2015 Statewide Long-Term Water Demand Forecast

OREGON'S INTEGRATED WATER RESOURCES STRATEGY

— DECEMBER 2015 —

OREGON WATER RESOURCES DEPARTMENT

In Partnership with MWH® BUILDING A BETTER WORLD

Oregon Statewide Long-Term Water Demand Forecast

State of Oregon
Water Resources Department
725 Summer Street NE, Suite A
Salem, Oregon 97301

Prepared by:

MWH
BUILDING A BETTER WORLD

Publication available electronically at:

http://www.oregon.gov/OWRD/

December 2015

Oregon
Kate Brown, Governor

Water Resources Department
North Mall Office Building
725 Summer St NE, Suite A
Salem, OR 97301
Phone (503) 986-0900
Fax (503) 986-0904
www.wrd.state.or.us

Starting the Discussion

The 2015 drought brought public attention to issues the Oregon Water Resources Department has been focused on for years: understanding and meeting Oregon's water needs. Record low snow pack and average precipitation make 2015 a unique hydrologic year compared to past conditions, though researchers in Oregon claim that these precipitation and temperature conditions may be more common in the future. Part of responding to changing water supplies is understanding the state's current and future demand for water. To better identify what is ahead in the state's water future, the Department developed the *2015 Statewide Long-Term Water Demand Forecast*, as called for in the 2012 *Integrated Water Resources Strategy*.

The 2015 Demand Forecast document builds upon the *2008 Statewide Water Needs Assessment*, which explored future scenarios or pathways to possible conditions, based on certain assumptions. The 2015 studies, scenarios, and assumptions include a projected increase in both population and a longer, warmer growing season, leading to more demand from agricultural, commercial, residential and industrial water users by 2050. Oregon's agricultural sector currently accounts for 85 percent of the state's diverted water and irrigation needs are predicted to increase. If a hotter-drier scenario does develop, Oregon could be faced with a need for an additional 1.3 million acre feet of water annually, or nearly 424 billion gallons per year.

This report is a conversation starter, describing potential long-term water needs in an Oregon that may not be able to rely on historic patterns to predict future rainfall and snowpack. The total change in water demand rests on numerous assumptions about the future, assumptions that communities, governments and private partners can address together. Some counties and basins may face potentially important changes by 2050 because of the resulting growth in water demand.

To assist with local discussions and water supply planning, the Oregon Water Resources Department has launched the Water Resources Development Program, providing funding and technical assistance for Place-Based Planning, Feasibility Studies, and Water Supply Development. Please check our website for information about how to apply and who to contact.

Thomas M. Byler
Director

List of Preparers

Project Team

Rachel LovellFord, OWRD

Dr. Brenda Bateman, OWRD

Jeffrey Payne, MWH

Andrew Nishihara, MWH

Dick Talley, MWH

Dr. Justin Huntington, Huntington Hydrologic

Dr. Richard Allen, Evapotranspiration-Plus

Dr. Ayse Kilic, Evapotranspiration-Plus

The Project Team gratefully acknowledges the valuable technical review, comments, and contributions provided by the following:

Dr. Anu Acharya, OWRD
Harmony Burright, OWRD
Lisa Jaramillo, OWRD
Rich Marvin, OWRD
Alyssa Mucken, OWRD
Dorothy Pedersen, OWRD
Ken Smith, OWRD
Ken Stahr, OWRD

Alexandra Biering, MWH
Lisa Beutler, MWH
Kari Shively, MWH
Ryan Murdock, MWH
Dr. Yung-Hsin Sun, MWH
Stephen Irving, MWH
Robert Maurer, Commuter Industries
Glen Warren, Commuter Industries
Harry Seely, WestWater Research
Dr. Richard Cuenca, Oregon State University

The 2015 Water Demand Forecast was based on information collected and published by the following agencies and institutions:

Municipal water providers throughout Oregon who submitted Water Management and Conservation Plans
Oregon Department of Agriculture
Oregon Office of Economic Analysis
Oregon Water Resources Department
Oregon State University Extension Service
Portland State University, Population Research Center
U.S. Department of Agriculture, National Agricultural Statistics Service
U.S. Department of Commerce, U.S. Census Bureau
U.S. Department of the Interior, Bureau of Reclamation
U.S. Department of the Interior, U.S. Geological Survey

OWRD retained MWH Americas, Inc. to prepare this 2015 Statewide Long-Term Water Demand Forecast Report [Contract WRD 15 041].

Water is the foundation for our economies, communities, ecosystems, and quality of life. Oregon has a strong history of managing and caring for water to meet both instream and out-of-stream needs.

As of July 27 2015, I have declared drought emergencies in 23 of Oregon's 36 counties. These emergencies have been occasioned by drought conditions that include record-breaking low snowpack levels, high temperatures, and significantly low stream flows in many parts of the state. Many Oregon counties have experienced two consecutive years of drought conditions, and several have had multiple drought declarations over the past five years. ... In the longer-term, if climate predictions are correct, these conditions will become the new normal. Oregon, along with other western states, must plan for and address how a changing climate challenges our current systems and policies, and threatens our economy and quality of life.

EXECUTIVE ORDER NO. 15-09, signed on 27 July 2015

Kate Brown, Governor of Oregon

...just as we have finally comprehended how and why our atmosphere behaves as it does, we are on the threshold of a change in our weather and climate that will tax our understanding as never before. The future of our own species, as well as of those others with which we share the earth, will depend on our ability to understand and cope with these changes.

John Farrand, Jr., author (1937 – 1994)

TABLE OF CONTENTS

APPENDICES

Appendix A Calculations for Current and Future Agricultural Water Demands (Excel Spreadsheet)

Appendix B Calculations for Current and Future Municipal and Industrial Water Demands (Excel Spreadsheet)

Appendix C Current and Projected Future Irrigation Water Requirements for Oregon

Appendix D Methods for Estimating Crop Consumptive Water Demand by County

Appendix E Adjustments to Cuenca Irrigation Water Requirements to Reflect Climate Changes

Appendix F Comparison of Evapotranspiration Methods for the Klamath River Basin

Appendix G Database of Current and Future Crop Consumption and Irrigation Water Requirements (database)

These appendices are available for electronic download at: http://www.oregon.gov/OWRD/

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

CDL	USDA Cropland Data Layer
cfs	cubic feet per second
ET	evapotranspiration
gpm	gallons per minute
IPCC	Intergovernmental Panel on Climate Change
IWRS	Oregon's Integrated Water Resources Strategy
M&I	municipal and industrial (includes domestic water users)
MGD	millions of gallons per day
NIWR	net irrigation water requirement
OEA	Office of Economic Analysis
OUGB	Outside of UGB
OWRD	Oregon Water Resources Department
PSU	Portland State University
PSU-PRC	Portland State University, Population Research Center
Reclamation	United States Department of the Interior, Bureau of Reclamation
TAF/yr	thousand acre feet per year
UGB	urban growth boundary
USDA	U.S. Department of Agriculture
USGS	U.S. Department of the Interior, U.S. Geological Survey
WMCP	Water Management and Conservation Plans
WRC	Oregon Water Resources Commission
WWCRA	Reclamation's West-Wide Climate Risk Assessment

INTRODUCTION

Despite Oregon's reputation as a relatively "wet" state, water users across its varied landscape face real challenges in balancing out-of-stream and instream needs. Oregon's water resource challenges are expected to intensify over time, driven by increases in population, changes in the climate, and responsive shifts in land uses and technologies. In combination, these drivers may alter the availability and quality of water supplies as well as the nature and quantity of water demands across Oregon.

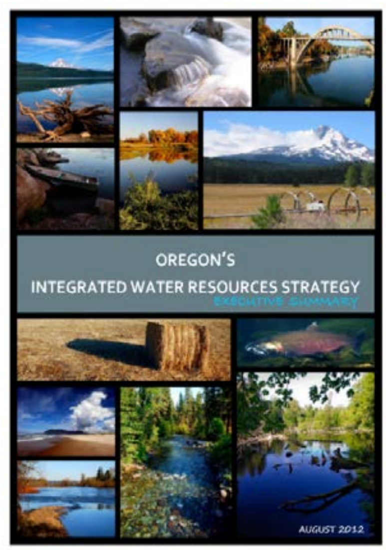
As its central purpose, this water demand forecast seeks to start a conversation about the changing water demands throughout Oregon. Understanding the drivers and uncertainties around water demand helps to frame discussions the Oregon Water Resources Department (OWRD) hopes to engage in with the help of water managers and users statewide.

Background and Authorization

In 2007, the Oregon Water Resources Commission (WRC) took a leadership role in defining and addressing the state's water resources-related challenges. The WRC consists of seven members that are appointed by the Governor, confirmed by the Oregon State Senate, and chosen for their general expertise in the governance of water resources. The WRC provides a public forum for discussing water policy, advises OWRD, and takes appropriate actions to further the development of policies that support sustainable water resource management and a healthy environment.

In response to the current and future water resource challenges facing Oregon, the WRC called for a statewide water strategy to be developed by OWRD and kept these issues at the forefront of public discussion. An early product of this direction was the 2008 Statewide Water Needs Assessment (hereafter, 2008 Water Demand Forecast; OWRD 2008). The 2008 Water Demand Forecast was an important, initial step in characterizing current and future water demands throughout Oregon.

In 2009, the Oregon Legislature authorized OWRD to produce an Integrated Water Resources Strategy (IWRS), with updates due every five years thereafter. In 2012, the WRC adopted Oregon's first IWRS. The IWRS presents a blueprint for defining and addressing Oregon's current and future water needs through thirteen recommended actions designed to help the state understand and meet its instream and out-of-stream water needs, including water quantity, water quality, and ecosystem needs. Specifically relevant to this report, Action 2.A calls for an update to the 2008 Water Demand Forecast.



The 2012 Integrated Water Resources Strategy recommended this 2015 Water Demand Forecast (Recommended Action 2.A)

During the past eight years, several changes in Oregon have increased competition between water users, consistent with the concerns that prompted the WRC to take action in 2007. The national economy has slowed and rebounded, postponing the anticipated timelines for growth in urban water use. Nevertheless, Oregon's population and municipal demands for water have steadily increased. International scientific consensus has been reached that the recent global climatic conditions have trended outside of the historical ranges, as has been observed locally in Oregon. Annual temperatures have risen and emerging research suggests that crop suitability and planting dates are shifting in response. In addition, the current and severe drought that extends across the Western U.S. and Oregon has increased competition for water across different uses and users.

As population forecasts are updated and the science surrounding climate change improves, decisions about the use and governance of land and water will continue to require updated information about the influence of these drivers on water demands; this report provides one such update.

Objectives of the 2015 Water Demand Forecast

The objectives of the 2015 Water Demand Forecast are guided by several IWRS recommended actions, including: 2.A – Update long-term water demand forecasts; 5.A – Support continued basin-scale climate change research efforts; 5.B – Assist with climate change adaptation and resiliency strategies; 6.A – Improve integration of water information into land use planning (and vice-versa); 8.D – Identify ongoing water-related research needs. Broadly, these actions can be summarized in the following four study objectives:

1. Provide estimates of current and forecasted water demands for municipal water use to **reflect changes in population projections** and **water use conservation efforts** that have occurred since the previous forecast (2008).

2. Describe the **sensitivity of agricultural demands to changes in climate**, incorporating advancements in the sciences of estimating current crop water demands and in projecting changes in climate.

3. Provide appropriate **information for water resources planning at multiple scales.**

4. **Identify uncertainties** in the 2015 Water Demand Forecast **and additional resources** to be considered when applying the 2015 forecasts to water resources planning efforts at multiple scales.

The techniques applied for estimating current and future statewide water demands were guided by these objectives and by the availability of reliable, uniform data for all regions of the state. As a result, this report provides estimates of water demand forecasts that are appropriate for planning at regional, tribal, county, and state levels. Where applicable and appropriate, this report notes special considerations, additional sources of information, and advice on how to apply this forecast for use in place-based water resources planning efforts.

Organization of this Report

This report is organized into the following chapters and appendices:

Introduction Describes the purpose, authorization, and objectives for the 2015 Water Demand Forecast, and provides an orientation to key terms for readers not intimately familiar with water resources.

Chapter 1 **Summary of the 2015 Water Demand Forecast,** providing key findings and estimates of total diversion demands, and advice on how to apply data in this report to place-based integrated water resources planning efforts. This chapter also identifies priority informational needs for improving future water demand forecast updates, and compares the results of this report to the 2008 Water Demand Forecast.

Chapter 2 **Agricultural Water Demand Forecast** provides statewide calculations of current and future agricultural water consumption (represented by the net irrigation water requirements (NIWR), which is the amount of irrigation water consumed by crops), summarizes the technical process for conducting the agricultural demand estimates, and recommends steps for improving the accuracy of agricultural demand estimates for consideration in future water demand forecasts and by place-based coordinators.

Chapter 3 **Municipal, Domestic, and Industrial Water Demand Forecast** provides estimates of current and future total diversion demands for municipal, domestic, and industrial (M&I) water, summarizes the technical process for conducting the M&I demand estimates, identifies uncertainties and recommends steps for improving the accuracy of agricultural demand estimates.

Appendix A **Calculations for Current and Future Agricultural Water Demands (Excel Spreadsheet)** provides the back-up calculations of agricultural water demand published in this report. This spreadsheet, combined with appendices C and D, can be used to understand the values used in estimating future agricultural demand.

Appendix B **Calculations for Current and Future Municipal and Industrial Water Demands (Excel Spreadsheet)** provides the back-up calculations of M&I water demand published in this report. This spreadsheet can be used to understand and adapt tools and components for local efforts.

Appendix C **Current and Projected Future Irrigation Water Requirements for Oregon** summarizes general methodologies for estimating historical and future projections of crop water demand, as developed by the U.S. Bureau of Reclamation as part of the West Wide Climate Risk Assessment (WWCRA) for the Klamath and Columbia river basins (Huntington, et al., 2015).

