unaccounted-for water percentage, (i.e., one of the 53 listed in the statistical totals above), the actual unaccounted-for water percentage was used in all analyses. For the remaining 37 M&I systems, the median value of unaccounted-for water percentage corresponding to the appropriate population size category was used in all analyses.

Table 4-3 shows unaccounted-for water descriptive statistics for the 90 study area M&I systems. The statistics include the actual data of 53 M&I systems and the appropriately-assigned median data for 37 M&I systems.

**Table 4-3**
**Study Area Descriptive Statistics: Unaccounted-for Water**

| Population Category | AVERAGE | MEDIAN | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| Under 1,000 | 17% | 16% | 5% | 45% |
| 1,000 to 5,000 | 17% | 14% | 7% | 59% |
| 5,000 to 10,000 | 19% | 18% | 12% | 29% |
| 10,000 to 25,000 | 11% | 10% | 6% | 19% |
| 25,000 to 50,000 | 10% | 8% | 5% | 19% |
| 50,000 to 100,000 | 11% | 12% | 1% | 20% |
| Over 100,000 | 12% | 7% | 6% | 23% |
| Overall | 15% | 13% | 1% | 59% |

## 4.3 Average Daily Demand and Average Gallons Per Capita Day

Generally, demands and consumption in M&I systems are expressed in units of million gallons per day (MGD). They may also be expressed in cubic feet per second (cfs) or gallons per minute (GPM). Average day demand (ADD) equals the total annual production divided by 365 days. Production refers to the total amount of water that enters the system from a surface water treatment plant, wholesale supplier, or groundwater well.

ADD for study area M&I systems was obtained through a direct examination of WMCPs and WSMPs for study area systems. ADD values were then divided by the M&I system's service area population to arrive at an Average Gallons Per Capita Day (Average GPCD) figure for each M&I system. Table 4-4 shows median values by Average GPCD figures derived from the examination of planning documents.

**Table 4-4**
**Median Values of Average GPCD Observed**

| Population Category | Number of Systems in Statistic | MEDIAN | Number of Systems Median Assigned |
|---|---|---|---|
| Under 1,000 | 7 | 109 | 17 |
| 1,000 to 5,000 | 18 | 112 | 10 |
| 5,000 to 10,000 | 4 | 126 | 6 |
| 10,000 to 25,000 | 8 | 130 | 3 |
| 25,000 to 50,000 | 6 | 115 | 1 |
| 50,000 to 100,000 | 7 | 156 | 0 |
| Over 100,000 | 3 | 160 | 0 |
| Overall | 53 | 127 | 37 |

The column named "Number of Systems in Statistic" represents the number of study area systems for which actual data were obtained through examination of the planning documents. Median values shown in the table are based on data from these systems. The column named "Number of Systems Median Assigned" represents the number of study area systems for which a median value was assigned because actual data were not available. As such, if an M&I system provided data in a planning document that describes Average GPCD, (i.e., one of the 53 listed in the statistical totals above), the actual Average GPCD was used in all analyses. For the remaining 37 M&I systems, the median value of Average GPCD corresponding to the appropriate population size category was used in all analyses.

Table 4-5 shows Average GPCD descriptive statistics for the 90 study area M&I systems. The statistics include the actual data of 53 M&I systems and the appropriately-assigned median data for 37 M&I systems.

**Table 4-5**
**Study Area Descriptive Statistics: Average GPCD**

| Population Category | AVERAGE | MEDIAN | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| Under 1,000 | 169 | 109 | 75 | 1,415 |
| 1,000 to 5,000 | 124 | 112 | 74 | 247 |
| 5,000 to 10,000 | 147 | 126 | 121 | 346 |
| 10,000 to 25,000 | 130 | 130 | 99 | 169 |
| 25,000 to 50,000 | 121 | 115 | 94 | 152 |
| 50,000 to 100,000 | 150 | 156 | 99 | 203 |
| Over 100,000 | 165 | 160 | 117 | 218 |
| Overall | 142 | 127 | 74 | 1,415 |

### 4.3.1 Residential and Non-Residential Sectors Average GPCD

In viewing the table above, the outlier of 1,415 Average GPCD is known to be a very small M&I system with a service area population of 615 persons. In addition, the residential portion of that

M&I supplier's water users is only 12 percent. The residential sector percentages assembled and developed in Section 4.1 above were used to estimate residential sector Average GPCD values, and are a shown in Table 4-6 below. Residential sector Average GPCD values were derived by multiplying each M&I system's residential percent use (either the actual value or an appropriately-assigned median value) by its Average GPCD (again, either the actual value or an appropriately-assigned median value). The statistics include the actual data of 53 M&I systems and the appropriately-assigned median data for 37 M&I systems. Table 4-7 shows descriptive statistics for the non-residential sector.

**Table 4-6**
**Study Area Descriptive Statistics: Residential Sector Average GPCD**

| Population Category | AVERAGE | MEDIAN | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| Under 1,000 | 99 | 91 | 63 | 177 |
| 1,000 to 5,000 | 103 | 95 | 68 | 166 |
| 5,000 to 10,000 | 81 | 76 | 69 | 111 |
| 10,000 to 25,000 | 94 | 97 | 78 | 125 |
| 25,000 to 50,000 | 91 | 84 | 73 | 122 |
| 50,000 to 100,000 | 90 | 85 | 70 | 130 |
| Over 100,000 | 109 | 91 | 86 | 150 |
| Overall | 97 | 91 | 63 | 177 |

**Table 4-7**
**Study Area Descriptive Statistics: Non-Residential Sector Average GPCD**

| Population Category | AVERAGE | MEDIAN | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| Under 1,000 | 70 | 91 | 5 | 1,245 |
| 1,000 to 5,000 | 21 | 95 | 1 | 121 |
| 5,000 to 10,000 | 66 | 76 | 31 | 235 |
| 10,000 to 25,000 | 36 | 97 | 13 | 84 |
| 25,000 to 50,000 | 30 | 84 | 9 | 67 |
| 50,000 to 100,000 | 60 | 85 | 20 | 117 |
| Over 100,000 | 56 | 91 | 32 | 69 |
| Overall | 46 | 91 | 1 | 1,245 |

### 4.3.2 Average GPCD Assuming Goal of 10 Percent Unaccounted-for Water Met

An important consideration in the evaluation of water use metrics is adjusting for unaccounted-for water. As shown in Table 4-3 above, the overall average unaccounted-for water is at 15 percent, the median is 13 percent, and the maximum unaccounted-for water ranges between 19 and 59 percent within the various population categories. A common goal of 10 percent unaccounted-for water is stated by most of the planning documents, and is often cited in literature as an industry goal.

Tables 4-8 and 4-9 below show the Average GPCD statistics for the residential and non-residential sectors, respectively, in the event that the M&I systems each achieve the goal of 10 percent unaccounted-for water. However, it is important to note that if a system had already achieved a rate of less than 10 percent unaccounted-for water, then that lower rate was used in the analysis.

**Table 4-8**
**Study Area Descriptive Statistics: Residential Sector**
**Average GPCD at 10 Percent Unaccounted-for Water Goal**

| Population Category | AVERAGE | MEDIAN | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| Under 1,000 | 90 | 85 | 59 | 161 |
| 1,000 to 5,000 | 94 | 92 | 67 | 137 |
| 5,000 to 10,000 | 74 | 70 | 67 | 90 |
| 10,000 to 25,000 | 92 | 97 | 78 | 114 |
| 25,000 to 50,000 | 88 | 82 | 73 | 112 |
| 50,000 to 100,000 | 87 | 83 | 68 | 130 |
| Over 100,000 | 102 | 91 | 86 | 130 |
| Overall | 90 | 85 | 59 | 161 |

**Table 4-9**
**Study Area Descriptive Statistics: Non-Residential Sector**
**Average GPCD at 10 Percent Unaccounted-for Water Goal**

| Population Category | AVERAGE | MEDIAN | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| Under 1,000 | 66 | 17 | 4 | 1,183 |
| 1,000 to 5,000 | 20 | 16 | 1 | 121 |
| 5,000 to 10,000 | 58 | 45 | 28 | 191 |
| 10,000 to 25,000 | 35 | 32 | 13 | 78 |
| 25,000 to 50,000 | 29 | 26 | 9 | 67 |
| 50,000 to 100,000 | 58 | 57 | 20 | 117 |
| Over 100,000 | 53 | 60 | 32 | 69 |
| Overall | 43 | 18 | 1 | 1,183 |

## 4.4 Maximum Daily Demand (MDD) and Peak Gallons Per Capita Day

Maximum Daily Demand (MDD) is an important value for water system planning. The supply facilities (treatment plants, pipelines, reservoirs) and water supply must be capable of meeting the MDD. If the MDD exceeds the combined supply capacity on any given day, finished water storage levels will be reduced. Consecutive days at or near the MDD may result in a water shortage. For water system planning, the sum of system water sources should be adequate to provide the MDD.

MDD for study area M&I systems was obtained through a direct examination of WMCPs and WSMPs. MDD values were then divided by the system's service area population to arrive at a Peak Gallons Per Capita Day (Peak GPCD) for each M&I system. Table 4-10 shows median values by M&I Peak GPCD figures derived from the examination of M&I system planning documents.

**Table 4-10**
**Median Values of Peak GPCD Observed**

| Population Category | Number of Systems in Statistic | MEDIAN | Number of Systems Median Assigned |
|---|---|---|---|
| Under 1,000 | 7 | 267 | 17 |
| 1,000 to 5,000 | 17 | 271 | 11 |
| 5,000 to 10,000 | 3 | 175 | 7 |
| 10,000 to 25,000 | 8 | 271 | 3 |
| 25,000 to 50,000 | 7 | 276 | 0 |
| 50,000 to 100,000 | 7 | 293 | 0 |
| Over 100,000 | 3 | 353 | 0 |
| Overall | 52 | 275 | 38 |

The column named "Number of Systems in Statistic" represents the number of study area systems for which actual data were obtained through examination of the planning documents. Median values shown in the table are based on data from these systems. The column named "Number of Systems Median Assigned" represents the number of study area systems for which a median value was assigned because actual data were not available. As such, if an M&I system provided data in a planning document that describes Peak GPCD, (i.e., one of the 52 listed in the statistical totals above), the actual Peak GPCD was used in all analyses. For the remaining 38 M&I systems, the median value of Peak GPCD corresponding to the appropriate population size category was used in all analyses.

Table 4-11 shows Peak GPCD descriptive statistics for the 90 study area M&I systems. The statistics include the actual data of 52 M&I systems and the appropriately-assigned median data for 38 M&I systems.

**Table 4-11**
**Study Area Descriptive Statistics: Peak GPCD**

| Population Category | AVERAGE | MEDIAN | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| Under 1,000 | 346 | 267 | 218 | 2,049 |
| 1,000 to 5,000 | 277 | 271 | 165 | 520 |
| 5,000 to 10,000 | 242 | 175 | 165 | 849 |
| 10,000 to 25,000 | 270 | 271 | 203 | 354 |
| 25,000 to 50,000 | 284 | 276 | 221 | 366 |
| 50,000 to 100,000 | 293 | 293 | 174 | 361 |
| Over 100,000 | 317 | 353 | 239 | 358 |
| Overall | 294 | 275 | 165 | 2,049 |

### 4.4.1 Residential and Non-Residential Sectors Peak GPCD

In viewing the table above, the outlier of 2,049 Peak GPCD is known to be a very small M&I supplier with a service area population of 615 persons. In addition, the residential portion of that M&I supplier's water users is only 12 percent. The residential sector percentages assembled and developed in Section 4.1 above were used to estimate residential sector Peak GPCD values, and are a shown in Table 4-12 below. Residential sector Average GPCD values were derived by multiplying each M&I system's residential percent use (either the actual value or an appropriately-assigned median value) by its Peak GPCD (again, either the actual value or an appropriately-assigned median value). The statistics include the actual data of 52 M&I systems and the appropriately-assigned median data for 38 M&I systems. Table 4-13 shows descriptive statistics for the non-residential sector.

**Table 4-12**
**Study Area Descriptive Statistics: Residential Sector Peak GPCD**

| Population Category | AVERAGE | MEDIAN | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| Under 1,000 | 228 | 221 | 197 | 341 |
| 1,000 to 5,000 | 230 | 230 | 163 | 300 |
| 5,000 to 10,000 | 125 | 106 | 90 | 272 |
| 10,000 to 25,000 | 196 | 177 | 153 | 273 |
| 25,000 to 50,000 | 216 | 193 | 164 | 293 |
| 50,000 to 100,000 | 177 | 173 | 122 | 282 |
| Over 100,000 | 207 | 201 | 174 | 246 |
| Overall | 208 | 221 | 90 | 341 |

**Table 4-13**
**Study Area Descriptive Statistics: Non-Residential Sector Peak GPCD**

| Population Category | AVERAGE | MEDIAN | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| Under 1,000 | 118 | 45 | 11 | 1,803 |
| 1,000 to 5,000 | 47 | 41 | 2 | 255 |
| 5,000 to 10,000 | 117 | 69 | 43 | 578 |
| 10,000 to 25,000 | 74 | 66 | 29 | 177 |
| 25,000 to 50,000 | 68 | 64 | 23 | 151 |
| 50,000 to 100,000 | 115 | 120 | 43 | 209 |
| Over 100,000 | 110 | 113 | 64 | 152 |
| Overall | 86 | 45 | 2 | 1,803 |

### 4.4.2 Peak GPCD Assuming Goal of 10 Percent Unaccounted-for Water Met

An important consideration in the evaluation of water use metrics is adjusting for unaccounted-for water. As shown in Table 4-3 above, the overall average unaccounted-for water is at 15 percent, the median is 13 percent, and the maximum unaccounted-for water ranges between 19 and 59 percent within the various population categories. A common goal of 10 percent unaccounted-for water is stated by most of the planning documents, and is often cited as an industry goal. Tables 4-14 and 4-15 below show the Peak GPCD statistics for the residential and non-residential sectors, respectively, in the event that the M&I systems each achieve the goal of 10 percent unaccounted-for water. However, it is important to note that if a system had already achieved a rate of less than 10 percent unaccounted-for water, then that lower rate was used in the analysis.

**Table 4-14**
**Study Area Descriptive Statistics: Residential Sector**
**Peak GPCD at 10 Percent Unaccounted-for Water Goal**

| Population Category | AVERAGE | MEDIAN | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| Under 1,000 | 209 | 208 | 167 | 273 |
| 1,000 to 5,000 | 212 | 222 | 104 | 287 |
| 5,000 to 10,000 | 112 | 97 | 88 | 220 |
| 10,000 to 25,000 | 192 | 177 | 152 | 273 |
| 25,000 to 50,000 | 210 | 180 | 164 | 268 |
| 50,000 to 100,000 | 172 | 157 | 119 | 282 |
| Over 100,000 | 197 | 201 | 174 | 214 |
| Overall | 194 | 208 | 88 | 287 |

**Table 4-15**
**Study Area Descriptive Statistics: Non-Residential Sector**
**Peak GPCD at 10 Percent Unaccounted-for Water Goal**

| Population Category | AVERAGE | MEDIAN | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| Under 1,000 | 111 | 208 | 9 | 1713 |
| 1,000 to 5,000 | 44 | 222 | 2 | 255 |
| 5,000 to 10,000 | 101 | 97 | 39 | 468 |
| 10,000 to 25,000 | 72 | 177 | 27 | 164 |
| 25,000 to 50,000 | 67 | 180 | 23 | 151 |
| 50,000 to 100,000 | 111 | 157 | 43 | 209 |
| Over 100,000 | 105 | 201 | 64 | 152 |
| Overall | 81 | 208 | 2 | 1,713 |

## 4.5 Average Peak Season Use

Average peak season use calculations are based on ADD and the portion of ADD that occurs during the months of June through September (months that define the peak season for M&I systems).

Most Oregon M&I water rights require the user to report water use to the WRD, as specified in ORS 537.099. This regulation requires federal and state agencies, cities, counties, schools, irrigation districts and other special districts to annually report water use by month. WRD maintains a database that contains water use data reported on a monthly basis, and these data were downloaded and analyzed for study area M&I systems. For each M&I system, monthly water use data were aggregated by month and divided by annual water use (as reported within the database – not as reported in WMCPs or WSMPs) in order to arrive at a percent value of each month's water use for each M&I system. Monthly percent use statistics were calculated for 68 of the study area M&I water suppliers. Table 4-16 shows median values of annual percent use for the peak season, which has been set as June 1 through September 30 of each year.

The column named "Number of Systems in Statistic" represents the number of study area systems for which actual data were obtained through examination of the planning documents. Median values shown in the table are based on data from these systems. The column named "Number of

Systems Median Assigned" represents the number of study area systems for which a median value was assigned because actual data were not available. As such, if an M&I system reported water use to WRD, (i.e., one of the 68 listed in the statistical totals below), the actual average peak season use percentage was used in all analyses. For the remaining 22 M&I systems, the median value of average peak season use percentage corresponding to the appropriate population size category was used in all analyses.