Appendix D **Methods for Computing Crop Consumptive Water Demand by County** describes the approaches used for selecting representative weather stations by crop and county throughout the WWCRA modeled basins.

Appendix E **Adjustments to Cuenca Irrigation Water Requirements to Reflect Climate Changes**, extends projected climate change scenarios from the WWCRA modeled basins to those not included in the WWCRA study (North Coast, South Coast, Umpqua, Rogue, Harney, and Goose and Summer Lakes Regions).

Appendix F **Comparison of Evapotranspiration Methods for the Klamath River Basin** provides comparisons of evapotranspiration estimates among three computational methods, being: Traditional Single Crop Coefficient – Monthly Reference ET; Dual Crop Coefficient – Daily Reference ET; and Actual ET from Satellite-based Energy Balance (METRIC).

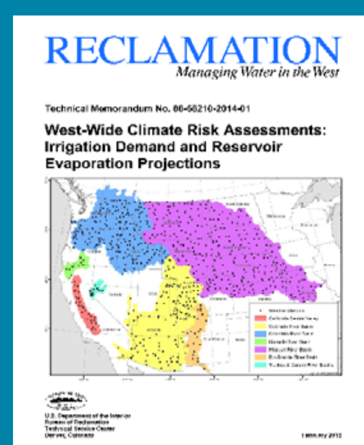
Appendix G **Database of Current and Future Crop Consumption and Irrigation Water Requirements (Access Database)** provides the estimated crop water demands from WWCRA that are relevant to Oregon agricultural demands. A summary of this database is included in Appendix C.

Featured Changes in this Forecast

The science and approaches for estimating agricultural demand have progressed considerably since the 2008 Water Demand Forecast, especially for estimating crop demands in future climates and with the assistance and development of remote sensing (satellite imagery). The 2015 Water Demand Forecast leverages analyses developed for the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) as part of the West-Wide Climate Risk Assessment (WWCRA) program (Reclamation 2011; Huntington et al. 2015).

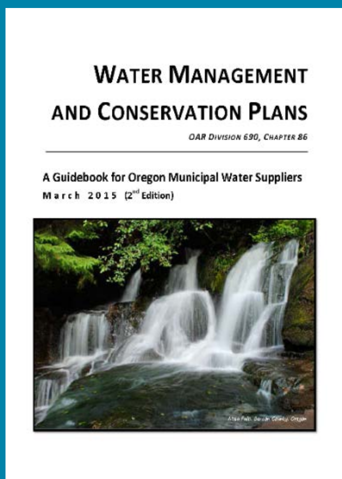
Reclamation's West-Wide Climate Risk Assessments

Baseline assessments of the risks and impacts of climate change have been developed through Reclamation's WaterSMART initiative. These studies include projections of future climate and related changes in water supplies, water demands, imbalances between supply and demand, and ecosystem responses. The assessments, broadly termed WWCRA, have been conducted for several watersheds across the Western U.S. where Reclamation projects serve an important role in the management of water resources, including the Klamath and Columbia river basins.



The 2015 Water Demand Forecast leverages scientific advancements funded through Reclamation's WWCRA assessments in projecting climate changes and associated agricultural demand for Oregon. Through this forecast, Oregon has obtained access to more detailed crop-specific demand information that can be used to project changes in crop demand through the end of the 21st century.

Municipal demand forecast methodologies used in this report are consistent with the previous forecast, and rely on updated forecasted populations and improved estimates of per capita demand for each of Oregon's incorporated and unincorporated communities. Population forecasts have changed since 2008, reflecting outcomes from the recent economic downturn, and estimates of per capita demand have become more broadly available and reliable.



Oregon's Water Management and Conservation Plans

Oregon has adopted rules that pertain to water right permit extensions (Oregon Administrative Rules Chapter 690, Division 315) and which require the preparation of **Water Management and Conservation Plans** (WMCP) (OAR 690-86). WMCPs describe a municipal water suppliers' strategy for managing water supplies to meet existing and future demands. **Many municipal water suppliers are required to prepare plans** under water right permit conditions, or for a long-term permit extension.

At the time the previous forecast was conducted, **WMCPs were relatively new** and consequently inconsistent, unavailable for some geographic locations, and difficult to apply in a reliable manner. **Recent improvements in the consistency and availability of WMCPs** provides more detailed and relevant information from across Oregon, **allowing this forecast to estimate municipal demand in all regions consistent with information reported by communities themselves (Figure 3.7).**

The 2008 Water Demand Forecast included estimates and forecasts for instream demand, including an approximation of ecological needs. An update to these assessments is being conducted through a separate effort by OWRD, in coordination with other state agencies.

Reader Orientation to Key Terms and Concepts

This report is intended for a broad audience interested in Oregon's water resources, including elected officials and policymakers, agency staff, local and regional planners, water users, and other organizations. Many of the terms and concepts in this report are commonly used by one intended audience, but may be unfamiliar to another. For example, irrigation district managers would likely feel comfortable with discussions about "applied water," but other readers may be less familiar with this term and how it relates to total agricultural diversions. Establishing a common understanding for some of this report's key terms and concepts is a crucial element in making this document useful.

The following section provides a brief orientation to concepts and terms used throughout this report. These topics include:

- Measuring and reporting volumes of water
- Key terminology for characterizing water demands
- The use of planning scenarios

Measuring and Reporting on Volumes of Water

Water resources professionals use different units for different projects, based on the needs of their tasks. For consistency, this report summarizes water demand volumes in **thousands of acre feet per year** (**TAF/yr**). An acre foot is the amount of water needed to cover one acre (43,560 square feet) to a depth of one foot.

The origin of the acre foot dates to early agricultural practices in the United States, where demand for irrigated crops was estimated in depths. For example, about 3.5 feet of water were needed to irrigate alfalfa on bottom-land soils in the high desert. With this example in mind, a farmer with similar lands and crops could calculate that 100 acres of alfalfa would require a water right for applying 350 acre feet. This unit of measurement for water volumes is common in large-scale water supply planning in the Western U.S., where irrigation water is often diverted from rivers and streams and stored for later use. Use of this standard unit of measurement for discussing volumes of water supply also reflects the enduring influence of irrigated agriculture on Western water resources development. Aside from tradition, the acre foot lends itself well to visualizations of large volumes of water, as it is often likened to roughly the area of a football or soccer field covered with one foot of water. Similarly, one acre foot roughly approximates the annual water demand of an average suburban family in the United States.

Municipal and industrial water suppliers typically use **millions of gallons per day** (**MGD**), which has its origins in planning for specific gallon-per-day rates of use per capita. **Cubic feet per second** (**cfs**) is prevalent in the measurement of streamflows, owing to the methods of calculating stream cross sections in square feet and measuring flow rates in feet per second. Design and planning for storm- and waste-water facilities focus on the sizes of pumps and thus use **gallons per minute** (**gpm**), a common unit for sizing pumps.

The following table provides general conversions between these common units of measurement.

1,000 acre feet per year (TAF/yr) =	1 cubic foot per second (cfs) =	1,000,000 gallons per day (MGD) =
0.89 MGD	0.724 TAF/yr	1.12 TAF/yr
1.38 cfs	0.646 MGD	1.55 cfs
620 gpm	449 gpm	694 gpm
1 acre foot =	1 cubic foot =	1,000,000 gallons =
43,560 cubic feet	7.48 gallons	3.07 acre feet
325,851 gallons		133,681 cubic feet

Key Terminology for Water Demand

A core purpose of assessing the volume of Oregon's water demands is to facilitate comparisons to the volume of water supply at a local or regional level. Calculating imbalances in supply and demand, however, requires understanding the lifecycle of diverted water; typically, only a fraction of the water diverted is fully consumed, and some portion returns to its source. Managing rivers, municipal services, and agricultural districts, alike, requires an understanding of the full volume of water required for a water use, as well as the fraction which is consumed and does not return. The following section explains how the various chapters of this report describe water demand for agricultural and M&I water users, such that the information in this report can be properly applied.

This report considers **M&I water demand** to be the total amount of water diverted from primary water sources for delivery to residential, industrial, and commercial customers. These diversion volumes will be familiar to municipalities, as these are the volumes used to design diversion structures, treatment facilities, pipelines, and other water service infrastructure. A large portion of water diverted for M&I use is delivered to customers, used, treated, and returned to streams or to groundwater where it may become available for other uses. The specific timing, volume, and quality of M&I return flows vary across the state depending on water use and location. For more detail about how M&I water demands are defined, see Chapter 3.

This report presents **agricultural water demand** in two ways, as: (a) a total diversion demand from primary water sources (similar to this report's treatment of M&I water demand) (Chapter 1), and (b) as the volumes of agricultural diversions which are consumed by crops (as Net Irrigation Water Requirement; NIWR) and, therefore, do not return to the environment (Chapter 2). Figure A.1 illustrates the relationship among agricultural diversions, applied water, and NIWR, and all three terms are defined on the following page.

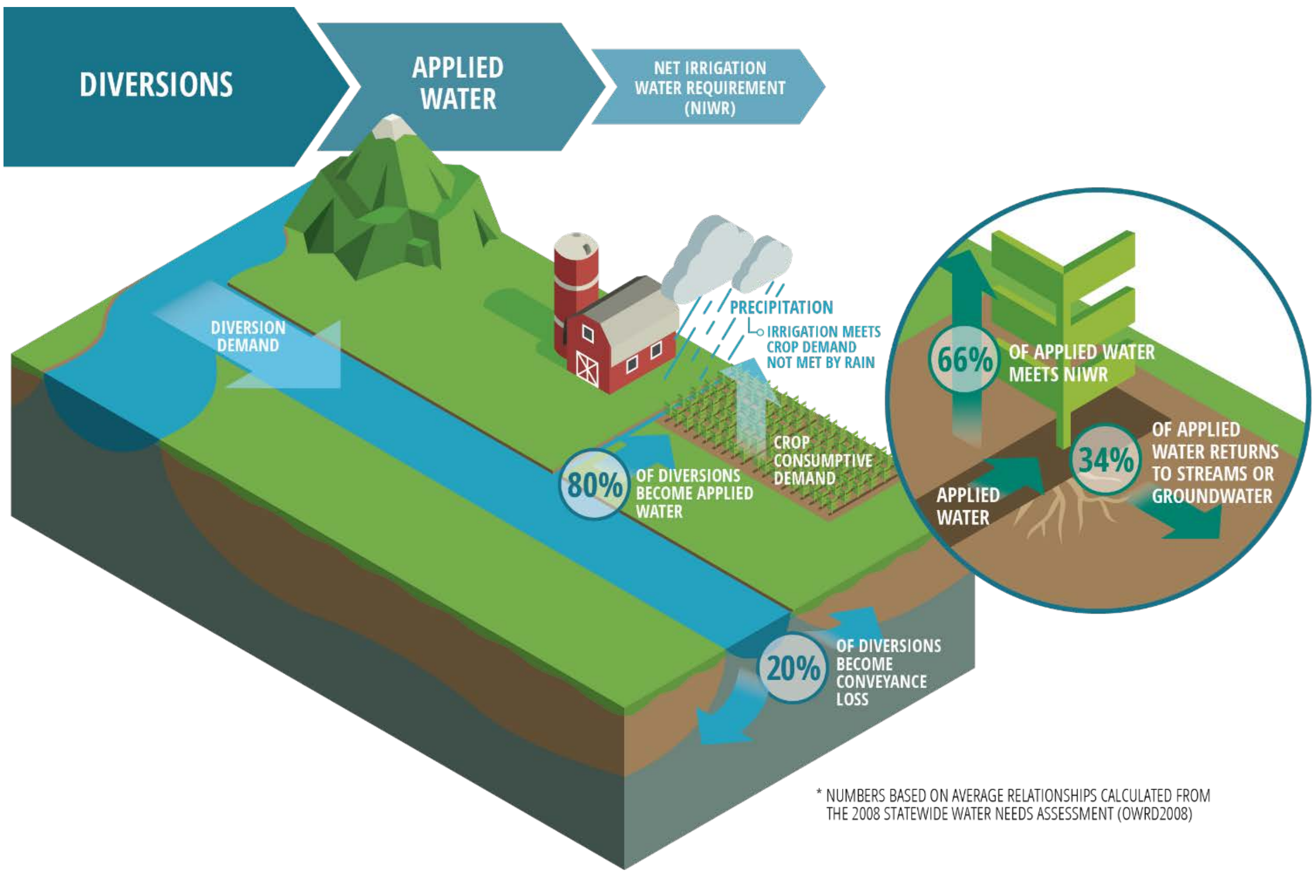
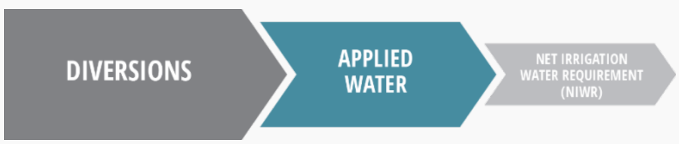


Figure A.1. Relationship Among Agricultural Diversions, Applied Water, and the Net Irrigation Water Requirement

Understanding the difference between diversion demand and NIWR is important for understanding the agricultural demands reported in Chapter 1 and 2: Chapter 1 reports on total diversion demands, and Chapter 2 on NIWR.

Diversion Demand – The volume of water that must be diverted from surface water systems (or extracted from groundwater) in order to meet full applied water demand for all of the farms in a given distribution network. Diversion demand is larger in volume than applied water demand, as many of the canals that supply irrigation water experience conveyance losses, such as seepage to groundwater through unlined portions of the network as well as losses to evaporation. The 2008 Water Demand Forecast estimated and used an average conveyance efficiency, statewide, of 80 percent for baseline conditions (OWRD 2008). In 2008, agricultural water demand was reported in terms of diversion demand.

Diversion Demand = Applied Water Demand + Conveyance Losses



Applied Water Demand – The volume of water required for application on a field through irrigation to meet crop consumptive demand. Applied water demand is larger in volume than NIWR due to factors such as on-farm application efficiency, which varies by irrigation technique (e.g., sprinklers, flood). The 2008 Water Demand Forecast identified various application efficiencies for crops, by county; the range of irrigation efficiency was 45 percent to 100 percent, with the average irrigation application efficiency of all crops, weighted by acreage, being 66 percent statewide (OWRD 2008).

Applied Water Demand = NIWR + Irrigation Losses

Net Irrigation Water Requirement – The portion of *crop consumptive demand* met by irrigation water. Crop consumptive demand is defined as the volume of water required to grow a well-watered crop under optimal conditions with a full water supply. Crop consumptive demand is assumed to have been met first with **effective precipitation**, or the amount of precipitation that satisfies a portion of crop needs. The remaining portion of crop consumptive demand is quantified as the NIWR, which is the volume of water needed to make up the difference between what a crop would naturally receive through precipitation and what is needed for a well-watered crop under ideal growing conditions. This report focuses on crop consumptive demand and often reports volumes of agricultural demand in terms of NIWR.

NIWR = Crop Consumptive Demand − Effective Precipitation

This report relies on statewide average conveyance and application loss estimates from the 2008 Water Demand Forecast to calculate diversion requirements (OWRD 2008). Thus, the diversion demand needed for meeting 100 acre feet of NIWR is 189 acre feet (nearly double). These conversion rates are applied uniformly, statewide. Because of the importance of these efficiencies to water use, planners may want to consider up-to-date information on conveyance and application efficiencies in order to apply this forecast at a local level.

Planners should also be aware that NIWR volumes are just estimates and the actual amount of water consumed by plants may be different from what was used for this analysis. Assumptions about the needs for fully watered crops sometimes include watering requirements through the winter that are not observed in practice. Another practice, termed “deficit irrigation,” provides less water to crops than would be assumed by the well-watered conditions. This practice may be implemented during scarcity or to improve the condition or timing of crop yields (for example, to enhance or promote the ripening of wine grapes). However, these practices are not standard across all production nor implemented every year, and the NIWR presented in this report provides a broadly accepted benchmark for estimating crop water needs across the Western United States.

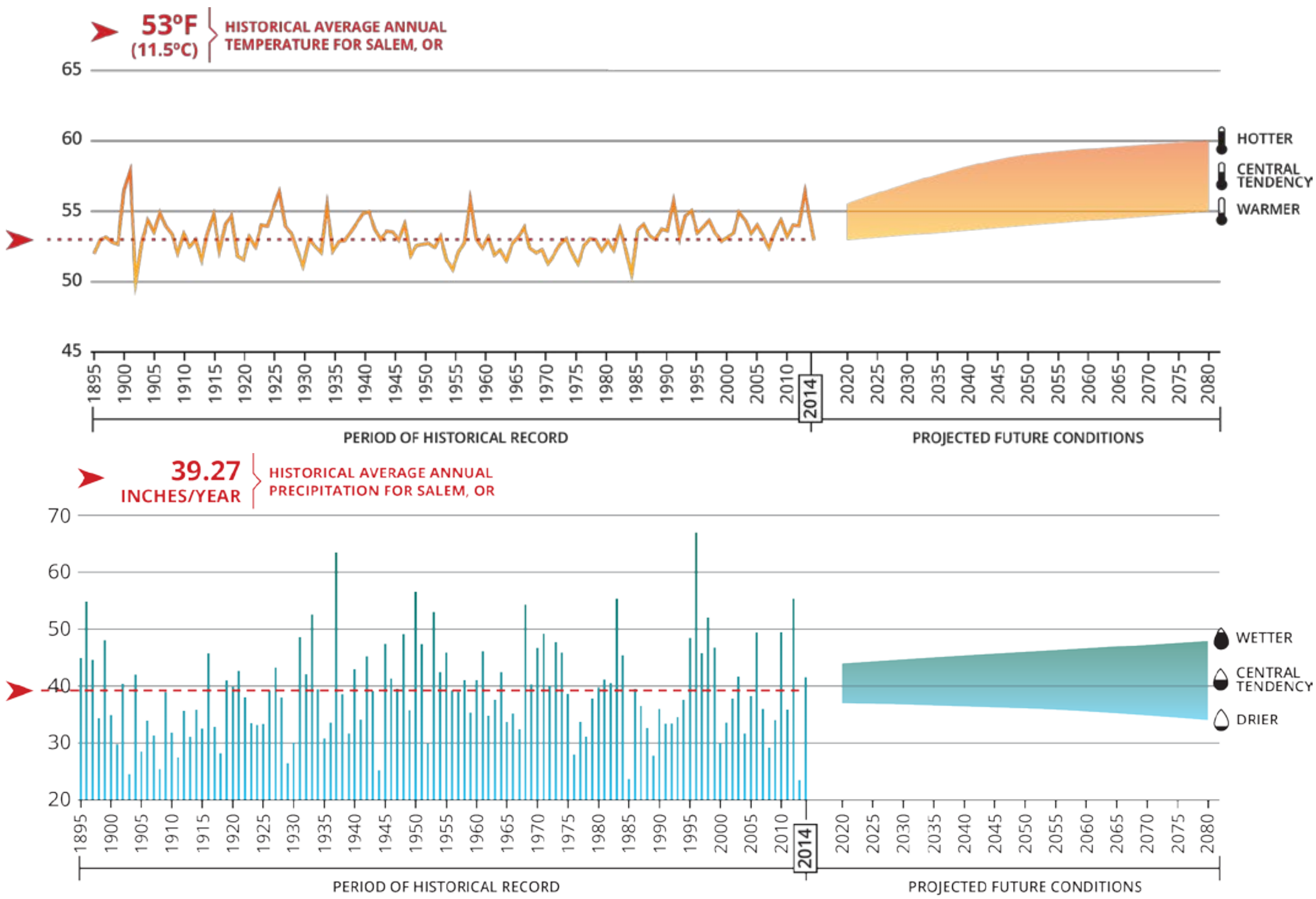
Planning Scenarios

A “scenario” is a combination of resource conditions (such as the extent of agricultural acreage in production, per capita demands for a community, or policies that influence water use) and key driving forces that are expected to alter conditions in the future (such as changes in population, climate, or land use). Scenarios have a long history of application in water resources planning, as they facilitate “what if” discussions and support the development of plans for uncertain or potentially variable future conditions.

This report uses scenarios to depict and compare current (2015) **and potential future** (2050) **water demands**. The water demands presented in this report relate to water used by agricultural and M&I water users. Because the factors influencing water use differ between agricultural and M&I water users, scenarios for both were created separately. A wider range of future conditions exists for agricultural water users stemming from the large uncertainty in future climate conditions and how climate changes may impact the volume and timing of water needed to sustain crops. As a result, **five scenarios** have been created to **depict future agricultural water demands**, whereas **future M&I demands are represented with a single scenario**.

Agricultural Water Demand Scenarios

This report includes one description of current agricultural water demand, and five descriptions of future demand that correspond with uncertainties in the science of projecting the future climate. A defining characteristic of climate change is a projected shift in “average” conditions. Figure A.2 provides context to this uncertainty by comparing historical climate records for Salem, Oregon to a range of projected future averages. Dashed red lines represent the historical average for temperature and precipitation. The cones that spread outward from 2020 represent the wide range of average conditions that are being projected through 2080 for Salem. The range of variability seen around the historical averages may also change.



***Source**: NOAA National Climate Center, Salem McNary Field Station, Accessed July 28, 2015*

Figure A.2. Comparison Between Historical and Projected Future Average Temperature and Precipitation in Salem, Oregon

The 2015 Water Demand Forecast approaches these uncertainties with multiple future scenarios, similar to the approach used in reports by the Intergovernmental Panel on Climate Change (IPCC) and Reclamation's approach to estimating future crop demands associated with climate change (IPCC 2007, Reclamation 2011, Huntington et al. 2015). Through this approach, the full range of projected future conditions (112 separate simulations) is combined in a manner that produces a manageable number of scenarios which maintains the range of scientific uncertainty. The resulting scenarios can vary significantly for different locations.

The scenarios used to describe agricultural water demand in this report are:

- **Current Agricultural Demand Scenario (1 scenario)** – This scenario provides a recent "snapshot" of agricultural water demands across Oregon approximating demand in 2015, based on estimates of average irrigation water requirements using historical climatic conditions.
- **Future Agricultural Demand Scenarios (5 scenarios)** – These five scenarios provide a range of potential future changes in demand for agricultural water across Oregon by the year 2050. The scenarios are named according to the relative combinations of future precipitation and temperature conditions they represent, as depicted in Figure A.3. All of the scenarios project an increase in temperature, from a more moderate increase ("Warmer") to a more severe increase ("Hotter"). Changes in precipitation are noted as either an increase ("Wetter") or decrease ("Drier"). The central tendency scenario represents a condition somewhat similar to an "average" of all future climate projections.

As all scenarios are equally likely to occur in the future, planners are encouraged to consider the full range of projected conditions in a manner that best reveals vulnerabilities to future change.

All six scenarios assume the same acreages and crop selections as the current scenario; thus, differences between the current and future scenarios result from projected changes in Oregon's climate only.

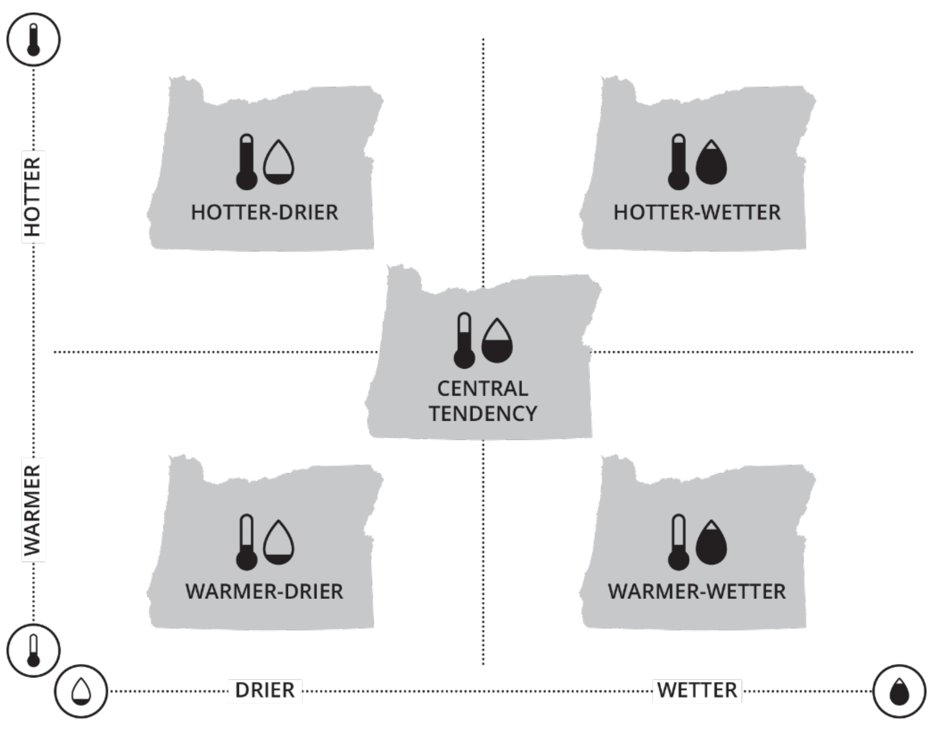


Figure A.3. Five Future Scenarios for Agricultural Demand, Based on Combinations of Future Temperature and Precipitation

In this report, Chapter 2 presents future agricultural water demand under each of the five scenarios. As noted earlier, demands in Chapter 2 are reported as the amount of irrigation water needed to sustain crops (reported as NIWR). In contrast, Chapter 1 presents total diversion of future agricultural water demands associated with the Hotter-Drier scenario only. A single scenario was selected for display in the summary for the purposes of brevity and for parity with the single future M&I demand scenario (reported as diversion demand). The Hotter-Drier scenario was used because it exhibits the largest increase in future water demand and is, therefore, the most likely to strain the balance between supplies and demands across the state (i.e., to highlight the most challenging conditions). As noted earlier, the demands reported in Chapter 1 are the combined diversion demand for M&I and agriculture.

Although this report focuses on future scenarios that could occur by 2050, agricultural demands were also calculated for 2020 and 2080 for each of the five scenarios. These forecasts are available in an electronic spreadsheet format (see Appendix A).

Municipal and Industrial Water Demand Scenarios

Two scenarios have been developed to describe current and future M&I water demand (including municipal, self-supplied industrial, and domestic well use) in Oregon through 2050:

- **Current M&I Demand Scenario (1 scenario)** – This scenario describes the existing set of M&I water demands, based on rates of use reported in WMCPs that have been submitted to OWRD.
- **Future M&I Demand Scenario (1 scenario)** – This scenario describes the best estimate of M&I water demands throughout Oregon by 2050 based on forecasted increases in population and reported expectations for per capita demand. The future M&I demand scenario does not reflect any changes in demand that could result from a changing climate.

The forecasts for M&I demand are available in an electronic spreadsheet format (see Appendix B).

CHAPTER 1

SUMMARY OF THE 2015 WATER DEMAND FORECAST

This chapter compares Oregon's current statewide water **diversion demands** for agricultural and M&I water use sectors to the future demands projected for 2050. This chapter includes a consolidated presentation of Oregon's current and future demand, with notes on drivers of future water demand and key findings for agricultural and M&I demand forecasts. Agricultural water demands are presented in greater detail in Chapter 2; M&I demands are detailed in Chapter 3.

Chapter 1 focuses on the Hotter-Drier scenario for future agricultural demand.

All five future scenarios for agriculture are reported in Chapter 2.