**Table 4-16**
**Median Values of Peak Season Use as Percent of Annual Use Observed**

| Population Category | Number of Systems in Statistic | MEDIAN | Number of Systems Median Assigned |
|---|---|---|---|
| Under 1,000 | 13 | 40% | 11 |
| 1,000 to 5,000 | 22 | 44% | 6 |
| 5,000 to 10,000 | 10 | 43% | 0 |
| 10,000 to 25,000 | 9 | 48% | 2 |
| 25,000 to 50,000 | 6 | 50% | 1 |
| 50,000 to 100,000 | 5 | 44% | 2 |
| Over 100,000 | 3 | 49% | 0 |
| Overall | 68 | 44% | 22 |

Table 4-17 shows peak season percentage use descriptive statistics for the 90 study area M&I systems. The statistics include the actual data of 68 M&I systems and the appropriately-assigned median data for 22 M&I systems.

**Table 4-17**
**Study Area Descriptive Statistics: Peak Season Use Percent of Annual Use**

| Population Category | AVERAGE | MEDIAN | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| Under 1,000 | 41% | 40% | 32% | 54% |
| 1,000 to 5,000 | 46% | 44% | 37% | 69% |
| 5,000 to 10,000 | 44% | 43% | 33% | 58% |
| 10,000 to 25,000 | 46% | 48% | 40% | 51% |
| 25,000 to 50,000 | 48% | 50% | 35% | 51% |
| 50,000 to 100,000 | 44% | 44% | 40% | 46% |
| Over 100,000 | 47% | 49% | 41% | 50% |
| Overall | 44% | 44% | 32% | 69% |

# 5 M&I System Demand Projections

This section provides M&I system demand projections in terms of:

- Annual M&I System Demand;
- Peak Season M&I System Demand – Peak GPD Use; and

- Peak Season M&I System Demand – Average Peak Season Use.

## 5.1 Demand Estimates Shown in the Summary Table and Detailed Tables

A summary table has been developed in order to simplify and consolidate the presentation of the three demand estimates listed above, and is presented prior to the detailed tables for each estimate. For the summary table and the detailed tables, the following generalities apply:

- All demand projections were assembled using population projections described in Section 3.3, and the M&I system use metrics described in Section 4. For each M&I system, its projected year population was multiplied by the M&I system's use metric, which, in turn were converted to acre-feet in order to arrive at the various M&I demand projections shown in the tables.
- The demand projections shown in the tables also provide breakdowns by residential and non-residential sector. To develop these estimates, residential and non-residential use metrics derived in Section 4 were applied to each M&I system's demand projection.
- As described in Section 4.2, the water supply industry strives for a goal of 10 percent unaccounted-for water. Specifically-noted demand projections in the tables reflect the study area M&I systems' assumed achievement of that goal.

Detailed tables for M&I system water demand projections are provided in the following sections:

- Section 5.2 – Annual M&I System Demand;
- Section 5.3 – Peak Season M&I System Demand based on Peak GPCD Use; and
- Section 5.4 – Peak Season M&I System Demand based on Average Peak Season Use

The detailed tables shown in Sections 5.2 through 5.4 provide the following projections segmented by population category:

- M&I System Demand
- M&I System Demand at 10 Percent Unaccounted-for Water Goal
- Residential M&I System Demand
- Non-Residential M&I System Demand
- Residential M&I System Demand at 10 Percent Unaccounted-for Water Goal
- Non-Residential M&I System Demand at 10 Percent Unaccounted-for Water Goal

**Table 5-1**
**Summary of M&I System Peak Season Water Demand Scenarios (acre-feet)**

| | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Annual Demand** | | | | | | |
| Residential | 191,000 | 217,500 | 240,900 | 263,900 | 288,600 | 315,800 |
| Non-Residential | 100,200 | 113,300 | 125,200 | 136,300 | 148,200 | 161,400 |
| **Total** | **291,200** | **330,800** | **366,100** | **400,200** | **436,800** | **477,200** |
| **Annual Demand – Unaccounted-for Water Goal of 10 Percent Achieved** | | | | | | |
| Residential | 182,500 | 207,900 | 230,200 | 252,200 | 275,900 | 302,000 |
| Non-Residential | 95,600 | 108,100 | 119,500 | 130,100 | 141,500 | 154,000 |
| **Total** | **278,100** | **316,000** | **349,700** | **382,300** | **417,400** | **456,000** |
| **Peak Season Demand (Peak GPCD Metric)** | | | | | | |
| Residential | 128,100 | 145,800 | 161,300 | 176,700 | 193,400 | 211,700 |
| Non-Residential | 65,300 | 73,800 | 81,500 | 88,700 | 96,400 | 104,900 |
| **Total** | **193,400** | **219,600** | **242,800** | **265,400** | **289,800** | **316,600** |
| **Peak Season Demand (Peak GPCD Metric) – Unaccounted-for Water Goal of 10 Percent Achieved** | | | | | | |
| Residential | 123,000 | 140,000 | 154,900 | 169,800 | 185,800 | 203,400 |
| Non-Residential | 62,500 | 70,700 | 78,100 | 84,900 | 92,300 | 100,500 |
| **Total** | **185,500** | **210,700** | **233,000** | **254,700** | **278,100** | **303,900** |
| **Peak Season Demand (Average Peak Season Use Metric)** | | | | | | |
| Residential | 86,900 | 98,900 | 109,500 | 119,900 | 131,100 | 143,500 |
| Non-Residential | 45,400 | 51,300 | 56,600 | 61,600 | 67,000 | 72,900 |
| **Total** | **132,300** | **150,200** | **166,100** | **181,500** | **198,100** | **216,400** |
| **Peak Season Demand (Avg Peak Seas Use Metric) – Unaccounted-for Water Goal of 10 Percent Achieved** | | | | | | |
| Residential | 83,200 | 94,700 | 104,800 | 114,800 | 125,600 | 137,400 |
| Non-Residential | 43,300 | 49,000 | 54,200 | 58,900 | 64,000 | 69,700 |
| **Total** | **126,500** | **143,700** | **159,000** | **173,700** | **189,600** | **207,100** |

## 5.2 Annual M&I System Demand Projections

**Table 5-2**
**Annual M&I System Demand Projection (acre-feet)**

| Population Category | 2015 Baseline | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| Under 1,000 | 2,400 | 2,600 | 2,900 | 3,200 | 3,500 | 3,800 | 4,100 |
| 1,000 to 5,000 | 9,500 | 10,200 | 11,600 | 12,900 | 14,100 | 15,400 | 16,700 |
| 5,000 to 10,000 | 13,000 | 13,900 | 15,900 | 17,700 | 19,300 | 21,100 | 23,100 |
| 10,000 to 25,000 | 28,900 | 32,000 | 36,800 | 40,900 | 44,400 | 48,400 | 52,900 |
| 25,000 to 50,000 | 31,900 | 35,500 | 40,800 | 45,000 | 49,900 | 55,300 | 61,400 |
| 50,000 to 100,000 | 77,200 | 84,000 | 95,100 | 105,100 | 114,900 | 125,300 | 136,700 |
| Over 100,000 | 105,200 | 113,000 | 127,600 | 141,300 | 154,000 | 167,600 | 182,400 |
| TOTAL | 268,200 | 291,200 | 330,800 | 366,100 | 400,200 | 436,800 | 477,200 |

**Table 5-3**
**Annual M&I System Demand Projection (acre-feet)**
**at 10 Percent Unaccounted-for Water Goal**

| Population Category | 2015 Baseline | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| Under 1,000 | 2,200 | 2,400 | 2,700 | 2,900 | 3,200 | 3,400 | 3,700 |
| 1,000 to 5,000 | 8,900 | 9,500 | 10,800 | 12,000 | 13,100 | 14,300 | 15,500 |
| 5,000 to 10,000 | 11,700 | 12,500 | 14,300 | 15,800 | 17,300 | 18,900 | 20,700 |
| 10,000 to 25,000 | 28,300 | 31,200 | 35,900 | 39,900 | 43,400 | 47,300 | 51,700 |
| 25,000 to 50,000 | 31,000 | 34,600 | 39,800 | 43,900 | 48,700 | 54,000 | 59,900 |
| 50,000 to 100,000 | 74,700 | 81,300 | 92,100 | 102,000 | 111,500 | 121,600 | 132,800 |
| Over 100,000 | 99,300 | 106,600 | 120,300 | 133,100 | 145,100 | 157,800 | 171,600 |
| TOTAL | 256,100 | 278,100 | 316,000 | 349,700 | 382,300 | 417,400 | 456,000 |

### 5.2.1 Annual M&I System Demand Projections by Sector

**Table 5-4**
**Annual Residential M&I System Demand Projection (acre-feet)**

| Population Category | 2015 Baseline | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| Under 1,000 | 1,300 | 1,400 | 1,600 | 1,800 | 1,900 | 2,100 | 2,300 |
| 1,000 to 5,000 | 8,000 | 8,600 | 9,900 | 11,000 | 12,000 | 13,000 | 14,200 |
| 5,000 to 10,000 | 7,200 | 7,700 | 8,800 | 9,800 | 10,700 | 11,700 | 12,800 |
| 10,000 to 25,000 | 20,600 | 22,600 | 26,000 | 28,900 | 31,500 | 34,300 | 37,500 |
| 25,000 to 50,000 | 24,200 | 27,000 | 31,100 | 34,200 | 38,100 | 42,300 | 47,100 |
| 50,000 to 100,000 | 44,700 | 48,700 | 55,200 | 61,100 | 66,900 | 73,100 | 79,900 |
| Over 100,000 | 69,700 | 75,000 | 84,900 | 94,200 | 102,800 | 112,000 | 122,100 |
| TOTAL | 175,700 | 191,000 | 217,500 | 240,900 | 263,900 | 288,600 | 315,800 |

**Table 5-5**
**Annual Non-Residential M&I System Demand Projection (acre-feet)**

| Population Category | 2015 Baseline | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| Under 1,000 | 1,100 | 1,200 | 1,300 | 1,400 | 1,600 | 1,700 | 1,800 |
| 1,000 to 5,000 | 1,500 | 1,600 | 1,700 | 1,900 | 2,100 | 2,400 | 2,500 |
| 5,000 to 10,000 | 5,800 | 6,200 | 7,100 | 7,900 | 8,600 | 9,400 | 10,300 |
| 10,000 to 25,000 | 8,300 | 9,400 | 10,800 | 12,000 | 12,900 | 14,100 | 15,400 |
| 25,000 to 50,000 | 7,700 | 8,500 | 9,700 | 10,800 | 11,800 | 13,000 | 14,300 |
| 50,000 to 100,000 | 32,500 | 35,300 | 39,900 | 44,000 | 48,000 | 52,200 | 56,800 |
| Over 100,000 | 35,500 | 38,000 | 42,700 | 47,100 | 51,200 | 55,600 | 60,300 |
| TOTAL | 92,500 | 100,200 | 113,300 | 125,200 | 136,300 | 148,200 | 161,400 |

**Table 5-6**
**Annual Residential M&I System Demand Projection (acre-feet)**
**at 10 Percent Unaccounted-for Water Goal**

| Population Category | 2015 Baseline | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| Under 1,000 | 1,200 | 1,300 | 1,400 | 1,600 | 1,700 | 1,900 | 2,000 |
| 1,000 to 5,000 | 7,500 | 8,000 | 9,200 | 10,200 | 11,100 | 12,100 | 13,200 |
| 5,000 to 10,000 | 6,500 | 7,000 | 8,000 | 8,900 | 9,700 | 10,600 | 11,600 |
| 10,000 to 25,000 | 20,100 | 22,100 | 25,400 | 28,300 | 30,800 | 33,600 | 36,700 |
| 25,000 to 50,000 | 23,500 | 26,300 | 30,300 | 33,400 | 37,100 | 41,300 | 46,000 |
| 50,000 to 100,000 | 43,300 | 47,200 | 53,600 | 59,300 | 65,000 | 71,000 | 77,700 |
| Over 100,000 | 65,600 | 70,600 | 79,900 | 88,600 | 96,700 | 105,300 | 114,700 |
| TOTAL | 167,800 | 182,500 | 207,900 | 230,200 | 252,200 | 275,900 | 302,000 |

**Table 5-7**
**Annual Non-Residential M&I System Demand Projection (acre-feet)**
**at 10 Percent Unaccounted-for Water Goal**

| Population Category | 2015 Baseline | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| Under 1,000 | 1,000 | 1,100 | 1,300 | 1,300 | 1,500 | 1,500 | 1,700 |
| 1,000 to 5,000 | 1,400 | 1,500 | 1,600 | 1,800 | 2,000 | 2,200 | 2,300 |
| 5,000 to 10,000 | 5,200 | 5,500 | 6,300 | 6,900 | 7,600 | 8,300 | 9,100 |
| 10,000 to 25,000 | 8,200 | 9,100 | 10,500 | 11,600 | 12,600 | 13,700 | 15,000 |
| 25,000 to 50,000 | 7,500 | 8,300 | 9,500 | 10,500 | 11,600 | 12,700 | 13,900 |
| 50,000 to 100,000 | 31,400 | 34,100 | 38,500 | 42,700 | 46,500 | 50,600 | 55,100 |
| Over 100,000 | 33,700 | 36,000 | 40,400 | 44,500 | 48,400 | 52,500 | 56,900 |
| TOTAL | 88,300 | 95,600 | 108,100 | 119,500 | 130,100 | 141,500 | 154,000 |

## 5.3 Peak Season M&I System Demand Projection – Peak GPCD Use

**Table 5-8**
**Peak Season M&I System Demand Projection – Peak GPCD Use (acre-feet)**

| Population Category | 2015 Baseline | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| Under 1,000 | 1,600 | 1,700 | 2,000 | 2,100 | 2,300 | 2,500 | 2,700 |
| 1,000 to 5,000 | 7,200 | 7,700 | 8,800 | 9,800 | 10,700 | 11,600 | 12,700 |
| 5,000 to 10,000 | 7,100 | 7,600 | 8,700 | 9,700 | 10,600 | 11,600 | 12,700 |
| 10,000 to 25,000 | 19,900 | 22,000 | 25,300 | 28,100 | 30,600 | 33,400 | 36,500 |
| 25,000 to 50,000 | 25,100 | 28,000 | 32,200 | 35,500 | 39,400 | 43,700 | 48,500 |
| 50,000 to 100,000 | 49,700 | 54,000 | 61,100 | 67,500 | 73,800 | 80,500 | 87,800 |
| Over 100,000 | 67,400 | 72,300 | 81,500 | 90,000 | 98,000 | 106,500 | 115,800 |
| TOTAL | 178,000 | 193,400 | 219,600 | 242,800 | 265,400 | 289,800 | 316,600 |

**Table 5-9**
**Peak Season (Peak GPCD) M&I System Demand Projection (acre-feet)**
**at 10 Percent Unaccounted-for Water Goal**

| Population Category | 2015 Baseline | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| Under 1,000 | 1,500 | 1,600 | 1,800 | 2,000 | 2,100 | 2,300 | 2,500 |
| 1,000 to 5,000 | 6,800 | 7,300 | 8,300 | 9,200 | 10,000 | 10,900 | 11,900 |
| 5,000 to 10,000 | 6,300 | 6,700 | 7,700 | 8,600 | 9,400 | 10,200 | 11,200 |
| 10,000 to 25,000 | 19,500 | 21,600 | 24,800 | 27,600 | 30,000 | 32,700 | 35,700 |
| 25,000 to 50,000 | 24,400 | 27,300 | 31,400 | 34,600 | 38,400 | 42,600 | 47,400 |
| 50,000 to 100,000 | 48,100 | 52,300 | 59,300 | 65,500 | 71,600 | 78,200 | 85,400 |
| Over 100,000 | 64,100 | 68,800 | 77,500 | 85,500 | 93,100 | 101,100 | 109,900 |
| TOTAL | 170,700 | 185,500 | 210,700 | 233,000 | 254,700 | 278,100 | 303,900 |

### 5.3.1 Peak Season (Peak GPCD) M&I System Demand Projections by Sector

**Table 5-10**
**Peak Season Residential M&I System Demand Projection**
**Based on Peak GPD (acre-feet)**

| Population Category | 2015 Baseline | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| Under 1,000 | 1,000 | 1,100 | 1,200 | 1,400 | 1,500 | 1,600 | 1,700 |
| 1,000 to 5,000 | 6,200 | 6,600 | 7,500 | 8,400 | 9,100 | 9,900 | 10,800 |
| 5,000 to 10,000 | 3,700 | 4,000 | 4,500 | 5,000 | 5,500 | 6,000 | 6,600 |
| 10,000 to 25,000 | 14,200 | 15,600 | 17,900 | 20,000 | 21,700 | 23,700 | 25,900 |
| 25,000 to 50,000 | 19,200 | 21,500 | 24,800 | 27,200 | 30,300 | 33,700 | 37,500 |
| 50,000 to 100,000 | 29,100 | 31,700 | 36,000 | 39,700 | 43,500 | 47,600 | 52,100 |
| Over 100,000 | 44,300 | 47,600 | 53,800 | 59,600 | 65,000 | 70,800 | 77,000 |
| TOTAL | 117,600 | 128,100 | 145,800 | 161,300 | 176,700 | 193,400 | 211,700 |