Only one of the five future agricultural demand scenarios was selected for discussion in this chapter (see introduction for more information on scenarios). A single scenario was selected for display in the summary for the purposes of brevity, for parity with the single future M&I demand scenario, and to facilitate comparisons with the 2008 Water Demand Forecast (OWRD 2008). The Hotter-Drier scenario was chosen because it exhibits the largest increase in future water demand and is, therefore, the most likely to strain the balance between supplies and demands across the state. The Hotter-Drier scenario represents a future climate with higher average temperatures and less rain and snow.

Both agricultural and M&I demand estimates are presented as a diversion demand in this chapter's summary figures – that is, the total demand figures do not account for how much of the water diverted is consumptively used or how much ultimately returns to its source, such as through discharge of treated wastewater or through irrigation return flows.

Key Findings & Assumptions

While several factors influence the demand for water, projected changes in Oregon's climate and population are expected to have the greatest effect on water demands throughout the state between now and 2050.

The agricultural sector accounts for approximately 85 percent of the current (2015) and future (2050) statewide water diversion demands, with the remaining portion belonging to M&I. In response to changes in climate by 2050, the statewide demands for irrigation (both total diversion and NIWR) are expected to increase by a statewide average as high as 14 percent. Changes in climate affect different parts of the state differently, and the highest percentage increase in agricultural irrigation are expected in western counties that historically relied the most heavily on precipitation for meeting crop consumptive demands.

Over the same planning horizon, increases in population are anticipated to increase M&I demands by 20 percent. The net increase in statewide agricultural water demand by 2050 depends on the climate condition, but varies between increases of 10 to 14 percent in both NIWR and agricultural diversion demands for Oregon as a whole.

Figure 1.1 presents a comparison of current and future diversion demand by county.

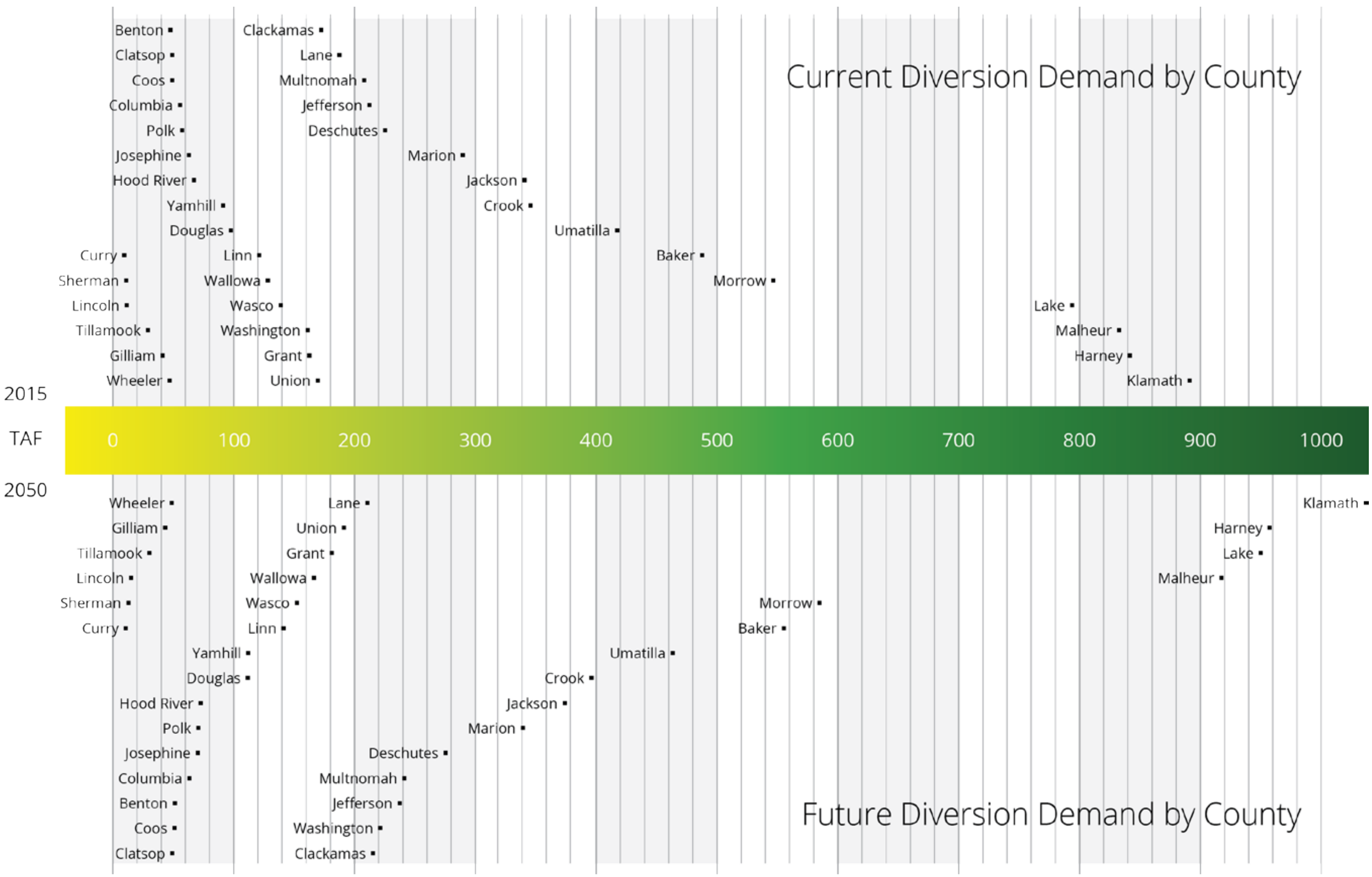


Figure 1.1. Comparison of Current and Future Diversion Demand by County

The volume of water diversion demands are expected to increase for all counties by 2050, and **the largest volumetric increases** are:

(1) Klamath, (2) Lake, (3) Harney, (4) Malheur, and (5) Washington counties.

The top four rank among counties with the highest current water demand and the highest total acreage in Oregon. Agricultural demands dominate the current and future demand increases in these four counties, with future increases in water demand being driven by increasing crop demand under projected climate change. Increasing demand in Washington County, home to one-third of Oregon's population, is driven by anticipated population growth.

The forecasted increases throughout Oregon do not occur proportionally. Some counties may experience more rapid growth in water diversion demand than the statewide average (15 percent). The counties with the **highest percentage increase** in total water demand by 2050 (relative to 2015) are:

(1) Washington, 39 percent; (2) Wallowa, 25 percent; and (3) Clackamas, Yamhill, and Polk counties, 24 percent each.

With the exception of in Wallowa County, changes in the counties with the fastest growing water demands are being driven by increases in population in the currently populous northern Willamette Valley. Wallowa and Clackamas counties have larger-than-average projected increases in agricultural demand, although the forecasted increases in Clackamas County are predominantly driven by population.

The following sub-sections summarize the key drivers, findings, and assumptions for the agricultural and M&I components of the 2015 Water Demand Forecast.

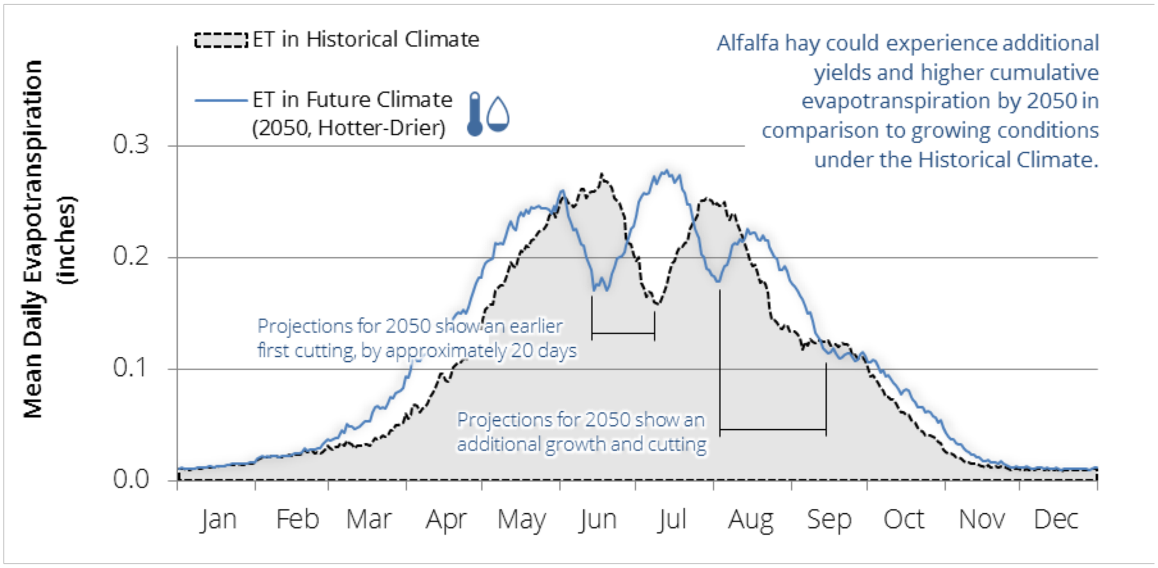
Changes in Future Agricultural Demands

Climate simulations for Oregon project an increase from 1970-1999 to 2041-2070 of average annual temperatures of between 2.0 to 8.5 degrees Fahrenheit. Annual precipitation within the same period is projected to change by -5 to +14 percent. Summer rainfall is projected by many models to decrease by as much as 34 percent (Mote et. al. 2013).

These projected changes are expected to alter crop water needs and may influence crop selection. For sensitive crops, the geographic extent of favorable conditions may migrate away from current areas. Additionally, warmer winter temperatures are anticipated to prolong the growing season for some crops and increase the volume of water needed to sustain crops.

Winegrapes present an example of how sensitive crops may be affected by climate change. The regions and climatic conditions that produce an optimum quality are considered to be narrow and differ for each varietal, ultimately putting winegrapes at a heightened risk to climatic variations and change. Research has shown that some of the gradual, historical shifts in the climate (1948 through 2002) have been beneficial to some winegrape varietals currently grown in Oregon (Jones 2005). However the projected climate changes over the coming century may not continue to benefit winegrapes in Oregon and could result in the migration of optimal conditions to more northerly regions that have traditionally been too cold for cultivation (Campbell 2013, Jones 2005). While these anticipated changes may occur over a period as long as 50 years, Oregon's winegrape growers have begun considering adjustments to watering practices, varietal choices, and locations of vineyards. These changes are anticipated to be decision points across the agricultural sector in Oregon as related to a changing climate.

Less-sensitive crops may be faced with changes in their growing seasons and increases in water consumption. Figure 1.2 illustrates this for alfalfa hay in the Klamath River basin. The grey area shows the simulated consumption of water by alfalfa. Alfalfa is produced through several cuttings each year, visible in Figure 1.2 with the sharp declines in evapotranspiration, followed by a resurgence with the regrowth of the crop. With higher annual temperatures expected by 2050, the last frost is projected to occur several weeks earlier and the growing season is expected to last longer. The prolonged growing season for alfalfa is projected to increase the overall yield (number of cuttings) for alfalfa. However, the longer season may also require larger volumes of water.



Source: *Huntington et al. 2015*

Figure 1.2. Historical and Future Mean Daily Alfalfa Hay Evaporation (ET), in Klamath River Basin

Changes in agricultural demands are expected to vary across Oregon, based on differences in total acreages of crops, crop types, and the extent to which the climate is expected to change in each county. Counties with the largest quantity of irrigated acreage may experience the largest increase in agricultural water demand by 2050. The five counties with the **highest volumetric increase** in agricultural demand account for 45 percent of the current irrigated acreage in Oregon, and are:

(1) Klamath, (2) Lake, (3) Harney, (4) Malheur, and (5) Baker.

Areas of the state that have relied more heavily on precipitation to meet crop consumptive demands are forecasted to experience a larger relative increase in water demand than the statewide average of up to 14 percent. The Mid-Coast, Willamette, and Sandy Administrative Basins all experience increases in agricultural water demand by more than 20 percent, driven by reductions in the amount that precipitation is projected to meet crop demands. The counties with the **highest percent increase** in agricultural water demand by 2050 (relative to 2015) are:

(1) Clatsop, 49 percent; (2) Columbia, 27 percent; (3) Wallowa, 26 percent; (4) Multnomah, 22 percent; and (5) Clackamas, 20 percent.

Key Findings for Agricultural Water Diversion Demands

- Future increases in temperature are expected to prolong agricultural growing seasons and increase the total consumptive water demand for crops (NIWR plus effective precipitation) by 6 to 9 percent, while also increasing demand for irrigation (for both total diversion demand and NIWR), specifically, by 7 to 14 percent.

- The extent of increases in demand varies significantly by region. The portions of Oregon that are currently driest will likely experience the largest increases in demand for irrigation supplies. Lake, Klamath, and Harney counties have the highest volumetric increases in demand related to climate change.

- Crops may increase their reliance on irrigation as less of their consumptive demand can be met with precipitation. This potential effect may be more noticeable in counties that have traditionally relied more on rainfall during the growing season for meeting crop water demands. Resulting increases in demand for irrigation may need to be managed with increases in supplies, conservation measures, or land-use changes.

Important Assumptions in Estimating Agricultural Water Diversion Demands

- County crop acreages and the types of crops grown within each county are held constant between current (2015) and future (2050) conditions. The estimates assume that the amount and type of crops do not change.

- The NIWR calculations are based on crops being maintained in well-watered, theoretically optimal conditions, which may differ from current agricultural practices.

- The NIWR assumes the full availability of water supplies, and thus existing or potential shortages are not considered in the calculation.

- NIWR is used to back-calculate total diversion demand. Calculation of total diversion demand is based on a NIWR that was estimated for each county, and on assumed statewide conveyance and application efficiencies (80 percent and 66 percent, respectively). These efficiencies are based on reported information in the 2008 Water Demand Forecast (OWRD 2008) and do not consider any efficiency improvements through new agricultural technologies or practices that have occurred since 2008.