**Table 5-11**
**Peak Season Non-Residential M&I System Demand Projection**
**Based on Peak GPCD (acre-feet)**

| Population Category | 2015 Baseline | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| Under 1,000 | 600 | 600 | 800 | 700 | 800 | 900 | 1,000 |
| 1,000 to 5,000 | 1,000 | 1,100 | 1,300 | 1,400 | 1,600 | 1,700 | 1,900 |
| 5,000 to 10,000 | 3,400 | 3,600 | 4,200 | 4,700 | 5,100 | 5,600 | 6,100 |
| 10,000 to 25,000 | 5,700 | 6,400 | 7,400 | 8,100 | 8,900 | 9,700 | 10,600 |
| 25,000 to 50,000 | 5,900 | 6,500 | 7,400 | 8,300 | 9,100 | 10,000 | 11,000 |
| 50,000 to 100,000 | 20,600 | 22,300 | 25,100 | 27,800 | 30,300 | 32,900 | 35,700 |
| Over 100,000 | 23,100 | 24,700 | 27,700 | 30,400 | 33,000 | 35,700 | 38,800 |
| TOTAL | 60,400 | 65,300 | 73,800 | 81,500 | 88,700 | 96,400 | 104,900 |

**Table 5-12**
**Peak Season Residential M&I System Demand Projection (acre-feet)**
**Based on Peak GPCD at 10 Percent Unaccounted-for Water Goal**

| Population Category | 2015 Baseline | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| Under 1,000 | 900 | 1,000 | 1,100 | 1,200 | 1,300 | 1,500 | 1,600 |
| 1,000 to 5,000 | 5,800 | 6,200 | 7,100 | 7,800 | 8,500 | 9,300 | 10,100 |
| 5,000 to 10,000 | 3,300 | 3,600 | 4,100 | 4,500 | 5,000 | 5,400 | 5,900 |
| 10,000 to 25,000 | 13,900 | 15,300 | 17,600 | 19,600 | 21,400 | 23,300 | 25,500 |
| 25,000 to 50,000 | 18,700 | 21,000 | 24,200 | 26,600 | 29,600 | 32,900 | 36,700 |
| 50,000 to 100,000 | 28,200 | 30,800 | 34,900 | 38,600 | 42,300 | 46,300 | 50,700 |
| Over 100,000 | 42,000 | 45,200 | 51,100 | 56,600 | 61,700 | 67,100 | 73,000 |
| TOTAL | 112,900 | 123,000 | 140,000 | 154,900 | 169,800 | 185,800 | 203,400 |

**Table 5-13**
**Peak Season Non-Residential M&I System Demand Projection (acre-feet)**
**Based on Peak GPCD at 10 Percent Unaccounted-for Water Goal**

| Population Category | 2015 Baseline | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| Under 1,000 | 600 | 600 | 700 | 800 | 800 | 800 | 900 |
| 1,000 to 5,000 | 1,000 | 1,100 | 1,200 | 1,400 | 1,500 | 1,600 | 1,800 |
| 5,000 to 10,000 | 3,000 | 3,100 | 3,600 | 4,100 | 4,400 | 4,800 | 5,300 |
| 10,000 to 25,000 | 5,600 | 6,300 | 7,200 | 8,000 | 8,600 | 9,400 | 10,200 |
| 25,000 to 50,000 | 5,700 | 6,300 | 7,200 | 8,000 | 8,800 | 9,700 | 10,700 |
| 50,000 to 100,000 | 19,900 | 21,500 | 24,400 | 26,900 | 29,300 | 31,900 | 34,700 |
| Over 100,000 | 22,100 | 23,600 | 26,400 | 28,900 | 31,400 | 34,000 | 36,900 |
| TOTAL | 57,800 | 62,500 | 70,700 | 78,100 | 84,900 | 92,300 | 100,500 |

## 5.4 Peak Season M&I System Demand Projection – Average Peak Season Use

**Table 5-14**
**Peak Season M&I System Demand Projection – Average Peak Season Use (acre-feet)**

| Population Category | 2015 Baseline | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| Under 1,000 | 1,000 | 1,000 | 1,200 | 1,300 | 1,400 | 1,500 | 1,600 |
| 1,000 to 5,000 | 4,400 | 4,700 | 5,400 | 6,000 | 6,500 | 7,100 | 7,700 |
| 5,000 to 10,000 | 6,000 | 6,500 | 7,400 | 8,200 | 9,000 | 9,800 | 10,700 |
| 10,000 to 25,000 | 13,300 | 14,800 | 17,000 | 18,800 | 20,500 | 22,300 | 24,400 |
| 25,000 to 50,000 | 15,200 | 17,000 | 19,500 | 21,500 | 23,900 | 26,500 | 29,400 |
| 50,000 to 100,000 | 33,600 | 36,500 | 41,400 | 45,800 | 50,000 | 54,500 | 59,500 |
| Over 100,000 | 48,200 | 51,800 | 58,400 | 64,500 | 70,300 | 76,500 | 83,200 |
| TOTAL | 121,800 | 132,300 | 150,200 | 166,100 | 181,500 | 198,100 | 216,400 |

**Table 5-15**
**Peak Season (Average Peak Season Use) M&I System Demand Projection (acre-feet)**
**at 10 Percent Unaccounted-for Water Goal**

| Population Category | 2015 Baseline | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| Under 1,000 | 900 | 1,000 | 1,100 | 1,200 | 1,300 | 1,400 | 1,500 |
| 1,000 to 5,000 | 4,100 | 4,400 | 5,000 | 5,500 | 6,000 | 6,600 | 7,200 |
| 5,000 to 10,000 | 5,400 | 5,800 | 6,600 | 7,300 | 8,000 | 8,700 | 9,500 |
| 10,000 to 25,000 | 13,000 | 14,400 | 16,600 | 18,400 | 20,000 | 21,800 | 23,800 |
| 25,000 to 50,000 | 14,800 | 16,500 | 19,000 | 21,000 | 23,300 | 25,800 | 28,700 |
| 50,000 to 100,000 | 32,500 | 35,400 | 40,100 | 44,400 | 48,500 | 52,900 | 57,700 |
| Over 100,000 | 45,700 | 49,100 | 55,400 | 61,200 | 66,700 | 72,400 | 78,700 |
| TOTAL | 116,500 | 126,500 | 143,700 | 159,000 | 173,700 | 189,600 | 207,100 |

### 5.4.1 Peak Season (Average Peak Season Use) M&I System Demand Projections by Sector

**Table 5-16**
**Peak Season Residential M&I System Demand Projection**
**Based on Average Peak Season Use (acre-feet)**

| Population Category | 2015 Baseline | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| Under 1,000 | 500 | 600 | 600 | 700 | 800 | 800 | 900 |
| 1,000 to 5,000 | 3,700 | 4,000 | 4,500 | 5,000 | 5,500 | 6,000 | 6,500 |
| 5,000 to 10,000 | 3,200 | 3,500 | 4,000 | 4,400 | 4,800 | 5,300 | 5,800 |
| 10,000 to 25,000 | 9,400 | 10,400 | 11,900 | 13,300 | 14,500 | 15,800 | 17,200 |
| 25,000 to 50,000 | 11,700 | 13,200 | 15,100 | 16,600 | 18,500 | 20,600 | 22,900 |
| 50,000 to 100,000 | 19,400 | 21,100 | 24,000 | 26,500 | 29,000 | 31,700 | 34,600 |
| Over 100,000 | 31,800 | 34,200 | 38,700 | 42,900 | 46,800 | 51,000 | 55,500 |
| TOTAL | 79,900 | 86,900 | 98,900 | 109,500 | 119,900 | 131,100 | 143,500 |

**Table 5-17**
**Peak Season Non-Residential M&I System Demand Projection**
**Based on Average Peak Season Use (acre-feet)**

| Population Category | 2015 Baseline | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| Under 1,000 | 500 | 400 | 600 | 600 | 600 | 700 | 700 |
| 1,000 to 5,000 | 700 | 700 | 900 | 1,000 | 1,000 | 1,100 | 1,200 |
| 5,000 to 10,000 | 2,800 | 3,000 | 3,400 | 3,800 | 4,200 | 4,500 | 4,900 |
| 10,000 to 25,000 | 3,900 | 4,400 | 5,100 | 5,500 | 6,000 | 6,500 | 7,200 |
| 25,000 to 50,000 | 3,500 | 3,800 | 4,400 | 4,900 | 5,400 | 5,900 | 6,500 |
| 50,000 to 100,000 | 14,200 | 15,400 | 17,400 | 19,300 | 21,000 | 22,800 | 24,900 |
| Over 100,000 | 16,400 | 17,600 | 19,700 | 21,600 | 23,500 | 25,500 | 27,700 |
| TOTAL | 41,900 | 45,400 | 51,300 | 56,600 | 61,600 | 67,000 | 72,900 |

**Table 5-18**
**Peak Season Residential M&I System Demand Projection (acre-feet)**
**Based on Average Peak Season Use at 10 Percent Unaccounted-for Water Goal**

| Population Category | 2015 Baseline | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| Under 1,000 | 500 | 500 | 600 | 600 | 700 | 800 | 800 |
| 1,000 to 5,000 | 3,500 | 3,700 | 4,200 | 4,700 | 5,100 | 5,600 | 6,100 |
| 5,000 to 10,000 | 2,900 | 3,100 | 3,600 | 4,000 | 4,300 | 4,800 | 5,200 |
| 10,000 to 25,000 | 9,200 | 10,100 | 11,700 | 13,000 | 14,200 | 15,500 | 16,900 |
| 25,000 to 50,000 | 11,400 | 12,800 | 14,700 | 16,200 | 18,000 | 20,100 | 22,400 |
| 50,000 to 100,000 | 18,800 | 20,500 | 23,300 | 25,700 | 28,200 | 30,800 | 33,700 |
| Over 100,000 | 30,100 | 32,400 | 36,600 | 40,600 | 44,300 | 48,200 | 52,400 |
| TOTAL | 76,400 | 83,200 | 94,700 | 104,800 | 114,800 | 125,600 | 137,400 |

**Table 5-19**
**Peak Season Non-Residential M&I System Demand Projection (acre-feet)**
**Based on Average Peak Season Use at 10 Percent Unaccounted-for Water Goal**

| Population Category | 2015 Baseline | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| Under 1,000 | 400 | 500 | 500 | 600 | 600 | 600 | 700 |
| 1,000 to 5,000 | 600 | 700 | 800 | 800 | 900 | 1,000 | 1,100 |
| 5,000 to 10,000 | 2,500 | 2,700 | 3,000 | 3,300 | 3,700 | 3,900 | 4,300 |
| 10,000 to 25,000 | 3,800 | 4,300 | 4,900 | 5,400 | 5,800 | 6,300 | 6,900 |
| 25,000 to 50,000 | 3,400 | 3,700 | 4,300 | 4,800 | 5,300 | 5,700 | 6,300 |
| 50,000 to 100,000 | 13,700 | 14,900 | 16,800 | 18,700 | 20,300 | 22,100 | 24,000 |
| Over 100,000 | 15,600 | 16,700 | 18,800 | 20,600 | 22,400 | 24,200 | 26,300 |
| TOTAL | 40,100 | 43,300 | 49,000 | 54,200 | 58,900 | 64,000 | 69,700 |

# 6 Reliable Peak Season Supply Evaluation for M&I Systems

All M&I water providers in the study area obtain their water supply from groundwater and natural flow from the Willamette River or its tributaries. While the data maintained by WRIS provides detailed information on each entity's water rights, additional analyses (in-depth review of WMCPs) were required to determine the extent to which each entity can rely on its water rights for supply during the peak season.

## 6.1 Reliable Peak Season Supply Overview

The database of study area M&I water providers shows aggregate rights of 2,570 cfs from groundwater and surface water sources for the providers to draw upon to satisfy daily customer demand. However, very real supply constraints (e.g. curtailment conditions based on instream flow targets) exist for the vast majority of providers that limit the total of 2,586 cfs rights to a total of 1,020 cfs for reliable supply. Over the 122-day peak season (June 1 through September 30) for which WVP stored water can be used, the reliable supply of 1,020 cfs equates to roughly 246,700 acre-feet. An additional 15,000 acre-feet can be used as reliable supply from existing water storage projects (these existing water storage projects are not WVP reservoirs).

Water rights listed in each M&I system's WMCP were evaluated in order to determine a reliable volume of water which could be stated as existing supply during peak season.

## 6.2 Mainstem Willamette Surface Water Permits – Peak Season Reliability

M&I suppliers that draw surface water from the Willamette River mainstem face several permit limitations. The various surface water permit categories that are subject to peak season limitations are:

- extended permits (i.e., not fully perfected);
- permits issued after the BiOp was issued; and
- permits junior in priority date to minimum perennial streamflow water rights.

### 6.2.1 Extended Permits Peak Season Reliability Limitations

For extended permits[7] with fish persistence conditions, there is a 20 percent cap on curtailment of the undeveloped portion of the permit when BiOp flow objectives are not met (except Adair Village, which was capped at 30 percent in the analysis). These conditions require curtailment based on the percentage by which BiOp flow objectives[8] are missed ("share the shortfall"

[7] The term "extended permit" is defined as a water right that is not fully developed. Water use permits in Oregon generally require the permit holder to develop the water use within four or five years. The permit holder may apply for an extension of time to fully develop the water use.

[8] The National Marine Fishery Service and US Fish and Wildlife Service completed final separate, but coordinated, Biological Opinions (BiOps) in 2008 addressing the effects of the operation and maintenance of the Willamette Project on the listed species for which each agency is responsible. These BiOps specify actions to ensure that the continued operation of the Willamette Project dams, reservoirs, hatcheries and 42 miles of the riverbank protection projects will not reduce the likelihood of survival and recovery of four Endangered Species Act listed fish. Among the actions required by the BiOps are improvements in downstream flows.

conditions). The planning rate used for these types of permits is 80 percent of the rate subject to the conditions plus any amount not subject to the conditions.

Older municipal water rights from the Willamette River (priority date earlier than June 1964) do not have BiOp flow objective conditions that completely preclude use when specified flow objectives are not met. However, in 2005, legislation established a new review process for extensions of time for existing municipal permits. As part of the review of extension applications, OWRD must request Oregon Department of Fish & Wildlife (ODFW) to develop any necessary conditions to maintain the persistence of listed fish in the stream associated with the undeveloped portion of the permit. For Willamette River M&I permits, ODFW identifies flow targets that generally follow the BiOp flow objectives for the mainstem Willamette River as the flow needed to maintain the persistence of fish. However, since the permits being reviewed are already existing and may be relatively old, ODFW does not recommend conditions that preclude water use when the flow targets are not met. Instead, the agency recommends a “share the shortfall” approach and typically caps the curtailment at 20 percent.

### 6.2.2 Permits Issued Post-BiOp Peak Season Reliability Limitations

For permits that were issued after BiOp flow objectives were established, no water use would be allowed when flow objectives are not met (“on/off” conditions). Such permits were regulated off for 147 days during the peak demand season of 2015. The planning rate for these permits is 0 cfs. It is important to note that when ORD issues a new surface water right, it requests that ODFW determine whether the proposed use would be detrimental to fish species listed under the state and federal endangered species acts, and if the water right could be conditioned to ensure the use was not detrimental to those fish. Since about 2008 (after the BiOp flows were established), new water rights from the Willamette River have been conditioned to only allow diversion when certain flow objectives are being met. These flow objectives generally follow the BiOp flow objectives for the Willamette River mainstem measured at Salem. The water user cannot divert any water when the flow objectives are not met.

### 6.2.3 Permits Junior to MPSFs Peak Season Reliability Limitations

For permits upstream of Salem that are junior in priority to minimum perennial streamflows (MPSFs), a planning rate of 20 percent of the total rate was used. This is based on the expectation that after the MPSFs are converted to instream water rights, all but “domestic” use would be regulated off when instream flows are not met. There are several minimum perennial streamflows (administratively established flow targets /objectives) upstream of Salem that, under existing statutory requirements, will eventually be converted to an instream water right held by OWRD. These instream water rights will be for the use of natural streamflow and releases of WVP stored water and will carry a priority date of mid-1964. There are municipal water supply water rights above Salem that will be “junior” in priority date to the instream water rights when established. Historically, when the minimum perennial streamflows are converted to instream water rights, the instream rights contain a condition that includes language stating that “… this right will not have priority over domestic use…” In other words, instead of the junior municipal supply users being completely shut off in favor of the senior user, the junior user can still use some amount of water to satisfy “domestic use”.

## 6.3 Willamette Major Tributary Permits – Peak Season Supply Reliability Limitations

Surface water permits issued for diversion of water from Willamette River tributaries also face peak season supply reliability limitations.

### 6.3.1 Extended Permits Peak Season Reliability Limitations

For extended permits with fish persistence conditions, future use was assumed to be limited to 50% of undeveloped portion of the permit.

### 6.3.2 Permits Junior to MPSFs Peak Season Reliability Limitations

For water rights that are junior to an instream water right (or minimum perennial streamflow) the planning rate is 20 percent of the applicable rate under the assumption that all but "domestic or "human" consumption could be regulated off to meet senior instream flow requirements. The planning rate of 20 percent was established using the same logic as stated for permits junior to MPSFs for the mainstem Willamette River.

## 6.4 Permits with Undeveloped Infrastructure

For sources with no infrastructure developed, a planning rate of zero was used under the assumption that development will not occur if the possibility of access to WVP stored water becomes available. This assumption is based on an expectation that when a M&I water provider has a water right from a particular source, but they have not invested in any infrastructure to develop water from that source, it is often because that source is not expected to provide a reliable water supply for a number of potential reasons (water quality, lack of flow, listed fish species, junior to existing water rights, etc.). Given the choice between investing in infrastructure to obtain water from a relatively reliable source (such as WVP stored water) or from a less reliable source, a municipality will invest in infrastructure that will provide access to a reliable water supply.

## 6.5 Groundwater Permits

For groundwater permits, the planning rate is limited to current well capacities. Costs to repair wells or drill new wells may be avoided if WVP stored water is available, especially when limitations on the groundwater supply or quality would also affect the feasibility of new wells.

## 6.6 Combined Reported Permits

In some cases, M&I systems report capacities only for all water rights associated with a source or for all of its sources combined. In such instances, a total planning rate that matches the stated capacity was used.

## 6.7 Results of Analysis

Table 6-1 shows median values the ratio of reliable peak season M&I system rights to M&I system rights as stated in WRIS. The column named "Number of Systems in Statistic" represents the number of study area systems for which actual data were obtained through examination of the planning documents and rights documentation. Median values shown in the table are based on data from these systems. The column named "Number of Systems Median Assigned" represents the number of study area systems for which a median value was assigned because actual data were not available. As such, if an M&I system's water rights and WMCP were analyzed for reliable peak season supply, (i.e., one of the 68 listed in the statistical totals below), the actual total reliable peak season rights was used in all analyses.

For the remaining 22 M&I systems, the median value of the ratio of reliable peak season M&I system rights to stated M&I system rights corresponding to the appropriate population size category was used as an adjustment factor. For those 22 M&I systems, the adjustment factor was multiplied by the M&I system's stated water rights in order to provide an estimate of reliable peak season M&I system rights.

Table 6-2 shows summary statistics for the ratio of reliable peak season M&I system rights to stated M&I system rights, which includes each of the 90 study area M&I systems. The statistics include the actual data of 57 M&I systems and the appropriately-assigned median data for 33 M&I systems.

**Table 6-1**
**Median Values of Reliable Peak Season Rights to Unrestricted Rights Ratio Observed**

| Population Category | Number of Systems in Statistic | MEDIAN | Number of Systems Median Assigned |
|---|---|---|---|
| Under 1,000 | 11 | 25% | 13 |
| 1,000 to 5,000 | 18 | 46% | 10 |
| 5,000 to 10,000 | 5 | 30% | 5 |
| 10,000 to 25,000 | 8 | 48% | 3 |
| 25,000 to 50,000 | 5 | 19% | 2 |
| 50,000 to 100,000 | 7 | 47% | 0 |
| Over 100,000 | 3 | 63% | 0 |
| Overall | 57 | 39% | 33 |

**Table 6-2**
**Study Area Descriptive Statistics: Peak Season Rights to Unrestricted Rights Ratio**

| Population Category | AVERAGE | MEDIAN | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| Under 1,000 | 28% | 25% | 5% | 62% |
| 1,000 to 5,000 | 44% | 46% | 5% | 99% |
| 5,000 to 10,000 | 33% | 30% | 22% | 67% |
| 10,000 to 25,000 | 47% | 48% | 0% | 86% |
| 25,000 to 50,000 | 31% | 19% | 12% | 85% |
| 50,000 to 100,000 | 49% | 47% | 5% | 100% |
| Over 100,000 | 60% | 63% | 18% | 99% |
| Overall | 39% | 39% | 0% | 100% |

# 7 M&I Reliable Supply Deficits and Source Redundancy

This section provides M&I system projected supply deficits[9] in terms of:

- Peak Season M&I System Supply Deficits – Peak GPD Use; and
- Peak Season M&I System Supply Deficits – Average Peak Season Use.; and
- Single Source Redundant Supply Needs.

All supply deficit projections were assembled using the M&I peak season demand forecasts provided in Section 5, and the M&I peak season reliable supply analyses described in Section 6. For each M&I system, its projected peak season demand (in acre-feet) for each year of the analysis period was subtracted from its reliable peak season supply (converted to acre-feet) for that year in order to arrive at the various M&I peak season supply deficit projections shown in this section.

It is important to reiterate that the M&I analysis is based on a system-by-system accounting of peak season demand, reliable peak season supply, and the resulting peak season water supply deficits (if any). For this reason, a comparison of total peak season demand to total peak season reliable supply is irrelevant, and will provide misleading results. As an example, peak season demand and reliable peak season supply for two hypothetical M&I systems – System A and System B are illustrated below..

1. Total peak season demand for System A at Year 2040 is 1,000 acre feet and its reliable peak season water supply is 1,500 acre feet. System A would show a peak season reliable supply deficit of zero (0) acre feet in Year 2040.
2. Total peak season demand for System B at Year 2040 is 3,000 acre feet and its reliable peak season supply is 1,500 acre feet. System B would show a peak season reliable supply deficit of 1,500 acre feet in Year 2040.
3. Using a system-by-system accounting of reliable supply deficits, the Year 2040 reliable peak season supply deficit for the two-system study area would be 1,500 acre feet (0 acre feet + 1,500 acre feet)
4. If total peak season demand and total peak season reliable supply accounting were used (which is NOT the method used for this study), total peak season demand for the year 2040 would be equal to 4,000 acre feet and total peak season reliable supply would be equal to 3,000 acre feet. In this case, the supply deficit would be calculated as 1,000 acre feet, which is incorrect.

## 7.1 Peak Season Supply Deficits – Peak GPCD

Tables 7-1 and 7-2 provide M&I peak season supply deficits using the Peak GPCD metric in calculations of peak season demand. Table 7-1 shows the M&I peak season supply deficit assuming no change in unaccounted-for water for each system, and Table 7-2 provides the M&I

[9] It should be noted that Annual M&I system demand deficits are not relevant for decisions related to the reallocation of WVP conservation storage. As such, Annual M&I system demand deficits are not provided in this section.

peak season supply deficit assuming that a 10 percent level of unaccounted-for water is met by each system. Both tables segment the results by population size category.

**Table 7-1**
**M&I Peak Season Supply Deficit Projections**
**(Peak GPCD Use, units: acre-feet)**

| Population Category | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| Under 1,000 | 200 | 300 | 300 | 400 | 500 | 600 |
| 1,000 to 5,000 | 900 | 1,200 | 1,700 | 2,100 | 2,600 | 3,200 |
| 5,000 to 10,000 | 300 | 400 | 400 | 600 | 900 | 1,200 |
| 10,000 to 25,000 | 1,500 | 2,500 | 3,600 | 5,300 | 7,400 | 9,600 |
| 25,000 to 50,000 | 8,900 | 11,100 | 12,500 | 14,800 | 18,200 | 22,600 |
| 50,000 to 100,000 | 10,600 | 15,500 | 20,800 | 26,600 | 32,800 | 39,700 |
| Over 100,000 | 2,100 | 5,200 | 8,400 | 12,600 | 19,200 | 26,400 |
| **TOTAL** | **24,500** | **36,100** | **47,800** | **62,400** | **81,500** | **103,200** |

**Table 7-2**
**M&I Peak Season Supply Deficit Projections**
**Unaccounted-for Goal of 10 Percent Met**
**(Peak GPCD Use, units: acre-feet)**

| Population Category | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| Under 1,000 | 200 | 300 | 300 | 400 | 400 | 500 |
| 1,000 to 5,000 | 700 | 1,000 | 1,300 | 1,700 | 2,200 | 2,700 |
| 5,000 to 10,000 | 200 | 300 | 400 | 500 | 600 | 900 |
| 10,000 to 25,000 | 1,500 | 2,300 | 3,500 | 5,100 | 7,200 | 9,400 |
| 25,000 to 50,000 | 8,900 | 11,100 | 12,500 | 14,700 | 17,400 | 21,400 |
| 50,000 to 100,000 | 10,500 | 14,400 | 18,900 | 24,600 | 30,700 | 37,400 |
| Over 100,000 | 2,100 | 5,200 | 8,400 | 11,200 | 14,100 | 20,500 |
| **TOTAL** | **24,100** | **34,600** | **45,400** | **58,300** | **72,600** | **92,800** |

## 7.2 Peak Season Supply Deficits – Peak Season Average Use

Tables 7-3 and 7-4 provide M&I peak season supply deficits using the Peak Season Average Use metric in calculations of peak season demand. Table 7-3 shows the M&I peak season supply deficit assuming no change in unaccounted-for water for each system, and Table 7-4 provides the

M&I peak season supply deficit assuming that a 10 percent level of unaccounted-for water is met for each system. Both tables segment the results by population size category.

**Table 7-3**
**M M&I Peak Season Supply Deficit Projections**
**(Peak Season Average Use, units: acre-feet)**

| Population Category | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| Under 1,000 | 0 | 100 | 100 | 100 | 100 | 100 |
| 1,000 to 5,000 | 200 | 400 | 500 | 600 | 800 | 900 |
| 5,000 to 10,000 | 200 | 300 | 400 | 400 | 600 | 800 |
| 10,000 to 25,000 | 400 | 600 | 700 | 900 | 1,300 | 1,900 |
| 25,000 to 50,000 | 3,700 | 4,900 | 5,800 | 7,100 | 8,600 | 10,400 |
| 50,000 to 100,000 | 4,400 | 6,700 | 9,500 | 11,900 | 14,400 | 17,300 |
| Over 100,000 | 0 | 0 | 900 | 2,900 | 5,000 | 7,200 |
| **TOTAL** | **9,000** | **12,900** | **17,800** | **24,000** | **30,700** | **38,700** |

**Table 7-4**
**M&I Peak Season Supply Deficit Projections**
**Unaccounted-for Goal of 10 Percent Met**
**(Peak Season Average Use, units: acre-feet)**

| Population Category | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| Under 1,000 | 0 | 0 | 100 | 100 | 100 | 100 |
| 1,000 to 5,000 | 200 | 300 | 400 | 500 | 600 | 800 |
| 5,000 to 10,000 | 200 | 300 | 300 | 400 | 400 | 600 |
| 10,000 to 25,000 | 400 | 600 | 700 | 800 | 1,100 | 1,800 |
| 25,000 to 50,000 | 3,700 | 4,900 | 5,800 | 7,100 | 8,600 | 10,400 |
| 50,000 to 100,000 | 4,400 | 6,600 | 9,300 | 11,700 | 14,200 | 16,900 |
| Over 100,000 | 0 | 0 | 900 | 2,900 | 5,000 | 7,200 |
| **TOTAL** | **8,900** | **12,700** | **17,400** | **23,500** | **30,100** | **37,700** |

### 7.2.1 M&I System Single Source Redundancy Needs

Many of the study area M&I systems may enter into contracts for WVP stored water as a means to provide source redundancy for their systems so that stored water can be relied on in the event that their primary source becomes unavailable. An M&I system's need for source redundancy was evaluated using the following criteria:

1. An M&I system is considered to have a single source if all of its water rights authorize the use of groundwater, or if all of its water rights authorize the use of a single surface water source.
2. If an M&I system uses the Willamette River as its single source, this is noted and the M&I system is not considered to have having a single source. Since the single source evaluation is intended to determine whether access to WVP stored water would be available in the event of contamination or low flow, stored water may not be a solution for these entities.
3. If existing documentation shows that an M&I system has a single source (i.e., right) but is known to rely on water supply from another water provider, it is not considered to have a single source.

Using these criteria, a total of 42 out of the 90 study area M&I systems (47 percent) were determined to be served by a single source. For this analysis, the volume estimate of water required to provide system redundancy was estimated by using the Peak Season Average Use metric in calculating M&I system demand.[10] Table 7-5 shows summary redundant supply needs over the peak season (June 1 through September 30) for M&I systems with a single source of water supply.

**Table 7-5**
**M&I System Single Source Redundancy Needs (acre-feet)**

| Population Category | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| Under 1,000 | 400 | 500 | 500 | 500 | 600 | 600 |
| 1,000 to 5,000 | 2,300 | 2,600 | 2,900 | 3,200 | 3,400 | 3,700 |
| 5,000 to 10,000 | 1,400 | 1,600 | 1,800 | 1,900 | 2,000 | 2,200 |
| 10,000 to 25,000 | 4,700 | 5,400 | 6,100 | 6,600 | 7,200 | 7,900 |
| 25,000 to 50,000 | 6,000 | 6,800 | 7,500 | 8,100 | 8,800 | 9,500 |
| 50,000 to 100,000 | 8,900 | 10,000 | 10,900 | 12,000 | 13,300 | 14,600 |
| Over 100,000 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 23,700 | 26,900 | 29,600 | 32,400 | 35,300 | 38,600 |

[10] This estimation methodology provides substantially lower estimates than peak season demand based on a Peak GPCD metric.

# 8 Self-Supplied Industrial Demand

The Self-Supplied Industrial (SSI) water use category represents self-supplied industrial and commercial facilities that have their own water rights separate from M&I systems. These include a variety of user, from small facilities to major industrial plants. It is important to recognize that much of the Willamette River basin's commercial and industrial water use is provided by municipal systems and is therefore captured in the M&I systems category of the demand analysis and not contained in this category. The SSI category includes only those facilities with their own, separate supplies. It was necessary to treat these facilities separately because the data and methodology needed to forecast peak season demand for this category is different from those used for M&I systems.

## 8.1 Estimating Future SSI Demand

OWRD's WRIS was the sole data source used to conduct the SSI demand analysis. WRIS was queried for industrial water use categories, and the associated water rights were exported for further processing and vetting to remove duplicate records and outliers. Industrial storage rights (i.e., the right to fill a reservoir for future water use) were included in the analysis by incorporating the right to divert water for filling of privately-owned reservoirs. The methodology used to forecast SSI water use consists of the following steps:

1. Identify SSI permits issued annually based on WRIS water rights records. This included seven categories under the water use classification system: Manufacturing (IM), Commercial Uses (CM), Shop (SH), Sawmill (SM), Log Deck Sprinkling (LD), Laboratory (LA), and Geothermal (GT);
2. Determine nominal water rights based on OWRD records. The instantaneous water right flow value associated with each permit was used to determine nominal water rights. This flow value represents the maximum quantity a water rights holder is permitted to divert or pump on an instantaneous basis. It is measured in gallons per minute or cubic feet per second; and
3. Apply standard assumptions to all SSI users identified to convert nominal water rights into estimated acre-feet of water use during the peak season of June through September. The conservative assumptions were[11]:
    - facility operations use one-half the instantaneous water right; and
    - facilities operate at this level for two shifts (16 hours) per day, seven days a week, 52 weeks of the year.

Thirty years of permit data were examined to develop an estimate of an annual incremental increase in SSI demand expected to materialize over the period of analysis. The 75$^{th}$ percentile of the distribution was selected as conservative estimate[12] (i.e., overestimate) of annual incremental

[11] The two assumptions listed below were taken from OWRD's Statewide Water Needs Assessment, September 2008. OWRD's SSI estimate for its 2015 report was unchanged from the 2008 report. As such, the methodology used by OWRD appears only in the 2008 report.

[12] To ensure that SSI would not be under-stated – selection of the median (530 AF) of the distribution would be considered a less conservative estimate.

permit demand, was approximately 840 acre-feet per year. Data maintained in WRIS includes the beginning and ending days in the year for which all water rights are authorized to be exercised. These data were relied upon in the allocation of SSI water demanded across months in the year. For rights showing no calendar restrictions (i.e., the right could be used over the entire calendar year), demand was allocated equally across all months. For rights showing a date restricted use (e.g., begin day authorized: January 1 / end day authorized: March 1) use of the right was allocated entirely to the authorized use window. Using these data, it was determined that the 122-day conservation season accounts for 42-percent of SSI water use.