- Stockwater demands, which accounted for 0.5 percent of the statewide agricultural water demand in the 2008 Water Demand Forecast, were not considered in this report.

Changes in Future Municipal and Industrial Water Demands

This demand forecast focuses on how anticipated changes in population for Oregon, as well as reported changes in per capita demand, is projected to influence M&I water demands. Population was found to be a more influential driver of future water demands than changes in community per capita demands. Most population growth is forecasted to occur in Oregon's large urban areas, with Central Oregon projecting the highest percentage growth through 2050. Conversely, rural and unincorporated areas are expected either to remain stable in population or to experience some decline.

The counties with the **highest volumetric increase** in M&I water demand by 2050 are:

(1) Washington, (2) Deschutes, (3) Multnomah, (4) Clackamas, and (5) Lane.

The M&I demands for some counties are forecasted to increase more than the statewide average of 20 percent. The counties with the **highest percent increases** in M&I water demand by 2050 are:

(1) Deschutes, 54 percent; (2) Washington, 50 percent; (3) Polk, 47 percent; (4) Yamhill, 43 percent; and (5) Jefferson, 35 percent.

Key Findings for Municipal and Industrial Water Diversion Demands

- Population growth is a more influential driver of future M&I water demand than per capita use rates. Statewide, per capita demands have declined over the past seven years, attributable to efforts by water utilities to improve water accounting, decreased economic activity, increased conservation efforts by the public, and development of WMCPs. Many WMCPs referenced in this report stated that the most cost-effective water conservation and efficiency projects have already been implemented and a majority of the water savings from these planned conservation efforts has already been realized. Further conservation efforts would likely require significant investments relative to their expected savings.

- Overall M&I demand is expected to increase 20 percent by 2050, at a similar pace to population growth. Statewide population growth has slowed in comparison to the rates of growth projected in 2008, coinciding with a downturn in the national and state economies. However, growth has begun to rebound with recently improved economic conditions.

- As Oregon's population continues to migrate from rural or unincorporated areas to urban areas, the statewide average per capita demands may increase because incorporated per-capita use includes commercial and industrial use – even as per capita demands for individual communities throughout Oregon are forecasted to remain steady. Urban areas have higher per capita demands than unincorporated areas and, as populations remain steady for unincorporated areas but grow for urban areas, the statewide average per capita demand for Oregon may increase.

Important Assumptions in Estimating Municipal and Industrial Water Diversion Demands

- Changes in population by 2050 were based on forecasts obtained from the Portland State University (PSU) Population Research Center (PRC), which produces a periodic population forecast for Oregon. The most recently completed forecast extends to 2050, and the 2065 update is partially underway.
- Changes in per capita demand were estimated from 50 of the most recent WMCPs from communities across Oregon. In many cases, communities with similar characteristics were identified for estimating per capita demands in communities without recent WMCPs.

Changes in the Forecast from 2008

As an update to the 2008 Water Demand Forecast, this report builds upon a comprehensive, initial description of water use and demands across Oregon. Differences between the projections in this 2015 report and in the 2008 report result from different conditions in 2015 than were anticipated in 2008, different outlooks for 2050, and improvements in information and techniques for estimating future conditions. Table 1.1 compares the total statewide agricultural and M&I demand from the 2008 forecast and this forecast.

Table 1.1. Comparison of Statewide M&I Water Demand Between 2008 and 2015 Forecasts

Year of Forecast	2008 Water Demand Forecast (TAF/yr)		2015 Water Demand Forecast (TAF/yr)		Difference relative to the 2008 Water Demand Forecast (TAF/yr; %)		
	M&I Diversion Demands	Agricultural Diversion Demands	M&I Diversion Demands	Agricultural Diversion Demands[1]	M&I	Agricultural	Difference in Total Diversion Demand
2015	1,219	7,984	1,211	7,216	-8 (-0.7%)	-768 (-10%)	-775 (-8%)
2050	1,534	8,772	1,465	8,229	-69 (-5%)	-543 (-6%)	-612 (-6%)

Key:
M&I = municipal and industrial
TAF/yr = thousand acre feet per year
Notes:
1 – Future agricultural water demands for the 2015 Water Demand Forecast reflect Hotter-Drier climate scenario

Although the 2015 Water Demand Forecast takes advantage of improvements in information and techniques for estimating future demands, this forecast remains susceptible to several uncertainties and limitations that were also present in the 2008 Water Demand Forecast. Areas of uncertainty and recommendations for future resolution are identified in Chapters 2 and 3 of this report.

Municipal and industrial (M&I) water diversion demands for this forecast have been estimated in a manner nearly identical to the 2008 forecast. Importantly, this report takes advantage of higher quality information on per capita water demands from municipal WMCPs that have been updated and collected since 2008. The availability of improved information allows for more specific consideration of municipal water demands that occur inside and outside of Oregon's urban growth boundaries (**UGB**). Thus, where the 2008 report relies upon water rights information to approximate water demand Outside of UGBs (**OUGB**), this report calculates demands for OUGBs in a manner consistent with methods for UGBs.

The decrease in the forecasted M&I demand for 2050 relative to the 2008 Water Demand Forecast results from several factors, including a slower rate of population growth and improved municipal conservation. The majority of WMCPs evaluated for the 2015 forecast indicated a decrease in per capita demand during the 2008 to 2010 time period, and attributed the reductions to weather, conservation efforts, and the downturn in the economy. Primarily, the lower demand corresponds to decreases in the anticipated population growth related to the economic downturn; however, these differences were also influenced by municipal conservation efforts that have been implemented since 2008.

Agricultural water diversion demands appear similar between the two forecasts, but the diversion demands have been calculated in a significantly different manner for the 2015 forecast. The 2008 Water Demand Forecast projected increases in agricultural demands that were the result of a projected increase in the acres of land under cultivation across Oregon. This report does not consider changes in the acreage of cultivated land in Oregon or its counties as part of the agricultural demand estimate. The increases in agricultural water demand in this forecast result solely from changes in the projected future climate.

The projected future agricultural demands in this report rely on recent scientific advancements in the calculation of crop water consumption. These advancements were leveraged from climate-related research that was conducted by Reclamation as part of the WWCRA studies, as described in the Introduction to this report (Reclamation 2011, Huntington et al. 2015).

Although not addressed in this forecast, future changes in the extent of agricultural lands being cultivated, the selection of crops, market prices, and the application of different farming and irrigation technologies and cultural practices – conditions that may also be influenced by changes in climate – may also affect agricultural water demands. Each of these changes is heavily dependent on human behavior and decisions which, perhaps even more so than climate, is highly uncertain to predict.

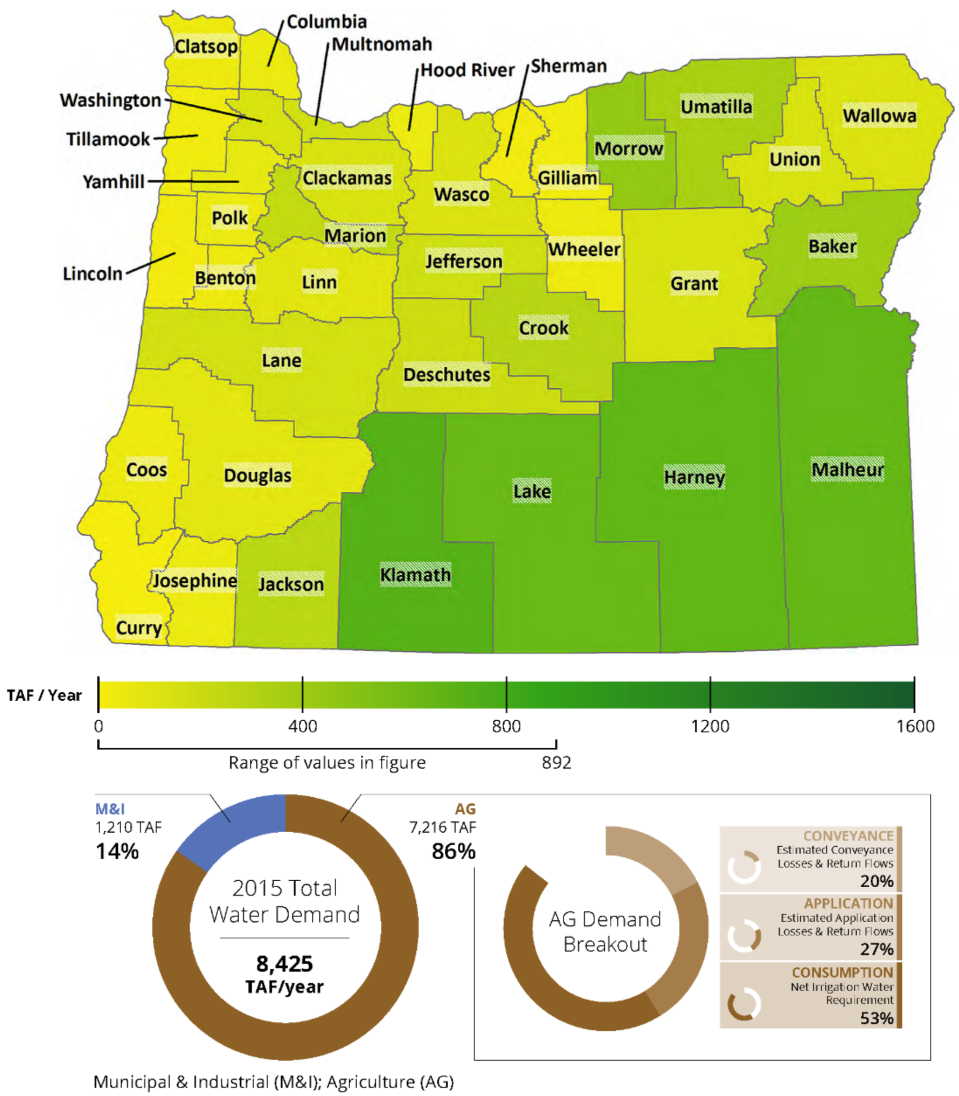
Other categories of demand were included in the 2008 Water Demand Forecast report, but are not included in this report. These categories include:

- Estimated ecological and instream water demands – The demands that were provided in the 2008 forecast are being updated through separate efforts, in close coordination with partner resource agencies.
- Hydropower demand was not considered, given the relatively low impact of hydropower operations on water supply, as reported in the 2008 forecast report.

Current and Future Water Demands by County and Administrative Basin

The subsequent four pages of this report include companion figures and tables that display estimates of current and future statewide water demand in Oregon by county and by Administrative Basin.

2015 | Current Projected Demand by County

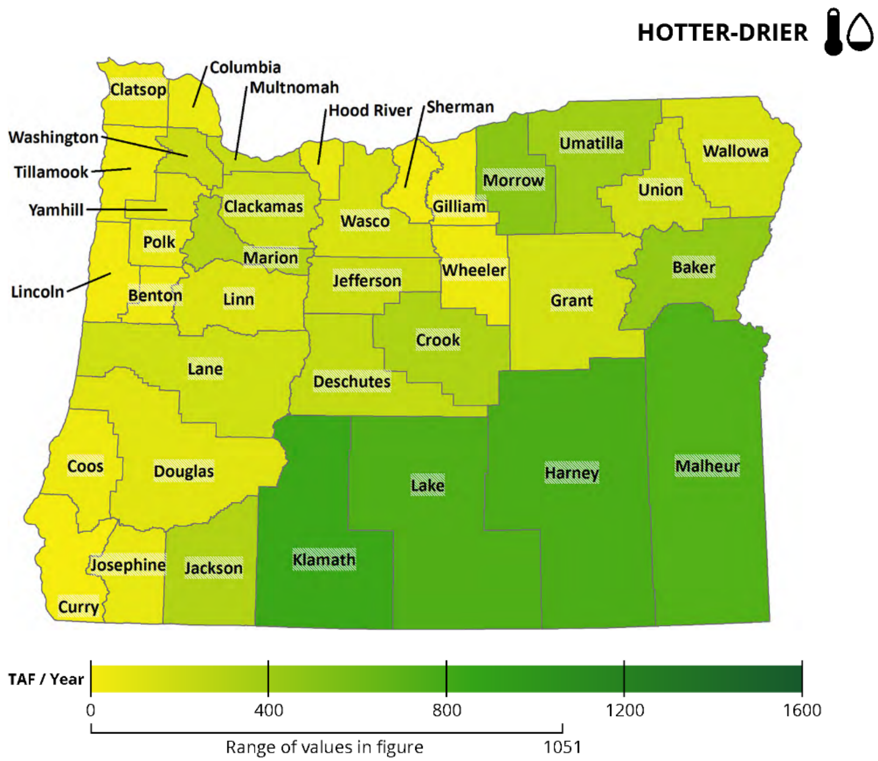


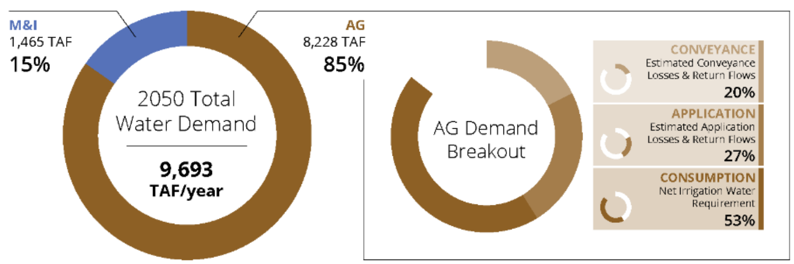
County	2015 M&I (TAF/yr)	2015 AG (TAF/yr)	2015 Total (TAF/yr)
Klamath	23.4	868.5	891.9
Harney	6.6	835.3	841.9
Malheur	14.3	821.6	835.9
Lake	3.2	791.6	794.8
Morrow	7.7	536.8	544.5
Baker	7.6	480.8	488.4
Umatilla	39.1	380.7	419.8
Crook	9.8	335.5	344.2
Jackson	44.0	296.9	340.9
Marion	77.9	211.7	289.6
Deschutes	59.7	165.0	224.7
Jefferson	5.5	208.7	214.2
Multnomah	192.9	15.6	208.5
Lane	138.1	49.2	187.3
Clackamas	98.0	77.6	175.6
Union	14.5	154.6	169.1
Grant	5.2	156.6	161.8
Washington	111.5	49.5	161.0
Wasco	18.7	120.8	139.5
Wallowa	4.3	129.9	134.2
Linn	47.6	72.7	120.3
Douglas	31.3	68.2	99.5
Yamhill	23.4	67.7	91.1
Hood River	13.9	50.8	64.7
Josephine	21.3	41.6	62.9
Polk	12.5	46.8	59.3
Columbia	51.6	6.8	58.4
Coos	30.2	18.4	48.6
Clatsop	46.7	1.5	48.2
Benton	18.8	29.1	47.9
Wheeler	0.2	45.2	45.4
Gilliam	1.4	39.0	40.4
Tillamook	8.7	21.4	30.1
Lincoln	16.7	0.9	17.6
Sherman	1.0	13.0	14.0
Curry	3.5	5.7	9.2
TOTAL	1,210	7,216	8,425