New SSI demand (through the issuance of new permits) was calculated for all years in the period of analysis by application of the annual growth in new SSI permits (840 acre-feet per year) multiplied by the seasonal factor of 42 percent –roughly 350 acre-feet per year. Future SSI seasonal demand and deficit projections differ from future M&I seasonal demand and deficit projections in that future SSI demand over the period of analysis was estimated as a function of new permit demand expected to materialize each year. Therefore, all future SSI water demand should not be considered to be an increased use of existing SSI water rights.[13]

While future SSI demand is expressed in terms of demand for additional water rights, it is unlikely that new SSI water rights would be available under existing conditions because:

1. OWRD has determined that surface water is not available for "new" appropriations;
2. The Willamette Basin Program[14] does not allow for appropriation of water for industrial use on a year-round basis;
3. Conditions would be placed on "new" permits by reviewing resource agencies (ODFW, DEQ, etc.) that would limit use under certain low flow scenarios (i.e., peak season);
4. A "new" permit, which would be subject to existing instream water rights and future converted minimum perennial streamflows, would be subject to regulation (cut back or shut off) to protect existing senior water rights; and
5. Groundwater is insufficient or of poor quality for SSI use, and the use of groundwater is limited by the Willamette Basin Program.

For these reasons, all future incremental SSI demand is classified as a supply deficit, which is shown in Table 8-1 in acre-feet, cumulatively, by decade over the period of analysis.

[13] Increased use of existing SSI water rights can occur over the period of analysis without impacting the demand for new SSI water rights, which are independent of existing SSI water rights.

[14] The Willamette Basin Program is a set of administrative rules that sets out allowable uses of water.

**Table 8-1**
**SSI Peak Season Supply Deficits (new Permits) for the Period of Analysis**

| Year | Peak Season Deficits New SSI Rights (acre feet) |
|---|---|
| 2020 | 350 |
| 2030 | 3,850 |
| 2040 | 7,400 |
| 2050 | 10,900 |
| 2060 | 14,450 |
| 2070 | 17,950 |

# 9 M&I Demands for WVP Stored Water

This section provides an overall summary of M&I system and SSI demands (which in total are classified as M&I demands) for WVP stored water. No new calculations were used to develop the tables presented in this section. Tables from Sections 7 and 8 were combined to provide scenarios of M&I demand for WVP stored water.

Each of the tables presented in this section include three categories for the demand for WVP stored water:

- M&I Systems Demand for WVP Stored Water;
- M&I Systems Single Source Redundancy Demand for WVP Stored Water; and
- SSI Demand for WVP Stored Water

While no new calculations were performed, this section reflects the adoption of final terminology used in the reallocation of WVP conservation storage. The focus of analyses presented in Sections 7 and 8 was on the estimation of peak season supply deficits, (the difference between future demand for water and the future reliable supply of water) peak season supply redundancy needs, and new SSI peak season needs. Because all of the peak season needs also represent a need for an alternative source of water supply, the peak season needs represent a demand for WVP stored water.

Two of the demand categories listed above remain constant in each of the summary tables:

- M&I Systems Single Source Redundancy Demand for WVP Stored Water; and
- SSI Demand for WVP Stored Water.

M&I Systems Demand for Stored Water varies in each of the summary tables to reflect the two different methods used to calculate peak season demand (Peak GPCD and Peak Season Average Use), and the two different methods used to estimate conservation (unaccounted-for water at current levels and unaccounted-for water at a goal of no more than 10 percent).

## 9.1 Summary Tables of M&I Demand for WVP Stored Water

Table 9-1 provides an estimate of total M&I demand for WVP stored water that combines:

- Table 7-1, M&I Peak Season Supply Deficit Projections (**Peak GPCD Use**);
- Table 7-5, M&I System Single Source Redundancy Needs; and
- Table 8-1, Self-Supplied Industrial Peak Season Supply Deficits.

Table 9-1 reflects no change in unaccounted-for water loss over the planning period, and M&I peak season supply deficits are calculated using the Peak GPCD metric for demand. As shown in Table 9-1, demand for WVP stored water grows from 48,550 acre feet in year 2020 to 159,750 acre feet at the end of the period of analysis in the year 2070.

**Table 9-1**
**Total M&I Peak Season WVP Stored Water Needs**
**(Peak GPCD basis used for M&I Systems Demand)**

| WVP Stored Water Demand Category | 2020 AF | 2030 AF | 2040 AF | 2050 AF | 2060 AF | 2070 AF |
|---|---|---|---|---|---|---|
| M&I Systems Deficits (Peak GPCD Basis) | 24,500 | 36,100 | 47,800 | 62,400 | 81,500 | 103,200 |
| M&I Systems Single Source Redundancy Demand | 23,700 | 26,900 | 29,600 | 32,400 | 35,300 | 38,600 |
| SSI Demand | 350 | 3,850 | 7,400 | 10,900 | 14,450 | 17,950 |
| **Total WVP Stored Water Needs** | **48,550** | **66,850** | **84,800** | **105,700** | **131,250** | **159,750** |

Table 9-2 provides an estimate of total M&I demand for WVP stored water that combines:

- Table 7-2, M&I Peak Season Supply Deficit Projections (**Peak GPCD Use**) with an Unaccounted-for Water Goal of 10 Percent Met;
- Table 7-5, M&I System Single Source Redundancy Needs; and
- Table 8-1, Self-Supplied Industrial Peak Season Supply Deficits.

Table 9-2 reflects achievement of a goal of 10 percent unaccounted-for water loss over the planning period, and M&I peak season supply deficits are calculated using the Peak GPCD metric for demand. As shown in the table, demand for WVP stored water grows from 48,150 acre feet in year 2020 to 149,350 acre feet in 2070.

**Table 9-2**
**Total M&I Peak Season WVP Stored Water Needs**
**Unaccounted-for Water Goal of 10 Percent Met**
**(Peak GPCD basis used for M&I Systems Demand)**

| WVP Stored Water Demand Category | 2020 AF | 2030 AF | 2040 AF | 2050 AF | 2060 AF | 2070 AF |
|---|---|---|---|---|---|---|
| M&I Systems Deficits (Peak GPCD Basis) | 24,100 | 34,600 | 45,400 | 58,300 | 72,600 | 92,800 |
| M&I Systems • Single Source Redundancy Demand | 23,700 | 26,900 | 29,600 | 32,400 | 35,300 | 38,600 |
| SSI Demand | 350 | 3,850 | 7,400 | 10,900 | 14,450 | 17,950 |
| **Total WVP Stored Water Needs** | **48,150** | **65,350** | **82,400** | **101,600** | **122,350** | **149,350** |

Table 9-3 provides an estimate of total M&I demand for WVP stored water that combines:

- Table 7-3, M&I Peak Season Supply Deficit Projections (**Average Peak Season Use**);
- Table 7-5, M&I System Single Source Redundancy Needs; and
- Table 8-1, Self-Supplied Industrial Peak Season Supply Deficits.

Table 9-3 reflects no change in unaccounted-for water loss over the planning period, and M&I peak season supply deficits are calculated using the Average Peak Season Use metric for demand. As shown in the table, demand for WVP stored water grows from 33,050 acre feet in year 2020 to 92,250 acre feet at the end of the period of analysis in the year 2070.

**Table 9-3**
**Total M&I Peak Season WVP Stored Water Needs**
**(Average Peak Season Use basis used for M&I Systems Demand)**

| WVP Stored Water Demand Category | 2020 AF | 2030 AF | 2040 AF | 2050 AF | 2060 AF | 2070 AF |
|---|---|---|---|---|---|---|
| M&I Systems Deficits (Average Peak Season Basis) | 9,000 | 12,900 | 17,800 | 24,000 | 30,700 | 38,700 |
| M&I Systems • Single Source Redundancy Demand | 23,700 | 26,900 | 29,600 | 32,400 | 35,300 | 38,600 |
| SSI Demand | 350 | 3,850 | 7,400 | 10,900 | 14,450 | 17,950 |
| **Total WVP Stored Water Needs** | **33,050** | **43,650** | **54,800** | **67,300** | **80,450** | **95,250** |

Table 9-4 provides an estimate of total M&I demand for WVP stored water that combines:

- Table 7-4, M&I Peak Season Supply Deficit Projections (**Average Peak Season Use**)with an Unaccounted-for Water Goal of 10 Percent Met
- Table 7-5: M&I System Single Source Redundancy Needs; and
- Table 8-3: Self-Supplied Industrial Supply Deficits.

Table 9-4 reflects achievement of a 10 percent unaccounted-for water loss goal over the planning period, and M&I peak season supply deficits are calculated using the Average Peak Season Use metric for demand. As shown in the table, demand for WVP stored water grows from 32,950 acre feet in year 2020 to 94,250 acre feet at the end of the period of analysis in the year 2070.

**Table 9-4**
**Total M&I Peak Season WVP Stored Water Needs**
**Unaccounted-for Water Goal of 10 Percent Met**
**(Average Peak Season Use basis used for M&I Systems Deficits)**

| WVP Stored Water Demand Category | 2020 AF | 2030 AF | 2040 AF | 2050 AF | 2060 AF | 2070 AF |
|---|---|---|---|---|---|---|
| M&I Systems<br>Deficits (Average Peak Season Basis) | 8,900 | 12,700 | 17,400 | 23,500 | 30,100 | 37,700 |
| M&I Systems<br>• Single Source Redundancy Demand | 23,700 | 26,900 | 29,600 | 32,400 | 35,300 | 38,600 |
| SSI Demand | 350 | 3,850 | 7,400 | 10,900 | 14,450 | 17,950 |
| **Total WVP Stored Water Needs** | **32,950** | **43,450** | **54,400** | **66,800** | **79,850** | **94,250** |

# 10 M&I Demands for Willamette Valley Project Stored Water Distributed Among Contract Reaches

The U.S. Bureau of Reclamation (Reclamation) administers irrigation contracts for the WVP, and has separated reaches of the Willamette River and its tributaries based on which WVP dams may be called upon to release water to satisfy an irrigation contract. The reaches are commonly known as “contract reaches”, and are distributed throughout the Willamette River basin as shown on Figure 10-1). This section provides Tables 10-1 through 10-4 – each showing the demands for WVP stored water presented in Section 9 allocated to the 15 contract reaches.

**Figure 10-1**
**U.S. Bureau of Reclamation Contract Reaches**


| Reach | Upstream Reservoir |
|---|---|
| 1 | All reservoirs |
| 2 | All reservoirs on North and South Santiam Rivers |
| 3 | Big Cliff, Detroit |
| 4 | Foster, Green Peter |
| 5 | All reservoirs except Santiam reservoirs |
| 6 | Fern Ridge |
| 7 | All reservoirs except Santiam and Fern Ridge |
| 8 | Blue River, Cougar |
| 9 | All except Santiam, Long Tom, and McKenzie reservoirs |
| 10 | Fall Creek, Dexter, Lookout Point, Hills Creek |
| 11 | Dexter, Lookout Point, Hills Creek |
| 12 | Fall Creek |
| 13 | Dorena, Cottage Grove |
| 14 | Dorena |
| 15 | Cottage Grove |

**Table 10-1**
**Total M&I Peak Season WVP Stored Water Needs**
**(Peak GPCD basis used for M&I Systems Demand)**
**by Reclamation Contract Reach**

| Contract Reach | 2020 AF | 2030 AF | 2040 AF | 2050 AF | 2060 AF | 2070 AF |
|---|---|---|---|---|---|---|
| 1 | 41,400 | 56,800 | 71,300 | 87,200 | 105,300 | 125,500 |
| 2 | 300 | 400 | 500 | 500 | 600 | 800 |
| 3 | 500 | 1,400 | 2,300 | 4,600 | 9,400 | 14,600 |
| 4 | 600 | 600 | 700 | 800 | 800 | 900 |
| 5 | 4,600 | 5,700 | 7,000 | 8,300 | 9,600 | 11,000 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 900 | 1,000 | 1,100 | 1,300 | 1,400 | 1,600 |
| 8 | 200 | 1,000 | 2,000 | 3,000 | 4,100 | 5,300 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TOTAL** | **48,550** | **66,850** | **84,800** | **105,700** | **131,250** | **159,750** |

**Table 10-2**
**Total M&I Peak Season WVP Stored Water Needs**
**Unaccounted-for Water Goal of 10 Percent Met**
**(Peak GPCD basis used for M&I Systems Demand)**
**by Reclamation Contract Reach**

| Contract Reach | 2020 AF | 2030 AF | 2040 AF | 2050 AF | 2060 AF | 2070 AF |
|---|---|---|---|---|---|---|
| 1 | 41,100 | 56,200 | 70,500 | 86,200 | 103,400 | 123,200 |
| 2 | 300 | 400 | 400 | 500 | 600 | 700 |
| 3 | 500 | 1,400 | 2,300 | 3,200 | 4,300 | 8,600 |
| 4 | 600 | 600 | 700 | 800 | 800 | 900 |
| 5 | 4,600 | 5,400 | 6,300 | 7,500 | 8,800 | 10,100 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 900 | 1,000 | 1,100 | 1,200 | 1,400 | 1,600 |
| 8 | 200 | 500 | 1,100 | 2,000 | 3,100 | 4,200 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TOTAL** | **48,150** | **65,350** | **82,400** | **101,600** | **122,350** | **149,350** |

**Table 10-3**
**Total M&I Peak Season WVP Stored Water Needs**
**(Average Peak Season Use basis used for M&I Systems Demand)**
**by Reclamation Contract Reach**

| Contract Reach | **2020 AF** | **2030 AF** | **2040 AF** | **2050 AF** | **2060 AF** | **2070 AF** |
|---|---|---|---|---|---|---|
| 1 | 26,100 | 34,600 | 43,600 | 53,700 | 64,600 | 76,500 |
| 2 | 200 | 200 | 300 | 400 | 400 | 500 |
| 3 | 500 | 1,400 | 2,300 | 3,200 | 4,300 | 5,500 |
| 4 | 600 | 600 | 700 | 800 | 800 | 900 |
| 5 | 4,600 | 5,400 | 6,100 | 6,800 | 7,500 | 8,500 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 900 | 1,000 | 1,100 | 1,200 | 1,300 | 1,400 |
| 8 | 200 | 500 | 800 | 1,200 | 1,600 | 2,000 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TOTAL** | **33,050** | **43,650** | **54,800** | **67,300** | **80,450** | **95,250** |

**Table 10-4**
**Total M&I Peak Season WVP Stored Water Needs**
**Unaccounted-for Water Goal of 10 Percent Met**
**(Average Peak Season Use basis for M&I Systems Deficits)**
**By Reclamation Contract Reach**

| Contract Reach | **2020 AF** | **2030 AF** | **2040 AF** | **2050 AF** | **2060 AF** | **2070 AF** |
|---|---|---|---|---|---|---|
| 1 | 26,100 | 34,400 | 43,200 | 53,200 | 64,000 | 75,800 |
| 2 | 100 | 200 | 300 | 400 | 400 | 500 |
| 3 | 500 | 1,400 | 2,300 | 3,200 | 4,300 | 5,500 |
| 4 | 600 | 600 | 700 | 800 | 800 | 900 |
| 5 | 4,600 | 5,400 | 6,100 | 6,800 | 7,500 | 8,300 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 900 | 1,000 | 1,100 | 1,200 | 1,300 | 1,400 |
| 8 | 200 | 500 | 800 | 1,200 | 1,600 | 2,000 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TOTAL** | **32,950** | **43,450** | **54,400** | **66,800** | **79,850** | **94,250** |

# 11 Impacts of Climate Change: M&I Demand for WVP Stored Water

The impact of climate change on water supply is expected to be an issue for water supply over the period of analysis. The U.S. Environmental Protection Agency states that many areas of the United States, especially the West, currently face water supply issues. The amount of water available in these areas (including the Willamette River basin throughout the peak season summer months) is already limited, and demand will continue to rise as population grows. Climate change is likely to alter river discharge, resulting in important impacts on water availability for instream and out-of-stream uses.

## 11.1 Climate Change Impact on M&I Water Supply

FR/EA Appendix K (Discussion of Climate Change Impact on Future Regulation) identifies the most comprehensive study of climate change in the Pacific Northwest as the "Pacific Northwest (PNW) Hydroclimate Scenarios Project (2860)"[15], a University of Washington study completed in 2010. The study contains estimated streamflows from a variety of calculation methodologies using CMIP3 Global Circulation Model (GCM) temperature and precipitation data for three estimated time horizons (2020, 2040, and 2080) for many locations throughout the Columbia River basin. Data are available for 30 separate sites in the Willamette River basin, as noted in Table 11-1 below.

**Table 11-1**
**Climate Impact Group Sites: Willamette River Basin**

| River | No. of Research Sites |
|---|---|
| Calapooia | 1 |
| Clackamas | 2 |
| Long Tom | 2 |
| Luckiamute | 1 |
| Mckenzie | 2 |
| Molalla | 1 |
| Row | 1 |
| Santiam | 6 |
| Tualatin | 1 |
| Upper Willamette | 2 |
| Willamette | 10 |
| Yamhill | 1 |

In order to simplify the analysis, a single location (Willamette River at Salem) from the 30 locations listed above was selected to represent climate-induced changes in flow for the basin.

15 Referred to as the Climate Impacts Group report throughout the remainder of this section.

The Willamette River at Salem data was downloaded from the Climate Impacts Group website and analyzed for changes in flow observed from 2020 to 2080 - dataset names are:

- mod_bias_adjusted_vic_streamflow_monthly_hd_2020.dat; and
- mod_bias_adjusted_vic_streamflow_monthly_hd_2080.dat

Both datasets are available online at:
http://warm.atmos.washington.edu/2860/products/sites/?site=4060

Each dataset contains 10 projected, climate changed streamflow records for an A1B emissions scenario and nine records for a B1 emissions scenario. The two emission scenarios were chosen by the Climate Impact Group to represent medium (A1B) and low (B1) emissions. (See Section 2.2.1 of Chapter 4 of the CIG report.) The 10 records for the A1B scenario represent ten global circulation model (GCM) results, and the nine records for the B1 scenario are representative of output from nine GCMs. These GCMs were chosen by the Climate Impact Group to have the smallest bias and most realistic annual cycle in temperature and precipitation. (See Section 2.2.2 of Chapter 4 of the CIG report.) It is felt that these GCMs present a reasonable representation of the range of future climate change impacts on the Willamette Basin. It was necessary to down select from the larger ensemble of GCM results available to reduce computational demand.

Raw CMIP3 GCM temperature and precipitation data is available at a monthly timescale and is representative of a large-scale spatial extent (~200 sq. km resolution). Consequently, GCM outputs must be downscaled to a spatial (1/16 degree or ~30 sq. km) and temporal scale relevant to water resources planning. A hybrid delta approach (combined traditional delta methods and bias correction and statistical downscaling- BCSD) was used for the hydrologic analysis. The Variable Infiltration Capacity (VIC) model of the Columbia River basin (of which the Willamette basin is a part) is used to convert meteorological inputs produced by the GCMs into a hydrologic response.

The hybrid delta (HD) downscaling technique has been developed specifically for this region and it combines some of the strengths associated with both the traditional delta method and the Bias Correction and Statistical Downscaling (BCSD) approach for downscaling GCM outputs to a finer spatial and temporal scale(See Chapter 8 of the Climate Impacts Group report for these details). The VIC model was calibrated by sub-watersheds on a monthly timestep to available unregulated streamflow data, where the Willamette calibration period was 1975-1989 with an N-S model efficiency of 0.89 and an $R^2$ of 0.93.

The three Salem files for 2020, 2040, and 2080 each contain 19 scenarios (10 GCM models run for A1B and 9 GCM models run for B1) in the files, which makes for 19 time series records, and each time series record consists of 91 water years of daily average streamflows at Salem. All of the time series in the files run from 01 October 1915 to 30 September 2006, with the dates corresponding to the historical flow used for the bias correction downscaling method. Each time series represents 91 water years of statistically downscaled, daily temperature/precipitation inputs, translated into a hydrologic response using the VIC model. Note that each series contains only 90 full calendar year records. For this analysis data was analyzed by calendar year to capture monthly variation in flow and to assess April through October cumulative water volumes. Consequently, only 90 complete years of record are available to support analysis at this temporal resolution.

In order to gauge the change in flows from 2020 to 2080, the average of the 19 separate streamflow projections (streamflow projections for each month represent the average daily streamflow for the month in the datasets) was calculated for each record for the 2020 dataset and the 2080 dataset.

Each dataset provides 1,092 average daily flow rates by month (12 average daily flow rates by month from 19 projections of future climate changed hydrology for 91 years of record: 12 x 91=1,092 values in the representative data sets). The percent change in flow was calculated based a subset of data for the four months of June, July, August, and September. June through September represent the peak water demand season for the Willamette River Basin. Thus, percent change in flow for each month during the peak demand season is analyzed based on a total of 364 records (4 x 91=364). Note that the each projection extends 91 years, which is consistent with the length of the historic period: 1916 through water year 2006 used for downscaling. Only a subset is shown in the tables to demonstrate the methodology. The variation in projected streamflow produced by using different combinations of GCMs and emission scenarios in Tables 11-2 and 11-4 illustrates some of the uncertainty associated with using projected, climate changed hydrology. The uncertainty associated with projected hydrologic data includes uncertainty in temporal downscaling, uncertainty in spatial downscaling, uncertainty in the hydrologic modeling, uncertainty associated with emissions scenarios, and uncertainty associated with GCMs. Table 11-4 shows the averages streamflow rates derived on Tables 11-2 and 11-3, along with the reduction in streamflow rate observed from 2020 to 2080 in both absolute and percentage terms.

Tables 11-2 through 11-4 provide clarification on how the percent reduction in streamflow was calculated. Table 11-2 and 11-3 show projected average daily streamflows (cfs) for months June through September for three water years tied to the seasonality and spatial distribution of flow represented in the historic streamflow records recorded in 1916, 1917, and 1918. Table 11-2 provides abridged (for presentation purposes) data for the 2020 projection, and Table 11-3 provides abridged data for the 2080 projection. Each table shows the 19 separate streamflow projections and the average monthly streamflow rate calculated for each month/year combination. Note that the each projection extends 91 years, which is consistent with the length of the historic period: 1916 through water year 2006 used for downscaling. Only a subset is shown in the tables to demonstrate the methodology. Table 11-4 shows the averages streamflow rates derived on Tables 11-2 and 11-3, along with the reduction in streamflow rate observed from 2020 to 2080 in both absolute and percentage terms. To illustrate the methodology, the average reduction in streamflow rate for the abridged period of record is shown on Table 11-4 is 30.4%.

Using the entire 2020 and 2080 datasets of projections (not shown in Tables 11-2 through 11-4), the average of the 364 monthly percent changes shows an average reduction in peak season flows from 2020 to 2080 of 21.7 percent, with a standard deviation of 10.4 percent. It should be noted that the models do not predict a consistently linear percent change in average daily streamflow. The percent reduction in average daily streamflow from 2020 to 2040 (20 years) for the peak demand months is 8.57% resulting in an annual rate of change of 0.43% for 2020-2040. The total average percent reduction in average daily streamflow projected for months of peak demand from 2040 to 2080 (40 years) is 14.43% resulting in an annual rate of change of 0.36% per year.

However, as a simplifying assumption for this analysis it is assumed that the percent change in average daily streamflow for the peak demand season decreases linearly over the sixty year period between 2020 and 2080. This implies an annual rate of change of 0.36% per year. An annual rate of change based on the average daily streamflow change between 2020 and 2080 is used to evaluate the impact to M&I systems supply deficits of a climate-change induced reduction in flows, reliable peak season supply for each M&I system was reduced by the following factors:

- Year 2020: 0%
- Year 2030 3.6%
- Year 2040 7.2%
- Year 2050 10.8%
- Year 2060 14.4%
- Year 2070 18.1%

## Table 11-2
## Projected Monthly, Averaged Daily Streamflow Rates (in cfs) at Salem Year 2020 (abridged)

| Year | Month | Average of 19 Volumes | GCM1 A1B | GCM2 A1B | GCM3 A1B | GCM4 A1B | GCM5 A1B | GCM6 A1B | GCM7 A1B | GCM8 A1B | GCM9 A1B | GCM10 A1B | GCM1 B1 | GCM2 B1 | GCM3 B1 | GCM4 B1 | GCM5 B1 | GCM6 B1 | GCM7 B1 | GCM8 B1 | GCM9 B1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1916 | 6 | **11019** | 11166 | 10074 | 12527 | 11716 | 10115 | 10233 | 9357 | 12820 | 8326 | 11645 | 9132 | 11003 | 12152 | 11795 | 9742 | 11926 | 12468 | 10172 | 13000 |
| 1916 | 7 | **8447** | 7329 | 6812 | 8849 | 7082 | 6469 | 6783 | 11500 | 8946 | 6963 | 8789 | 6707 | 9485 | 8159 | 8729 | 8506 | 9686 | 8842 | 9210 | 11650 |
| 1916 | 8 | **4621** | 4250 | 4297 | 4429 | 4657 | 4024 | 3905 | 5987 | 4511 | 4257 | 4592 | 4039 | 5274 | 4315 | 4658 | 4648 | 4911 | 4483 | 4750 | 5803 |
| 1916 | 9 | **3726** | 3535 | 4001 | 3807 | 4097 | 2918 | 3562 | 3702 | 3828 | 3348 | 3501 | 3405 | 4120 | 3503 | 4006 | 3840 | 3734 | 4082 | 3817 | 3996 |
| 1917 | 6 | **12633** | 12589 | 11641 | 14869 | 12517 | 11999 | 11578 | 12234 | 13212 | 10729 | 11842 | 10477 | 13087 | 14866 | 14977 | 11092 | 13026 | 15334 | 11031 | 12933 |
| 1917 | 7 | **5221** | 4932 | 4802 | 6423 | 5110 | 5406 | 4181 | 4612 | 5952 | 4724 | 4726 | 4243 | 5628 | 5682 | 6236 | 4357 | 5173 | 6653 | 4362 | 5999 |
| 1917 | 8 | **2954** | 2763 | 2808 | 3203 | 2961 | 3048 | 2513 | 2784 | 3211 | 2928 | 2933 | 2574 | 3230 | 3198 | 3122 | 2696 | 2910 | 3332 | 2737 | 3170 |
| 1917 | 9 | **2939** | 2552 | 2954 | 3129 | 3267 | 2636 | 2781 | 2513 | 3389 | 2682 | 2694 | 3013 | 3574 | 2800 | 3024 | 3051 | 2617 | 4004 | 2485 | 2685 |
| 1918 | 6 | **3349** | 2972 | 4514 | 5133 | 3130 | 2815 | 2741 | 2293 | 4325 | 2685 | 2998 | 2477 | 5256 | 4928 | 3321 | 2398 | 3083 | 2643 | 2627 | 3283 |
| 1918 | 7 | **1655** | 964 | 2367 | 2807 | 1594 | 993 | 1448 | 850 | 1641 | 912 | 1690 | 785 | 2860 | 2776 | 1739 | 1049 | 1677 | 1178 | 1537 | 2585 |
| 1918 | 8 | **1267** | 438 | 1603 | 1576 | 1691 | 1264 | 1272 | 371 | 1370 | 409 | 1416 | 337 | 1903 | 1784 | 1695 | 1262 | 1346 | 1501 | 1283 | 1550 |
| 1918 | 9 | **2071** | 2245 | 2455 | 2329 | 2261 | 1411 | 2291 | 1247 | 1712 | 1653 | 1900 | 1684 | 3172 | 2298 | 2363 | 1801 | 1935 | 2851 | 1938 | 1811 |

## Table 11-3
## Projected Monthly, Averaged Daily Streamflow Rates (in cfs) at Salem Year 2080 (abridged)

| Year | Month | Average of 19 Volumes | GCM1 A1B | GCM2 A1B | GCM3 A1B | GCM4 A1B | GCM5 A1B | GCM6 A1B | GCM7 A1B | GCM8 A1B | GCM9 A1B | GCM10 A1B | GCM1 B1 | GCM2 B1 | GCM3 B1 | GCM4 B1 | GCM5 B1 | GCM6 B1 | GCM7 B1 | GCM8 B1 | GCM9 B1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1916 | 6 | **7846** | 8074 | 8965 | 8332 | 8607 | 6332 | 5618 | 5407 | 6078 | 6690 | 8189 | 7382 | 9367 | 11454 | 8111 | 7247 | 9447 | 7955 | 6619 | 9193 |
| 1916 | 7 | **5182** | 5498 | 5474 | 4410 | 5308 | 2967 | 2995 | 6074 | 3738 | 4618 | 4834 | 5599 | 8128 | 6366 | 4477 | 3603 | 5276 | 4677 | 6135 | 8272 |
| 1916 | 8 | **3273** | 3150 | 3591 | 2851 | 3798 | 2221 | 1983 | 4136 | 2567 | 2906 | 3068 | 3671 | 4357 | 3648 | 3119 | 2694 | 3192 | 2982 | 3749 | 4503 |
| 1916 | 9 | **2759** | 2676 | 3263 | 2774 | 2771 | 1728 | 1766 | 3299 | 2426 | 2474 | 2509 | 2908 | 3998 | 2735 | 3504 | 1973 | 2574 | 3182 | 2478 | 3381 |
| 1917 | 6 | **8836** | 9252 | 12125 | 9354 | 8254 | 7387 | 7070 | 6049 | 7193 | 8301 | 8313 | 8321 | 10845 | 11290 | 8577 | 7270 | 11437 | 9847 | 7891 | 9099 |
| 1917 | 7 | **3350** | 3469 | 4190 | 3554 | 3037 | 3104 | 2972 | 2804 | 3010 | 3078 | 3152 | 3117 | 4123 | 4051 | 3121 | 2986 | 3641 | 3517 | 3181 | 3545 |
| 1917 | 8 | **2248** | 2216 | 2762 | 2315 | 2275 | 2008 | 1882 | 1930 | 2000 | 2145 | 2222 | 2071 | 2822 | 2521 | 2185 | 1962 | 2395 | 2412 | 2089 | 2508 |
| 1917 | 9 | **2704** | 2687 | 2692 | 2969 | 2520 | 2221 | 2185 | 2552 | 3984 | 2502 | 2487 | 2561 | 3404 | 2487 | 2919 | 2479 | 2529 | 3311 | 2189 | 2699 |
| 1918 | 6 | **2354** | 2325 | 2922 | 2735 | 2394 | 2151 | 2100 | 1040 | 2006 | 2090 | 3057 | 1882 | 2534 | 2427 | 2228 | 2616 | 2157 | 2467 | 2439 | 3149 |
| 1918 | 7 | **765** | 560 | 1034 | 744 | 725 | 546 | 516 | 468 | 588 | 563 | 883 | 533 | 1427 | 969 | 591 | 717 | 541 | 728 | 816 | 1586 |
| 1918 | 8 | **673** | 282 | 1435 | 325 | 1587 | 279 | 254 | 1648 | 315 | 301 | 426 | 238 | 1328 | 364 | 1259 | 343 | 270 | 384 | 338 | 1419 |
| 1918 | 9 | **1778** | 1758 | 2219 | 2291 | 1450 | 1150 | 1377 | 1759 | 1704 | 1577 | 1715 | 1405 | 2975 | 1569 | 2323 | 1350 | 1646 | 2167 | 1578 | 1775 |

**Table 11-4**
**Example Calculation – Change in Streamflow Rates in cfs from 2020 to 2080**

| Year | Month | 2020 Average of 19 Rates | 2080 Average of 19 Rates | 2020 to 2080 Change in Average Rates | 2020 to 2080 Percent Reduction in Streamflow |
|---|---|---|---|---|---|
| 1916 | 6 | 11019 | 7846 | -3173 | 28.8% |
| 1916 | 7 | 8447 | 5182 | -3265 | 38.7% |
| 1916 | 8 | 4621 | 3273 | -1348 | 29.2% |
| 1916 | 9 | 3726 | 2759 | -967 | 26.0% |
| 1917 | 6 | 12633 | 8836 | -3797 | 30.1% |
| 1917 | 7 | 5221 | 3350 | -1871 | 35.8% |
| 1917 | 8 | 2954 | 2248 | -706 | 23.9% |
| 1917 | 9 | 2939 | 2704 | -235 | 8.0% |
| 1918 | 6 | 3349 | 2354 | -995 | 29.7% |
| 1918 | 7 | 1655 | 765 | -890 | 53.8% |
| 1918 | 8 | 1267 | 673 | -594 | 46.9% |
| 1918 | 9 | 2071 | 1778 | -293 | 14.1% |
| **Average for Abridged Set of 12 month/year combinations** | | | | | **30.4%** |

It is important to note that a change in supply reliability will impact only the calculations of M&I system supply deficits. This is because a change in supply will not impact the demands for supply redundancy or SSI. As such, the demand values shown in Tables 11-5 and 11-6 are limited to M&I system deficits.

Table 11-5 shows that the climate change-induced impact of a reduction in reliable supply (based on the percentage reductions listed above) begin within 10 years of the period of analysis, as a 6.1 percent increase in M&I system peak season supply deficits (M&I peak season demand in Table 11-5 was calculated using the Peak GPCD use metric). By the end of the period of analysis at year 2070, M&I system peak season supply deficits rise to 128,900 acre-feet (an increase of 25,700 acre-feet, or a 24.9 percent increase).