Figure 1.3. Current Diversion Demand by County

2050 | Future Diversion Demand by County

2015 Water Demand Forecast



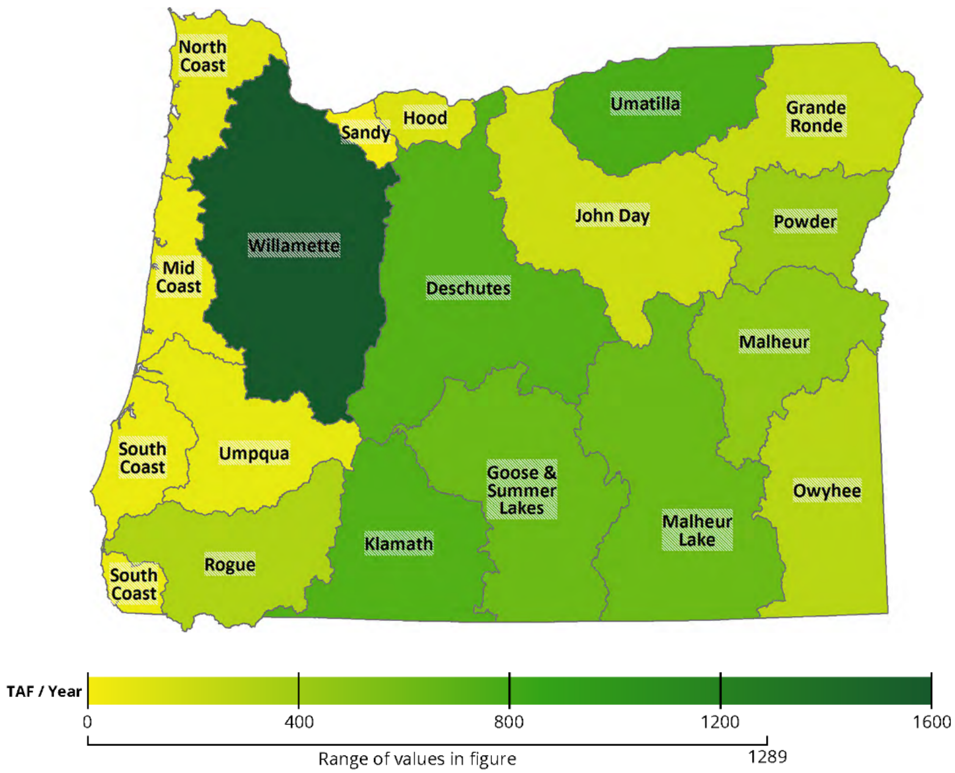


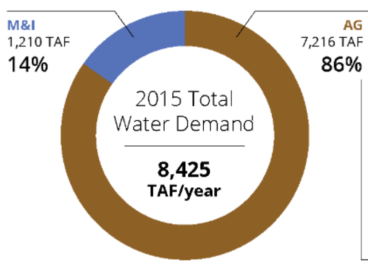
Municipal & Industrial (M&I); Agriculture (AG)

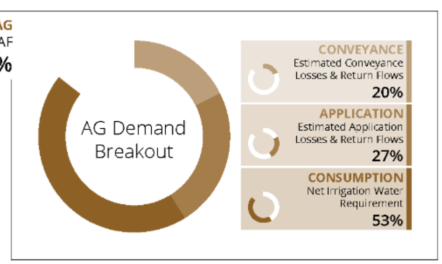
County	2050 M&I (TAF/yr)	2050 AG Hotter-Drier (TAF/yr)	2050 Total (TAF/yr)	Change from 2015 (TAF/yr; %)	
Klamath	24.4	1,026.3	1,050.7	158.8	18%
Harney	6.5	952.4	958.9	117.0	14%
Lake	3.1	944.5	947.6	152.8	19%
Malheur	14.9	904.3	919.2	83.2	10%
Morrow	8.7	576.5	585.2	40.7	7%
Baker	7.6	549.9	557.5	69.1	14%
Umatilla	46.0	416.6	462.6	42.8	10%
Crook	10.6	389.4	398.7	54.5	16%
Jackson	57.8	316.9	374.7	33.8	10%
Marion	97.1	244.5	341.6	52.1	18%
Deschutes	91.9	184.1	276.0	51.3	23%
Multnomah	223.6	19.0	242.6	34.1	16%
Jefferson	7.4	231.9	239.3	25.1	12%
Washington	166.8	57.2	224.0	63.0	39%
Clackamas	124.6	93.2	217.8	42.1	24%
Lane	157.4	56.4	213.8	26.6	14%
Union	16.0	176.2	192.2	23.1	14%
Grant	5.0	185.5	190.5	28.7	18%
Wallowa	4.2	163.4	167.6	33.4	25%
Wasco	20.5	136.9	157.4	18.0	13%
Linn	53.4	86.6	140.0	19.6	16%
Yamhill	33.5	79.9	113.4	22.3	24%
Douglas	36.1	77.0	113.1	13.6	14%
Hood River	16.0	59.4	75.4	10.8	17%
Polk	18.4	55.0	73.4	14.1	24%
Josephine	26.6	45.7	72.3	9.4	15%
Columbia	54.9	8.7	63.6	5.2	9%
Benton	21.7	33.2	54.9	7.0	15%
Coos	30.5	20.2	50.7	2.2	4%
Clatsop	47.3	2.2	49.5	1.3	3%
Wheeler	0.2	47.7	47.9	2.5	6%
Gilliam	1.6	41.7	43.3	2.8	7%
Tillamook	9.1	24.4	33.5	3.4	11%
Lincoln	17.6	0.9	18.5	1.0	5%
Sherman	1.0	14.3	15.3	1.3	9%
Curry	4.0	6.2	10.2	1.0	11%
TOTAL	1,465	8,228	9,693	1,268	15%

Figure 1.4. Future Diversion Demand by County

2015 | Current Diversion Demand by Administrative Basin







Municipal & Industrial (M&I); Agriculture (AG)

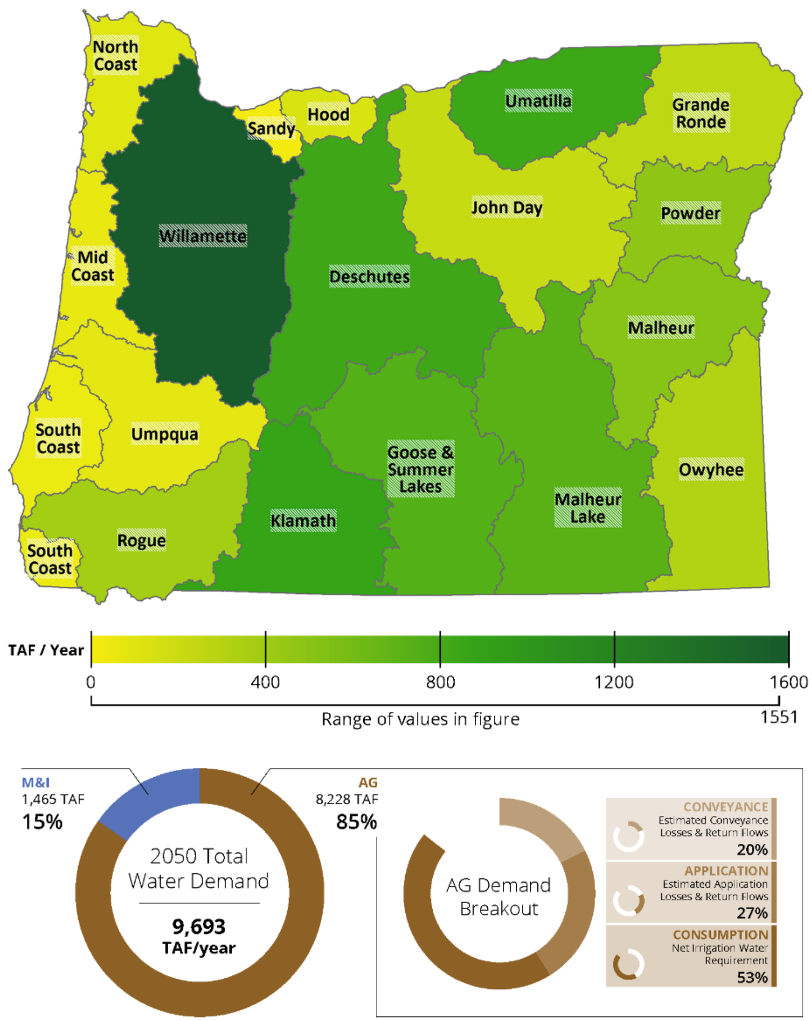
Administrative Basin	2015 M&I (TAF/yr)	2015 AG (TAF/yr)	2015 Total (TAF/yr)
Willamette	683.6	605.7	1,289.3
Umatilla	45.5	918.6	964.1
Klamath	22.4	894.1	916.5
Deschutes	86.3	809.7	896.0
Malheur Lake	20.1	756.9	777.0
Goose & Summer Lakes	1.9	769.0	770.9
Malheur	14.3	549.8	564.1
Powder	10.2	494.3	504.5
Rogue	68.9	334.7	403.6
Owyhee	0.6	348.8	349.4
Grande Ronde	10.9	263.0	273.9
John Day	9.8	218.0	227.8
Hood	22.5	117.0	139.5
North Coast	84.6	29.4	114.0
Umpqua	28.9	65.1	94.0
Mid Coast	54.7	8.0	62.7
South Coast	35.4	25.4	60.8
Sandy	9.4	8.0	17.4
TOTAL	1,210	3,810	5,020

Figure 1.5. Current Diversion Demand by Administrative Basin

2015 Water Demand Forecast

2050 | Future Diversion Demand by Administrative Basin

HOTTER-DRIER



Municipal & Industrial (M&I); Agriculture (AG)

Administrative Basin	2050 M&I (TAF/yr)	2050 AG Hotter-Drier (TAF/yr)	2050 Total (TAF/yr)	Change from 2015 (TAF/yr; %)	
Willamette	842.2	708.4	1,550.6	261.3	20%
Klamath	25.0	1,055.7	1,080.7	164.1	18%
Umatilla	53.9	994.2	1,048.1	84.1	9%
Deschutes	116.9	921.6	1,038.5	142.5	16%
Goose & Summer Lakes	1.9	913.9	915.8	144.9	19%
Malheur Lake	24.3	864.9	889.2	112.2	14%
Malheur	16.5	608.7	625.2	61.2	11%
Powder	10.2	565.2	575.4	70.9	14%
Rogue	91.7	359.6	451.3	47.7	12%
Owyhee	0.8	383.9	384.7	35.3	10%
Grande Ronde	11.1	315.0	326.1	52.2	19%
John Day	13.0	247.3	260.3	32.5	14%
Hood	23.0	134.5	157.5	18.0	13%
North Coast	86.7	34.7	121.4	7.4	6%
Umpqua	33.2	73.5	106.7	12.7	14%
Mid Coast	67.6	9.2	76.8	14.0	22%
South Coast	35.4	28.0	63.4	2.6	4%
Sandy	11.4	9.7	21.1	3.7	21%
TOTAL	**1,465**	**4,345**	**5,809**	**1,268**	**15%**

Figure 1.6. Future Diversion Demand by Administrative Basin

This page left blank intentionally.

CHAPTER 2

AGRICULTURAL WATER DEMAND FORECAST

Agricultural water use varies widely across Oregon, but as a category, it accounts for the largest volume of water demand in the state. As explained in the Introduction, the agricultural demand forecast is presented using the five scenarios representing different future climate conditions (e.g., Hotter-Drier). These five scenarios bracket the scientific range of uncertainties in the future climate, and readers are encouraged to treat each scenario as an equally possible future condition.

This chapter presents a summary of current and future agricultural water demands in Oregon, followed by a description of the methodology and information that was used in conducting demand estimates. Agricultural water demands in this chapter are reported in terms of NIWR, which is the portion of a crop's water consumption that is met through irrigation as opposed to precipitation. A summary definition of the NIWR is provided in the Introduction to this report, and a detailed discussion is provided in Appendix C.

Summary of Agricultural Demands

While several factors influence demands for agricultural water, projected changes in Oregon's climate alone are expected to have a significant effect on agricultural water demands throughout the state by 2050. Climate simulations for Oregon project an increase from 1970-1999 to 2041-2070 of average annual temperatures of between 2.0 to 8.5 degrees Fahrenheit. Annual precipitation within the same period is projected to change by -5 to +14 percent. Summer rainfall is projected by many models to decrease by as much as 34 percent (Mote et. al. 2013).