The reduction in reliable supply and its impact on peak season deficits was calculated for each system individually, and then aggregated. For example, in year 2030, there is an expected climate change-induced reduction in streamflow of 3.6 percent (see bulleted list above). For a system with reliable peak season supply of 6,485 acre-feet (assumed to be constant for the 50-year period of analysis under non climate change-induced conditions) is reduced to 6,134 (6,485 * (1-0.036)) acre-feet in the year 2030. To evaluate the impact of climate change-induced impacts to supply on the system's deficit (if any), the 2030 value of 6,134 peak season acre-feet of supply is compared the system's 2030 peak season demand. This analysis is conducted for each M&I system at a five-year time step (2035, 2040, 2045, etc.) through the year 2070.

**Table 11-5**
**Climate Change Impact to M&I Demands for WVP Stored Water**
**(Peak GPCD Basis, Supply Impact Only)**

| WVP Stored Water Demand | 2020 AF | 2030 AF | 2040 AF | 2050 AF | 2060 AF | 2070 AF |
|---|---|---|---|---|---|---|
| M&I Systems Deficits (Peak GPCD Basis) (Without Climate-Induced Supply Impact) | 24,500 | 36,100 | 47,800 | 62,400 | 81,500 | 103,200 |
| M&I Systems Deficits (Peak GPCD Basis) (**With Climate-Induced Supply Impact**) | **24,500** | **38,300** | **54,100** | **76,900** | **101,500** | **128,900** |
| Increase in Demand | **0** | **2,200** | **6,300** | **14,500** | **20,000** | **25,700** |
| Percentage Increase | **0.0** | **6.1** | **13.2** | **23.2** | **24.5** | **24.9** |

Table 11-6 shows that the climate change-induced impact of a reduction in reliable supply (based on the percentage reductions listed above) begin within 10 years of the period of analysis, as a 5.4 percent increase in M&I system peak season supply deficits (M&I peak season demand in Table 11-6 was calculated using the Average Peak Season metric). By the end of the period of analysis at year 2070, M&I system peak season supply deficits rise to 53,900 acre-feet (an increase of 15,200 acre-feet, or a 39.3 percent increase).

**Table 11-6**
**Climate Change Impact to M&I Demands for WVP Stored Water**
**(Average Peak Season Use, Supply Impact Only)**

| WVP Stored Water Demand | 2020 AF | 2030 AF | 2040 AF | 2050 AF | 2060 AF | 2070 AF |
|---|---|---|---|---|---|---|
| M&I Systems Deficits (Average Peak Season Use) (Without Climate-Induced Supply Impact) | 9,000 | 12,900 | 17,800 | 24,000 | 30,700 | 38,700 |
| M&I Systems Deficits (Average Peak Season Use) (**With Climate-Induced Supply Impact**) | **9,000** | **13,600** | **20,600** | **28,500** | **37,900** | **53,900** |
| Increase in Demand | **0** | **700** | **2,800** | **4,500** | **7,200** | **15,200** |
| Percentage Increase | **0.0** | **5.4** | **15.7** | **18.8** | **23.5** | **39.3** |

## 11.2 Climate Change Impact on M&I Water Demand

The Portland Water Bureau commissioned a study titled, "The Impacts of Climate Change on Portland's Water Supply"[16]. The study examines climate-related impacts on changes in water availability, changes in demand created by climate change, and changes in demand from regional growth. Change in demand created by climate change is of importance to this analysis, as the changes in water availability and regional growth have been addressed above. The report cites that the impact of climate change on demand is estimated at 8 percent during the peak season by the year 2040. The study shows an analysis beginning year of 2000, which means that the 8 percent increase was spread over 40 years, yielding an increase in demand of 0.2 percent per year.

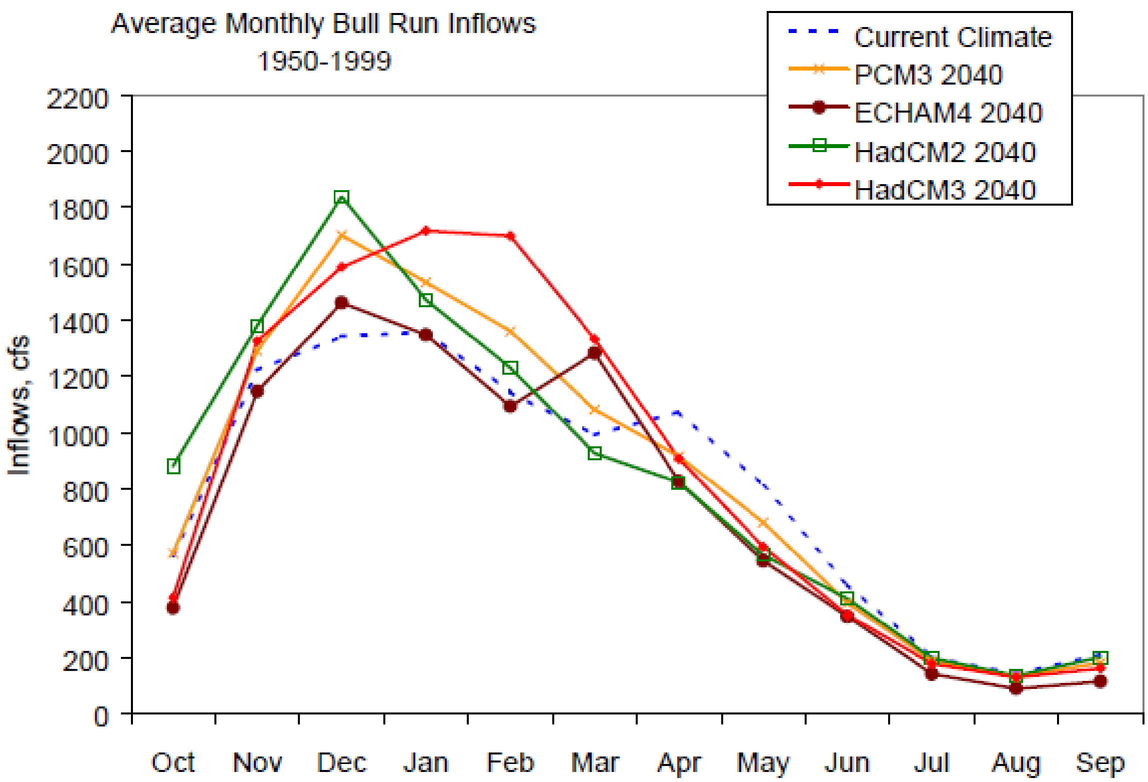
The study was targeted at assessing the impacts that climate change will have on the Portland Water Bureau's (PWB) ability to meet water demand in the future. The study effort focused on the Bull Run watershed. The PWB study used outputs from four global circulation models (GCMs) to estimate future climate changed hydrometeorology: the Department of Energy's Parallel Climate Model (PCM), the Max Planck Institute's ECHAM4 model, and the Hadley Centre's Had CM2 and HadCM3 models. Climate changed hydrometeorology was assessed to characterize 2020 demands and 2040 demands. For the assessment, the study assumed that carbon dioxide will increase by one percent per year. The models used for PWB study produce results consistent with the results produced as part of the WW2100 study. The PWB study indicates a general warming trend (1.5 deg C for decade 2020 and 2 deg C for decade 2040) and suggests that precipitation will increase slightly in the winter months and decrease in the summer. Like the WW2100 study, the PWB study indicates higher confidence in temperature trends than precipitation changes.

The outputs from the GCMs are not adopted directly, but are downscaled to a finer spatial resolution appropriate for subsequent hydrologic modeling. For this effort the average monthly temperature and precipitation outputs from the GCMs are downscaled from a multi-degree spatial scale to a one-degree scale using the Symap algorithm.

To translate the climate change meteorology into a hydrologic response the Distributed Hydrology, Soil-Vegetation Model (DHSVM) was used. Based on the PWB modeling, winter streamflows are expected to increase by 15% by the 2040 timeframe and spring flows are expected to decrease by approximately 30%. Warming temperatures would reduce snow accumulation resulting in decreases in spring snowmelt which would cause the study area to become a rain-driven system with lower late spring and summer flows. Changes in streamflows during the spring and summer months (April-September) are important because this is when the demand for water supply is highest. It is important to recognize the uncertainty associate with projected temperature and precipitation signals. Some of this uncertainty is revealed in the plot below. Note how the projected streamflows generated using the HadCM3 model deviate considerably from the projections generated using the other three GCMs. The plot reveals just a small portion of the uncertainty associated with generating climate changed, hydrology outputs. If more GCMs were adopted additional uncertainty would be revealed via the ensemble results. The selected emission scenario, downscaling method and the hydrologic model also add to the uncertainty associated with projected, future hydrology.

[16] Palmer, R.N. and Hahn, M. (2002) The Impacts of Climate Change on Portland's Water Supply. Portland Water Bureau, Portland, OR.

**Figure 11-1 Average Monthly Bull Run Inflows, 1950 - 1999**




Source: See footnote 16 above.

To evaluate the impact of climate change on demand, GPCD estimates were increased by 0.2 percent per year from year 2020 to year 2070. Climate-induced increases in the quantity of demanded water used in this analysis are shown below.

- Year 2020: 0%
- Year 2030 2%
- Year 2040 4%
- Year 2050 6%
- Year 2060 8%
- Year 2070 10%

Increases in demand were evaluated for M&I system deficits, source redundancy needs, and SSI. The results of these analyses are provided in Tables 11-7 and 11-8.

Table 11-7 shows that the climate change-induced impact of an increase in demand (based on the percentage increases listed above) begin within 10 years of the period of analysis, as a 3.6 percent increase in M&I demands for WVP stored water (M&I peak season deficits in Table 11-7 was calculated using the Peak GPCD use metric). By the end of the period of analysis at year 2070, M&I demands (combined deficits, redundancy needs, and SSI) rise to 189,350 acre-feet (an increase of 29,600 acre-feet, or an 18.5 percent increase).

**Table 11-7**
**Climate Change Impact to M&I Demands (Supply Deficits) for WVP Stored Water**
**(Peak GPCD Basis for Deficits, Demand Impact Only)**

| WVP Stored Water Demand | 2020 AF | 2030 AF | 2040 AF | 2050 AF | 2060 AF | 2070 AF |
|---|---|---|---|---|---|---|
| M&I Systems Deficits (Peak GPCD Basis) (Without Climate-Induced Dmd Impact) | 24,500 | 36,100 | 47,800 | 62,400 | 81,500 | 103,200 |
| M&I Systems Single Source Redundancy Demand (Without Climate-Induced Dmd Impact) | 23,700 | 26,900 | 29,600 | 32,400 | 35,300 | 38,600 |
| SSI Demand (Without Climate-Induced Dmd Impact) | 350 | 3,850 | 7,400 | 10,900 | 14,450 | 17,950 |
| Total M&I Demand (Without Climate-Induced Dmd Impact) | **48,550** | **66,850** | **84,800** | **105,700** | **131,250** | **159,750** |
| M&I Systems Deficits (Peak GPCD Basis) (**With Climate-Induced Dmd Impact)** | 24,500 | 38,100 | 52,800 | 74,000 | 99,000 | 127,500 |
| M&I Systems Single Source Redundancy Demand (**With Climate-Induced Dmd Impact)** | 23,700 | 27,200 | 30,500 | 34,000 | 37,800 | 42,100 |
| SSI Demand (**With Climate-Induced Dmd Impact)** | 350 | 3,950 | 7,700 | 11,550 | 15,600 | 19,750 |
| Total M&I Demand (**With Climate-Induced Dmd Impact**) | **48,550** | **69,250** | **91,000** | **119,550** | **152,400** | **189,350** |
| Increase in Demand | **0** | **2,400** | **6,200** | **13,850** | **21,150** | **29,600** |
| Percentage Increase | **0.0** | **3.6** | **7.3** | **13.1** | **16.1** | **18.5** |

Table 11-8 shows that the climate change-induced impact of an increase in demand (based on the percentage reductions listed above) begin within 10 years of the period of analysis, as a 2.5 percent increase in M&I demands for WVP stored water (M&I peak season demand in Table 11-8 was calculated using the Average Peak Season metric). By the end of the period of analysis at year 2070, M&I demands (combined deficits, redundancy needs, and SSI) rise to 110,850 acre-feet (an increase of 15,600 acre-feet, or a 16.4 percent increase).

**Table 11-8**
**Climate Change Impact to M&I Demands (Supply Deficits) for WVP Stored Water**
**(Average Peak Season Use Basis, Demand Impact Only)**

| WVP Stored Water Demand | 2020 AF | 2030 AF | 2040 AF | 2050 AF | 2060 AF | 2070 AF |
|---|---|---|---|---|---|---|
| M&I Systems<br>Deficits (Average Peak Season Use)<br>(Without Climate-Induced Dmd Impact) | 9,000 | 12,900 | 17,800 | 24,000 | 30,700 | 38,700 |
| M&I Systems<br>Single Source Redundancy Demand<br>(Without Climate-Induced Dmd Impact) | 23,700 | 26,900 | 29,600 | 32,400 | 35,300 | 38,600 |
| SSI Demand<br>(Without Climate-Induced Dmd Impact) | 350 | 3,850 | 7,400 | 10,900 | 14,450 | 17,950 |
| Total M&I Demand<br>(Without Climate-Induced Dmd Impact) | **33,050** | **43,650** | **54,800** | **67,300** | **80,450** | **95,250** |
| M&I Systems<br>Deficits (Average Peak Season Use)<br>(**With Climate-Induced Dmd Impact)** | 9,000 | 13,600 | 20,000 | 27,800 | 36,900 | 49,000 |
| M&I Systems<br>Single Source Redundancy Demand<br>(**With Climate-Induced Dmd Impact)** | 23,700 | 27,200 | 30,500 | 34,000 | 37,800 | 42,100 |
| SSI Demand<br>(**With Climate-Induced Dmd Impact)** | 350 | 3,950 | 7,700 | 11,550 | 15,600 | 19,750 |
| Total M&I Demand<br>(**With Climate-Induced Dmd Impact**) | **33,050** | **44,750** | **58,200** | **73,350** | **90,300** | **110,850** |
| Increase in Demand | **0** | **1,100** | **3,400** | **6,050** | **9,850** | **15,600** |
| Percentage Increase | **0** | **2.5** | **6.2** | **9.0** | **12.2** | **16.4** |

### 11.2.1 Combined Impact of Climate Change on Supply and Demand

The combined impact of climate change-induced supply and demand effects on M&I peak season demand for WVP stored water is shown on Tables 11-9 and 11-10. Both tables show a notable increase in M&I demand for stored water, reflecting the interrelationship of decreasing reliable peak season supply and increasing quantities of water during the peak season – both derived from climate change-induced effects.

In Table 11-9, which shows increases for demands calculated using the Peak GPCD basis, M&I demand for WVP stored water increases by 35.6 percent, to a level of 216,650 acre-feet by the year 2070 (an increase of 59,900 acre-feet).

**Table 11-9**
**Climate Change Impact to M&I Demands (Supply Deficits) for WVP Stored Water**
**(Peak GPCD Basis, Combined Demand and Supply Impact)**

| **WVP Stored Water Demand** | **2020 AF** | **2030 AF** | **2040 AF** | **2050 AF** | **2060 AF** | **2070 AF** |
|---|---|---|---|---|---|---|
| M&I Systems<br>Deficits (Peak GPCD Basis)<br>(Without Climate-Induced Dmd Impact) | 24,500 | 36,100 | 47,800 | 62,400 | 81,500 | 103,200 |
| M&I Systems<br>Single Source Redundancy Demand<br>(Without Climate-Induced Dmd Impact) | 23,700 | 26,900 | 29,600 | 32,400 | 35,300 | 38,600 |
| SSI Demand<br>(Without Climate-Induced Dmd Impact) | 350 | 3,850 | 7,400 | 10,900 | 14,450 | 17,950 |
| Total M&I Demand<br>(Without Climate-Induced Dmd Impact) | **48,550** | **66,850** | **84,800** | **105,700** | **131,250** | **159,750** |
| M&I Systems<br>Deficits (Peak GPCD Basis)<br>(**With Climate-Induced Dmd Impact)** | 24,500 | 40,300 | 61,000 | 88,800 | 119,400 | 154,800 |
| M&I Systems<br>Single Source Redundancy Demand<br>(**With Climate-Induced Dmd Impact)** | 23,700 | 27,200 | 30,500 | 34,000 | 37,800 | 42,100 |
| SSI Demand<br>(**With Climate-Induced Dmd Impact)** | 350 | 3,950 | 7,700 | 11,550 | 15,600 | 19,750 |
| Total M&I Demand<br>(**With Climate-Induced Dmd Impact**) | **48,550** | **71,450** | **99,200** | **134,350** | **172,800** | **216,650** |
| Increase in Demand | **0** | **4,600** | **14,400** | **28,650** | **41,550** | **56,900** |
| Percentage Increase | **0** | **6.9** | **17.0** | **27.1** | **31.7** | **35.6** |

In Table 11-10, which shows increases for demands calculated using the Average Peak Season Use basis, M&I demand for WVP stored water increases by 37.1 percent, to a level of 130,550 acre-feet by the year 2070 (an increase of 35,300 acre-feet).

**Table 11-10**
**Climate Change Impact to M&I Demands (Supply Deficits) for WVP Stored Water**
**(Average Peak Season Use Basis, Combined Demand and Supply Impact)**

| WVP Stored Water Demand | 2020 AF | 2030 AF | 2040 AF | 2050 AF | 2060 AF | 2070 AF |
|---|---|---|---|---|---|---|
| M&I Systems Deficits (Average Peak Season Use) (Without Climate-Induced Dmd Impact) | 9,000 | 12,900 | 17,800 | 24,000 | 30,700 | 38,700 |
| M&I Systems Single Source Redundancy Demand (Without Climate-Induced Dmd Impact) | 23,700 | 26,900 | 29,600 | 32,400 | 35,300 | 38,600 |
| SSI Demand (Without Climate-Induced Dmd Impact) | 350 | 3,850 | 7,400 | 10,900 | 14,450 | 17,950 |
| Total M&I Demand (Without Climate-Induced Dmd Impact) | **33,050** | **43,650** | **54,800** | **67,300** | **80,450** | **95,250** |
| M&I Systems Deficits (Average Peak Season Use) (**With Climate-Induced Dmd Impact)** | 9,000 | 14,300 | 22,900 | 32,900 | 47,700 | 68,700 |
| M&I Systems Single Source Redundancy Demand (**With Climate-Induced Dmd Impact)** | 23,700 | 27,200 | 30,500 | 34,000 | 37,800 | 42,100 |
| SSI Demand (**With Climate-Induced Dmd Impact)** | 350 | 3,950 | 7,700 | 11,550 | 15,600 | 19,750 |
| Total M&I Demand (**With Climate-Induced Dmd Impact**) | **33,050** | **45,450** | **61,100** | **78,450** | **101,100** | **130,550** |
| Increase in Demand | **0** | **1,800** | **6,300** | **11,150** | **20,650** | **35,300** |
| Percentage Increase | **0.0** | **4.1** | **11.5** | **16.6** | **25.7** | **37.1** |

# 12 Sensitivity Analysis

A sensitivity analysis was conducted to gauge the relative impact of increases in factors that influence M&I demand and supply estimates, as reflected in M&I supply deficits. Inputs to supply deficits that were varied in the analysis include population projections, GPCD estimates, and reliable water supply rights.

The sensitivity of supply deficits using the Peak GPCD metric basis for calculating M&I system deficits evaluated in this section. The first data row in each table presented in this section reads:

| | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| M&I Systems Deficit Forecast (Peak GPCD Basis) Without Parameter Change | 24,500 | 36,100 | 47,800 | 62,400 | 81,500 | 103,200 |

These base forecast values can be traced back to Table 7-1 shown above, as well as tables in Sections 9 and 10, and are used to compare the effect of percentage changes in the inputs used to calculate these values.

## 12.1 M&I Systems Supply Deficit Sensitivity to Population Projections

The base forecast values were evaluated for their sensitivity to changes in population estimates, which are components in M&I systems supply deficits (on the demand side of the equation). OEA forecasts for 2010 generated in 2004 vs. actual population for 2010 were examined for the study area counties in order to develop a range over which population forecasts would vary from actual population counts. For the study area counties overall, the forecast population for 2010 was within roughly 1 percent of the actual population measured for 2010. Given this estimate of forecast error, increasing population estimates by 10 percent, and decreasing population estimates by 10 percent more than captures the sensitivity of M&I systems deficit forecasts to changes in population.

Table 12-1[17] and Figure 12-1 show the changes in M&I systems deficit forecasts in response to variability in population forecasts. As shown in the table and figure, a 10 percent increase in the population forecast (each year in the period of analysis) is reflected as an increase of 13 percent in the M&I systems deficit forecast by the year 2070. A decrease of 10 percent in population forecast (each year in the period of analysis) is reflected as a decrease of 12 percent in the M&I systems deficit forecast by the year 2070.

## 12.2 M&I Systems Supply Deficit Sensitivity to the Peak GPCD Use Metric

The base forecast values were evaluated for their sensitivity to changes in the Peak GPCD use metric, which is a component of M&I systems supply deficits (on the demand side of the equation). Peak GPCD use metrics were examined for the group of M&I systems, and showed a standard deviation of 25% around the mean of the estimates, which is be an extensive range for capturing a

[17] Tables shown in this section break convention with the presentation order of tables shown in previous sections of this appendix. In order to show individual tables with their corresponding figures, this section's tables and figures are presented at the end of the discussion of results.

95% confidence interval (the 25% estimate would be doubled to 50% in order to capture a 95% confidence interval . Using this variation to gauge sensitivity of M&I system supply deficits to changes in the Peak GPCD use metric would not be an accurate depiction of the likely range of change in the Peak GPCD use metric for each individual M&I system for several reasons.

First, the analysis incorporates the Peak GPCD use metric in M&I systems demand for the full 122 days (June 1 through September 30) of the peak season. Because of the 122-day period used, slight variations in this use metric will result in dramatic changes to peak season demand, and in turn, dramatic changes to M&I system supply deficits.

Second, the standard deviation cited above was calculated from the Peak GPCD use metric for the population of 90 M&I systems. If an average Peak GPCD had been computed and used for all systems in the analysis, it would be perfectly reasonable to use the population standard deviation in a sensitivity analysis. However, the analysis of demand conducted throughout this appendix uses each M&I system's Peak GPCD metric to develop demand estimates for each individual M&I system. As such the sensitivity of M&I supply deficits to changes in this parameter can be reflected by a smaller change than 50% (2 x the metric's standard deviation around the mean). An increase and decrease of 10% in the Peak GPCD use metric (applied individually to each M&I system) was used to evaluate the sensitivity of M&I system supply deficits to this use metric.

Table 12-2 and Figure 12-2 show the changes in M&I systems deficit forecasts in response to variability in the Peak GPCD use metric. As shown in the table and figure, a 10 percent increase in the Peak GPCD use metric applied to each system (for each year in the period of analysis) is reflected as an increase of 24 percent in the M&I systems deficit forecast by the year 2070. A decrease of 10 percent in the Peak GPCD use metric applied to each system (each year in the period of analysis) is reflected as a decrease of 23 percent in the M&I systems deficit forecast by the year 2070.

## 12.3 Sensitivity to Reliable Rights Yield

The base forecast values were evaluated for their sensitivity to changes in the Peak GPCD use metric, which is a component of M&I systems supply deficits (on the supply side of the equation). Reliable rights yield in the climate change analysis was reduced over the period of analysis in response to reductions in flow as represented by 19 climate change models. For the sensitivity analysis, an increase and decrease of 20% in reliable supply (similar to that used for year 2070 in the climate change analysis) was used to evaluate the sensitivity of M&I system supply deficits to changes in reliable supply.

Table 12-3 and Figure 12-3 show the changes in M&I systems deficit forecasts in response to variability in reliable rights yield. As shown in the table and figure, a 20 percent increase in reliable rights applied to each system (for each year in the period of analysis) is reflected as a decrease of 26 percent in the M&I systems deficit forecast by the year 2070. A decrease of 20 percent in reliable rights applied to each system (each year in the period of analysis) is reflected as an increase of 28 percent in the M&I systems deficit forecast by the year 2070.

**Table 12-1**
**Sensitivity of M&I Deficit Forecast to Variations in Population Forecasts**

| | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| M&I Systems Deficit Forecast (Peak GPCD Basis) Without Parameter Change | 24,500 | 36,100 | 47,800 | 62,400 | 81,500 | 103,200 |
| M&I Peak Deficit Forecast (Peak GPCD Basis) Increase Each System Population Forecast by 10% | **24,700** | **38,100** | **51,400** | **69,500** | **91,500** | **116,100** |
| Ratio of Sensitivity Forecast to Forecast without Change | 101% | 106% | 108% | 111% | 112% | 113% |
| M&I Peak Deficit Forecast (Peak GPCD Basis) Decrease Each System Population Forecast by 10% | **24,300** | **34,400** | **44,500** | **55,900** | **72,100** | **91,000** |
| Ratio of Sensitivity Forecast to Forecast without Change | 99% | 95% | 93% | 90% | 88% | 88% |

**Figure 12-1**
**Sensitivity of M&I Deficit Forecast to Variations in Population Forecasts**

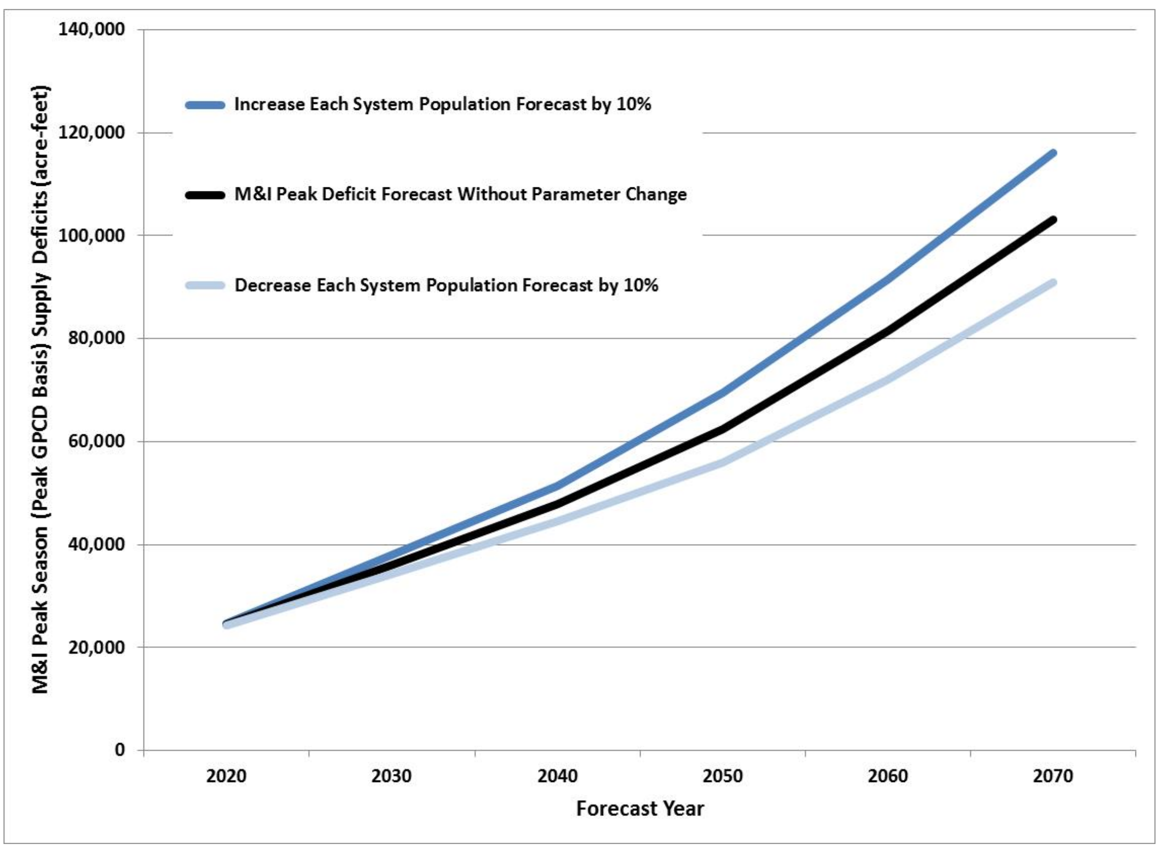


**Table 12-2**
**Sensitivity of M&I Deficit Forecast to Variations in Peak GPCD Use**

| | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| M&I Systems Deficit Forecast (Peak GPCD Basis) Without Parameter Change | 24,500 | 36,100 | 47,800 | 62,400 | 81,500 | 103,200 |
| M&I Peak Deficit Forecast (Peak GPCD Basis) Increase Each System GPCD Use by 10% | 32,100 | 46,200 | 62,100 | 81,900 | 103,400 | 127,500 |
| Ratio of Sensitivity Forecast to Forecast without Change | 131% | 128% | 130% | 131% | 127% | 124% |
| M&I Peak Deficit Forecast (Peak GPCD Basis) Decrease Each System GPCD Use by 10% | 18,000 | 27,400 | 36,600 | 47,000 | 60,400 | 79,100 |
| Ratio of Sensitivity Forecast to Forecast without Change | 73% | 76% | 77% | 75% | 74% | 77% |

**Figure 12-2**
**Sensitivity of M&I Deficit Forecast to Variations in Peak GPCD Use**

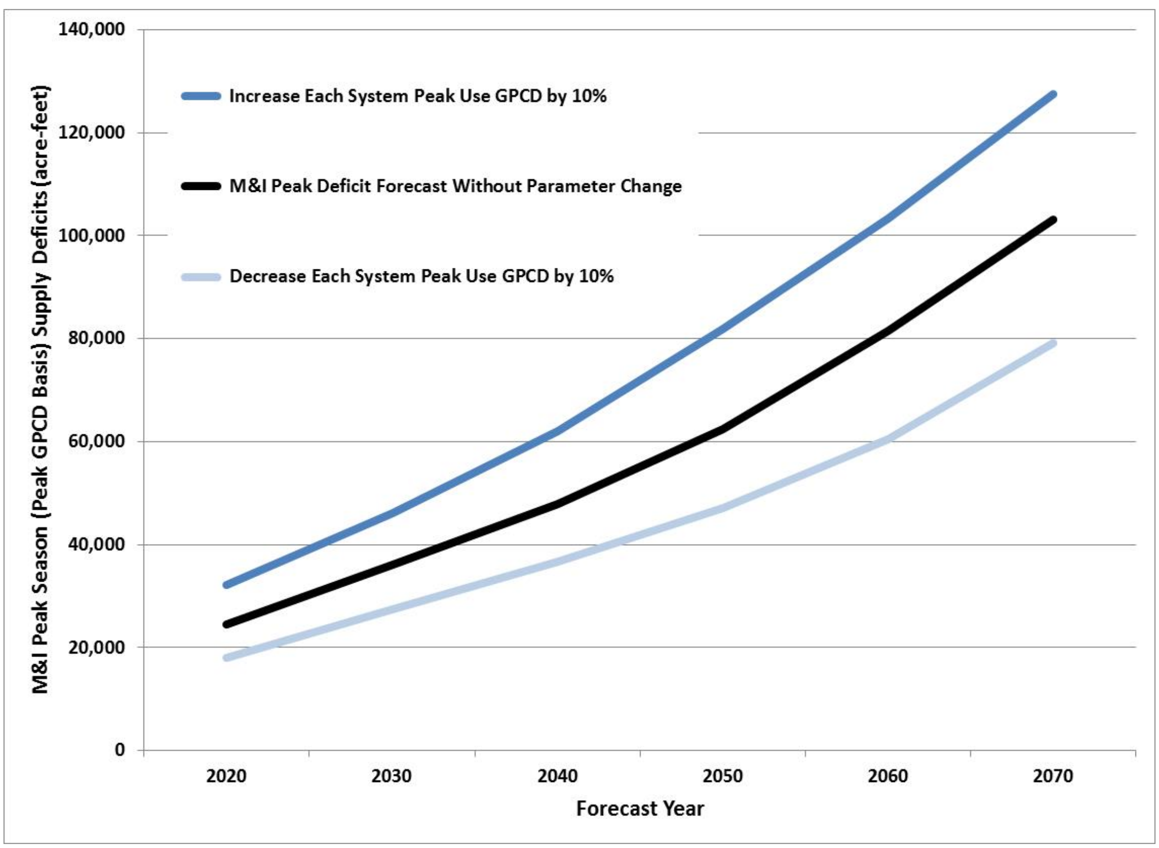


**Table 12-3**
**Sensitivity of M&I Deficit Forecast to Variations in Reliable Rights Yield**

| | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| M&I Systems Deficit Forecast (Peak GPCD Basis) Without Parameter Change | 24,500 | 36,100 | 47,800 | 62,400 | 81,500 | 103,200 |
| M&I Peak Deficit Forecast (Peak GPCD Basis) Increase Each System Rights Yield by 20% | 18,600 | 26,800 | 36,500 | 46,400 | 59,100 | 76,600 |
| Ratio of Sensitivity Forecast to Forecast without Change | 76% | 74% | 76% | 74% | 73% | 74% |
| M&I Peak Deficit Forecast (Peak GPCD Basis) Decrease Each System Rights Yield by 20% | 36,000 | 52,600 | 71,200 | 89,600 | 109,400 | 132,000 |
| Ratio of Sensitivity Forecast to Forecast without Change | 147% | 146% | 149% | 144% | 134% | 128% |

**Figure 12-3**
**Sensitivity of M&I Deficit Forecast to Variations in Reliable Rights Yield**