These projected climate changes are expected to alter crop water needs and may influence crop selection. Increases in agricultural water demands are expected for all counties by 2050. Figure 2.1 presents a comparison of current and future county-level water demands on a common scale.

Key Findings for Agricultural Water Demands

Changes in agricultural demands are expected to vary across Oregon, based on differences in total acreages of crops, crop blends, and the extent to which the climate is expected to change in each county. As an average, statewide demand for irrigation water is expected to increase from 7 to 14 percent. Counties with the largest quantity of irrigated acreages may experience the largest increase in agricultural water demand by 2050. The five counties with the **highest volumetric increase** in agricultural demand account for 45 percent of the current irrigated acreage in Oregon, and are:

> (1) Klamath, (2) Lake, (3) Harney, (4) Malheur, and (5) Baker.

Future crop water demands are expected to increase and further diverge from the timing of precipitation, resulting in a statewide increasing reliance on irrigation by 1 to 4 percent. Regions that have relied more heavily on precipitation to meet crop consumptive demands are forecasted to experience a larger relative increase in water demand than the statewide average. The Mid-Coast, Willamette, and Sandy Administrative Basins all experience increases in agricultural water demand by more than 20 percent, driven by reductions in the amount that precipitation may meet crop demands. The counties with the **highest increase in percent** of agricultural water demand by 2050 (relative to 2015) are:

> (1) Clatsop, 49 percent; (2) Columbia, 27 percent; (3) Wallowa, 26 percent; (4) Multnomah, 22 percent; and (5) Clackamas, 20 percent.

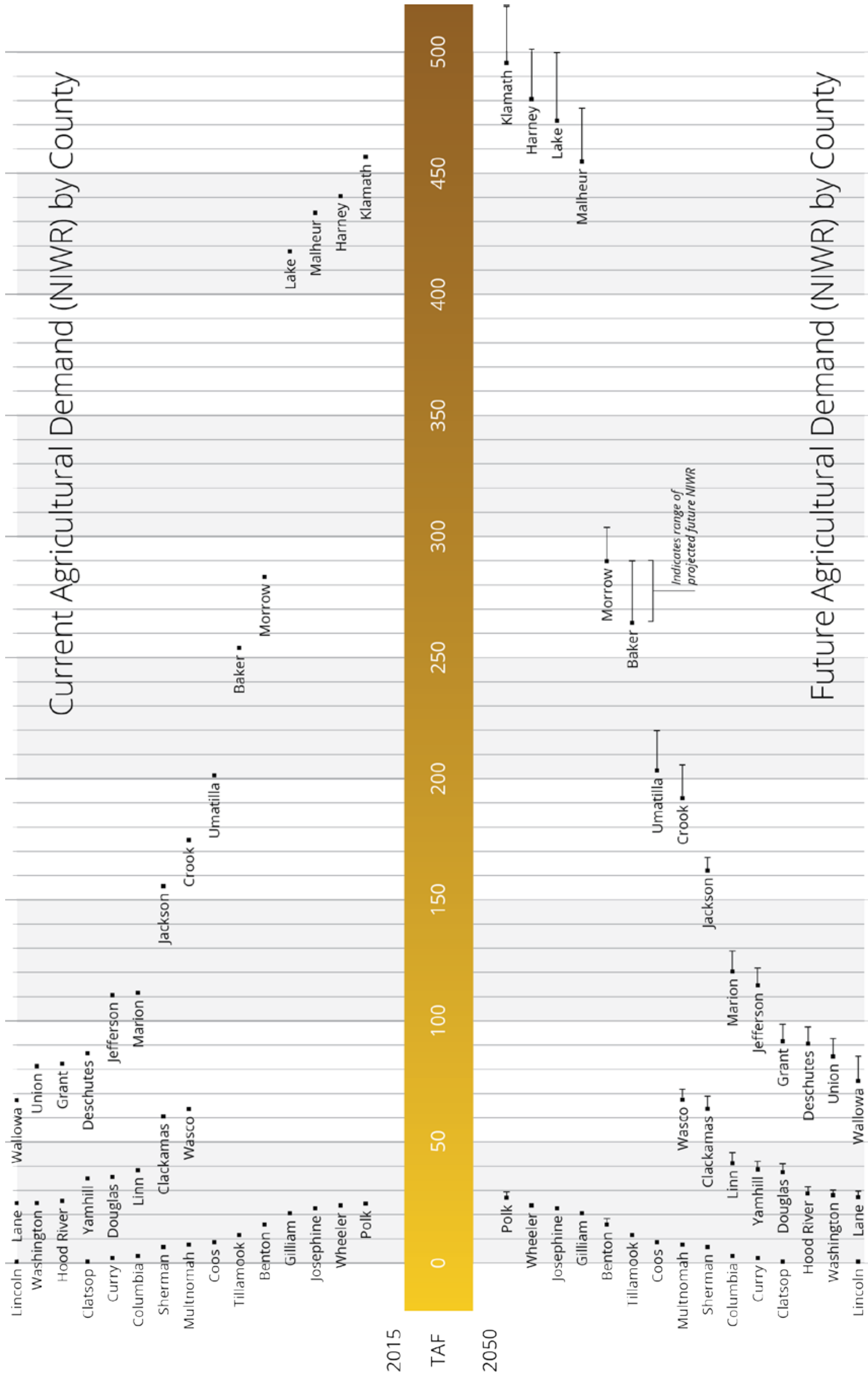


Figure 2.1. Comparison of Current and Future Agricultural Water Demand (NIWR) by County

Important Assumptions in Estimating Agricultural Water NIWR

- County crop acreages and the blend of crops within each county are held constant between current (2015) and future (2050) conditions.
- Reported water diversion demands are based on a calculation of NIWR, which assumes that crops are maintained in well-watered conditions. NIWR has not been limited by the availability of water supplies.
- Stockwater demands, which accounted for 0.5 percent of the statewide agricultural water demand in the 2008 Water Demand Forecast, were not considered in this report.

Agricultural Water Demands by County and Administrative Basin

This report includes five scenarios for describing the potential range of future agricultural water demands. In order to present this information in a consolidated manner and to assist with the visualization of where changes are occurring, future agricultural water demands are presented in a specialized manner: as a change relative to current (2015) demand. Additionally, the five future scenarios are presented on the same page with a layout that indicates the relative wetness and temperature of the future climate conditions. (See Figure 2.2)

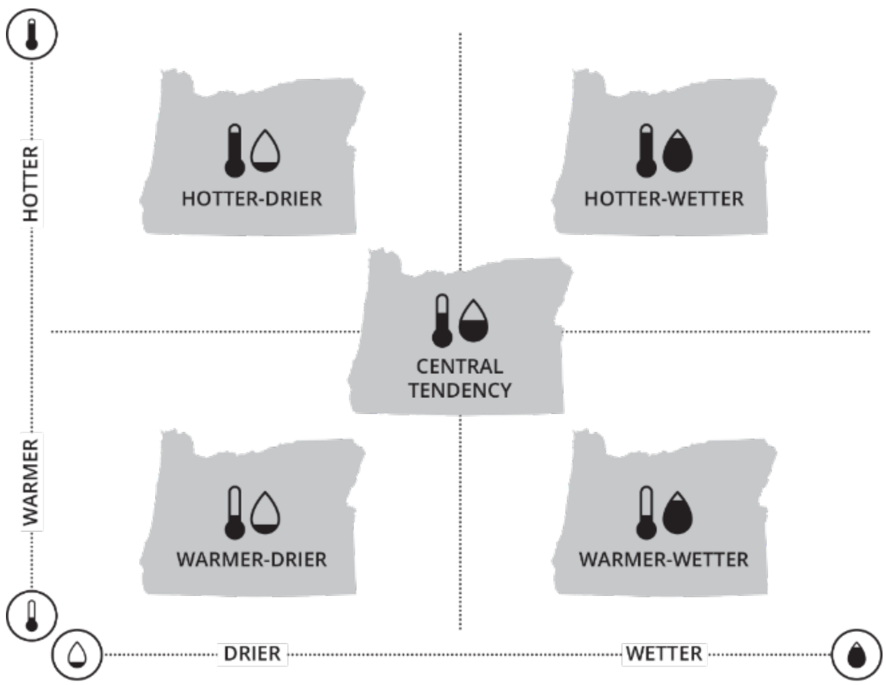
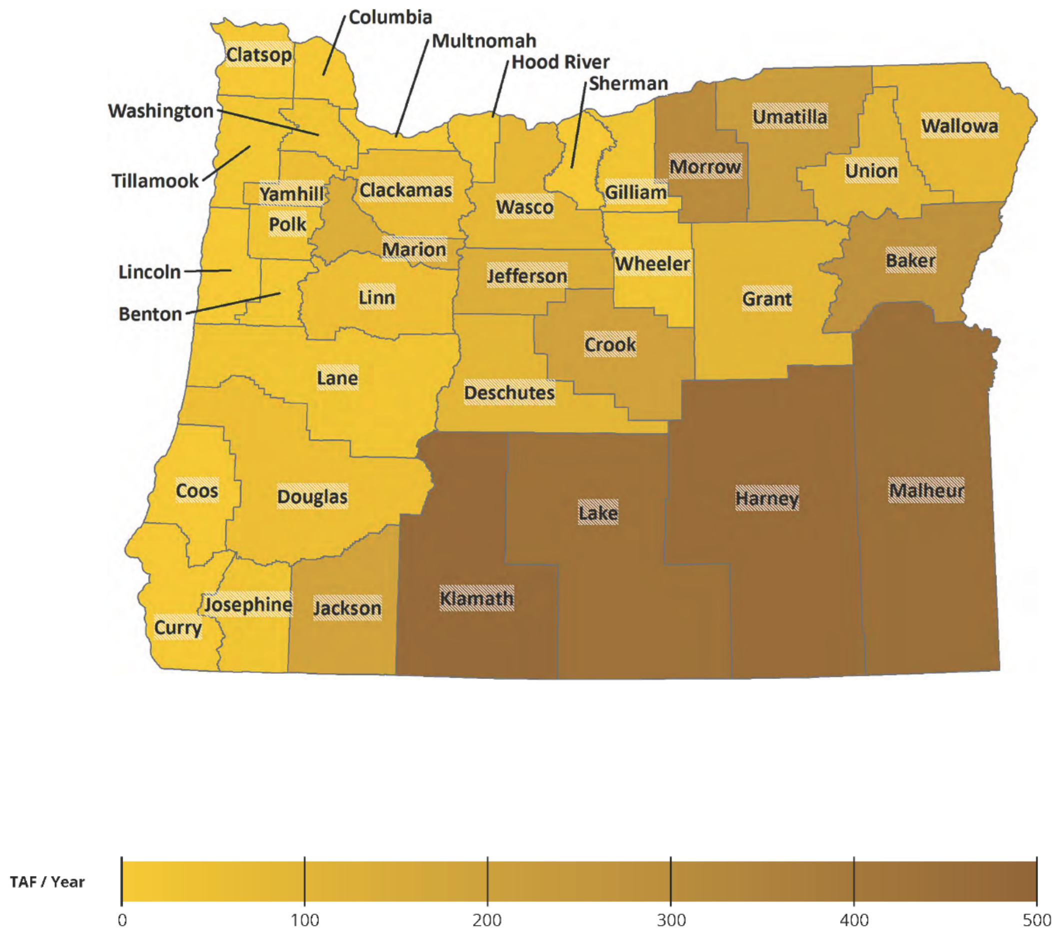


Figure 2.2. Orientation of the Five Future Scenarios for Agricultural Water Demand, Based on Combinations of Future Temperature and Precipitation

The subsequent pages of this chapter include companion figures and tables (Figures 2.3 through 2.6) that display estimates of current agricultural water demand in Oregon by county and by Administrative Basin. Tables describing changes in demand for each of the five scenarios, and for planning horizons at 2020, 2050 and 2080, are provided in Appendices B and G.

2015 | Current Agricultural Demand (NIWR) by County

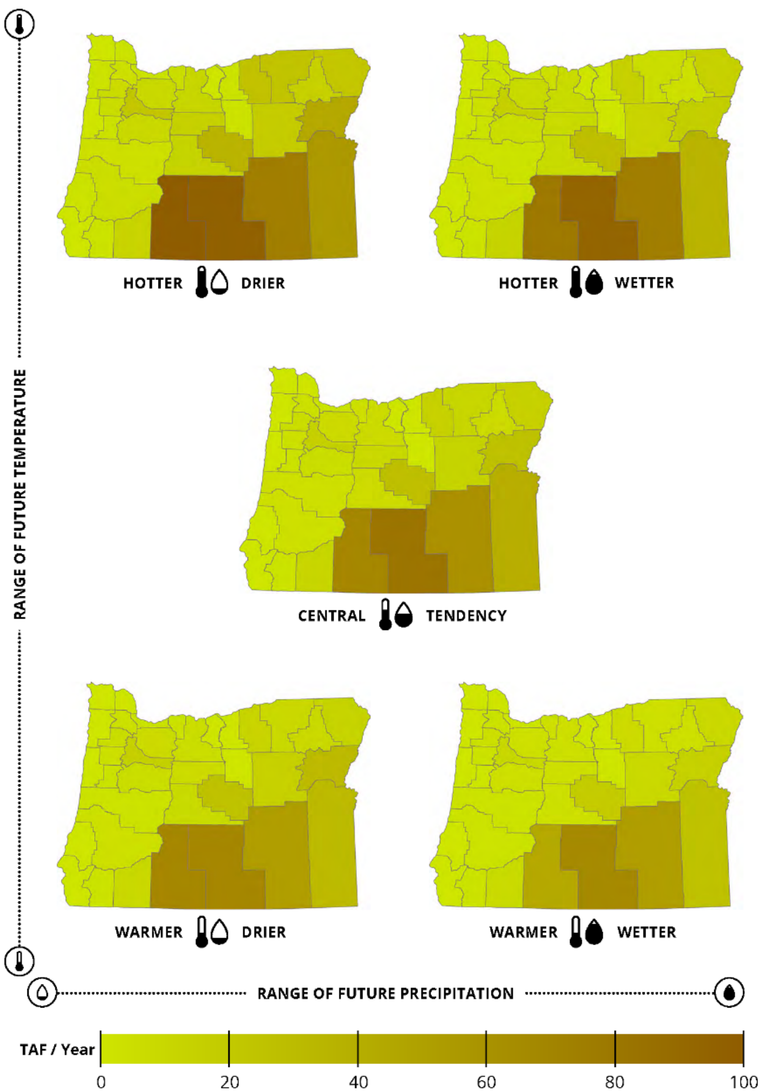


County	Irrigated Acreage	Net Irrigation Water Requirement (TAF/yr)
Klamath	231,680	458.6
Malheur	173,780	433.8
Lake	153,060	418.0
Baker	149,560	253.9
Harney	147,650	441.1
Morrow	133,830	283.4
Umatilla	133,830	201.0
Marion	100,530	111.8
Crook	72,420	177.1
Jackson	56,840	156.8
Jefferson	54,590	110.2
Union	52,400	81.6
Grant	42,870	82.7
Wallowa	41,640	68.6
Deschutes	38,650	87.1
Clackamas	37,490	41.0
Linn	35,840	38.4
Wasco	30,740	63.8
Yamhill	29,510	35.8
Washington	28,500	26.1
Lane	22,230	26.0
Polk	20,180	24.7
Hood River	16,750	26.8
Douglas	14,650	36.0
Tillamook	12,890	11.3
Benton	11,980	15.3
Multnomah	9,520	8.3
Coos	9,070	9.7
Gilliam	8,820	20.6
Wheeler	8,480	23.9
Josephine	7,340	22.0
Columbia	4,210	3.6
Curry	3,140	3.0
Sherman	3,080	6.9
Clatsop	2,090	0.8
Lincoln	870	0.5
TOTAL	**1,900,710**	**3,810**

Figure 2.3. Current Agricultural Demand (NIWR) by County

2050 | Future Increases in Agricultural Demand (NIWR) by County

2015 Water Demand Forecast



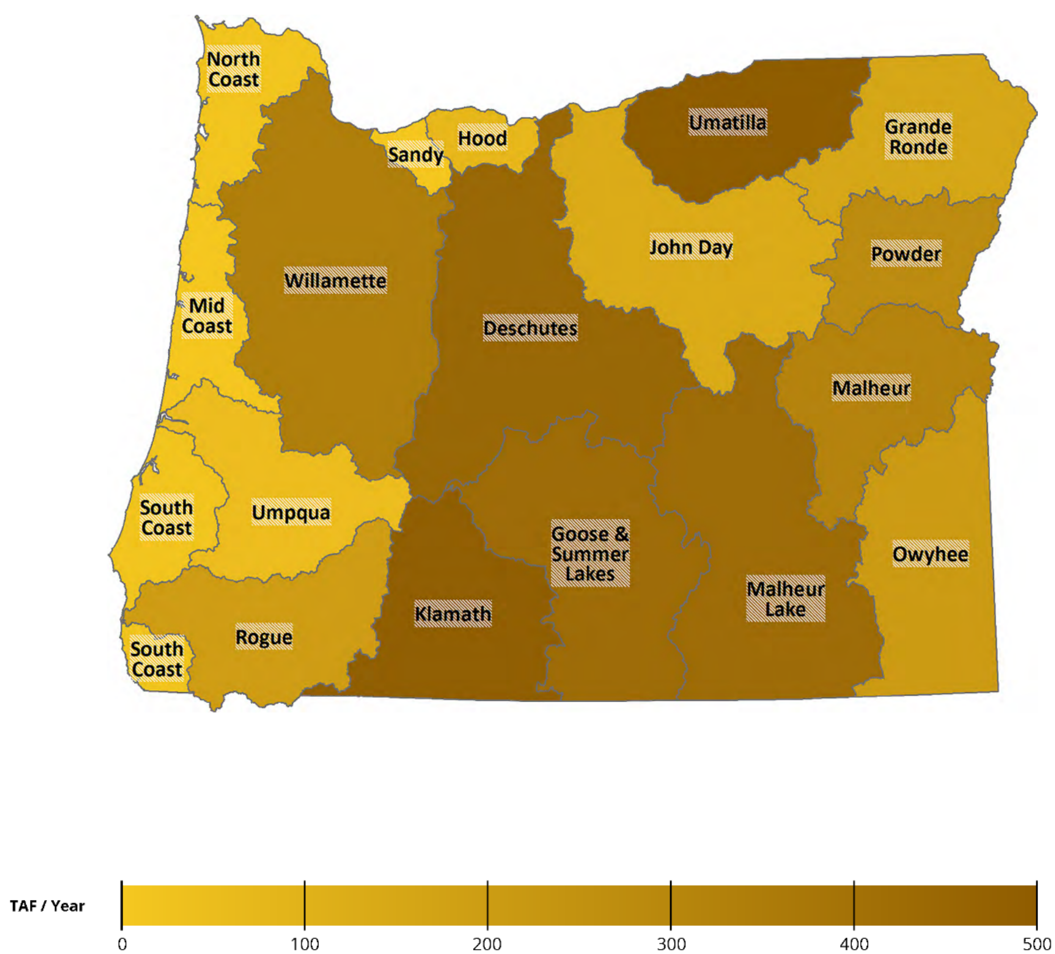
NIWR = Net Irrigation Water Requirement

County	Irrigated Acreage	PROJECTED CHANGES IN NIWR BY 2050 (TAF/yr): Central Tendency	Hotter Wetter	Hotter Drier	Warmer Drier	Warmer Wetter
Klamath	231,680	56.4	65.8	83.3	56.8	35.3
Malheur	173,780	30.2	29.3	43.6	24.7	19.8
Lake	153,060	69.6	79.3	80.8	56.5	54.1
Baker	149,560	20.4	13.3	36.5	24.9	11.2
Harney	147,650	50.1	62.7	61.8	40.0	40.9
Morrow	133,830	12.1	12.0	21.0	10.8	6.4
Umatilla	133,830	8.7	4.9	19.0	8.1	2.6
Marion	100,530	12.1	11.4	17.3	11.2	7.8
Crook	72,420	21.4	21.4	28.5	19.7	14.8
Jackson	56,840	8.7	9.7	10.5	8.0	5.6
Jefferson	54,590	7.1	5.5	12.2	6.2	4.0
Union	52,400	6.0	3.8	11.4	7.8	3.1
Grant	42,870	10.0	10.5	15.2	11.2	8.2
Wallowa	41,640	11.6	12.6	17.7	10.0	7.4
Deschutes	38,650	6.3	5.7	10.1	5.9	2.9
Clackamas	37,490	6.5	5.8	8.2	6.0	3.5
Linn	35,840	4.6	4.7	7.3	4.8	3.1
Wasco	30,740	6.0	5.8	8.5	5.0	4.1
Yamhill	29,510	4.8	4.6	6.4	4.3	3.4
Washington	28,500	2.7	1.9	4.1	2.7	2.0
Lane	22,230	2.6	2.3	3.8	2.2	1.3
Polk	20,180	3.0	3.0	4.3	2.7	2.1
Hood River	16,750	3.5	4.2	4.6	2.5	2.8
Douglas	14,650	3.8	3.9	4.7	3.3	2.2
Tillamook	12,890	0.4	0.6	1.6	0.5	0.3
Benton	11,980	1.4	1.3	2.2	1.1	0.6
Multnomah	9,520	1.0	0.9	1.8	1.2	0.8
Coos	9,070	0.4	0.4	1.0	0.4	0.0
Gilliam	8,820	0.6	0.7	1.4	0.6	0.2
Wheeler	8,480	0.5	0.2	1.3	0.7	0.4
Josephine	7,340	1.8	2.0	2.1	1.6	1.2
Columbia	4,210	0.6	0.6	1.0	0.6	0.4
Curry	3,140	0.1	0.1	0.3	0.1	0.0
Sherman	3,080	0.5	0.3	0.7	0.4	0.3
Clatsop	2,090	0.2	0.2	0.4	0.3	0.2
Lincoln	870	0.0	0.0	0.0	0.0	0.0
TOTAL	**1,900,710**	**376**	**391**	**535**	**343**	**253**

Figure 2.4. Future Increases in Agricultural Demand (NIWR) by County

2015 | Current Agricultural Demand (NIWR) by Administrative Basin

2015 Water Demand Forecast



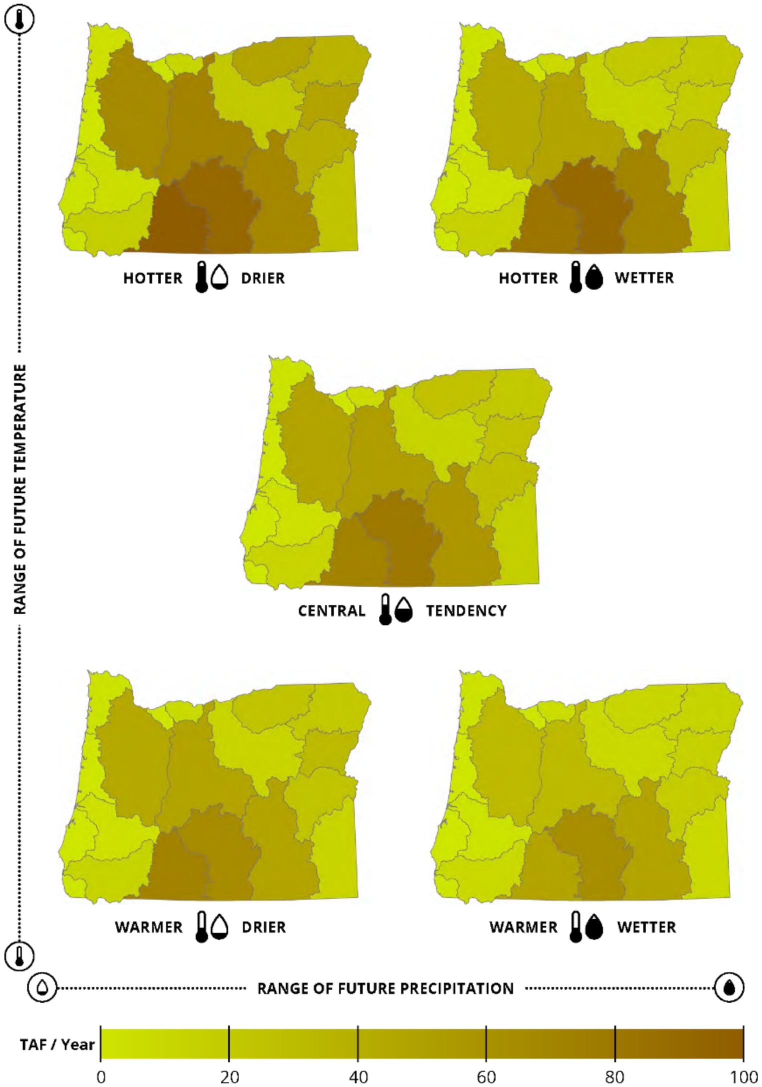
NIWR = Net Irrigation Water Requirement

Administrative Basin	Irrigated Acreage	Net Irrigation Water Requirement (TAF/yr)
Willamette	288,611	319.8
Umatilla	267,609	485.0
Klamath	232,242	472.1
Deschutes	191,685	427.5
Powder	154,299	261.0
Goose & Summer Lakes	148,486	406.0
Malheur Lake	135,668	399.6
Malheur	115,964	290.3
Grande Ronde	86,745	138.9
Owyhee	73,781	184.2
Rogue	64,604	176.7
John Day	53,936	115.1
Hood	33,578	61.8
North Coast	18,817	15.5
Umpqua	14,055	34.4
South Coast	12,078	13.4
Sandy	4,549	4.2
Mid Coast	3,965	4.2
TOTAL	**1,900,710**	**3,810**

Figure 2.5. Current Agricultural Demand (NIWR) by Administrative Basin

2050 | Future Increases in Agricultural Demand (NIWR) by Administrative Basin

2015 Water Demand Forecast



Administrative Basin	Irrigated Acreage	PROJECTED CHANGES IN NIWR BY 2050 (TAF/yr) Central Tendency	Hotter Wetter	Hotter Drier	Warmer Drier	Warmer Wetter
Umatilla	267,609	20.8	16.9	39.9	18.9	8.9
Klamath	232,242	59.2	68.8	85.3	58.3	38.0
Deschutes	191,685	40.6	38.7	59.1	37.1	25.5
Goose & Summer Lakes	148,486	65.5	75.0	76.5	53.2	50.9
Malheur Lake	135,668	46.1	57.3	57.0	37.2	37.6
Willamette	288,611	37.8	35.2	54.2	35.4	23.9
Malheur	115,964	21.9	22.2	31.1	18.3	15.0
Powder	154,299	20.8	13.6	37.4	25.6	11.5
Owyhee	73,781	12.8	12.4	18.5	10.5	8.4
Rogue	64,604	10.7	11.9	13.2	9.8	6.9
Grande Ronde	86,745	16.7	15.9	27.5	16.8	10.1
John Day	53,936	9.5	9.6	15.5	10.6	7.5
Hood	33,578	6.8	7.3	9.3	5.3	5.0
Umpqua	14,055	3.7	3.8	4.4	3.2	2.1
North Coast	18,817	1.1	1.3	2.8	1.2	0.9
South Coast	12,078	0.6	0.6	1.4	0.6	0.1
Mid Coast	3,965	0.4	0.3	0.6	0.3	0.2
Sandy	4,549	0.6	0.5	0.9	0.6	0.4
TOTAL	**1,900,673**	**376**	**391**	**535**	**343**	**253**

Figure 2.6. Future Increases in Agricultural Demand (NIWR) by Administrative Basin

Important Factors Contributing to Increases in Future NIWR

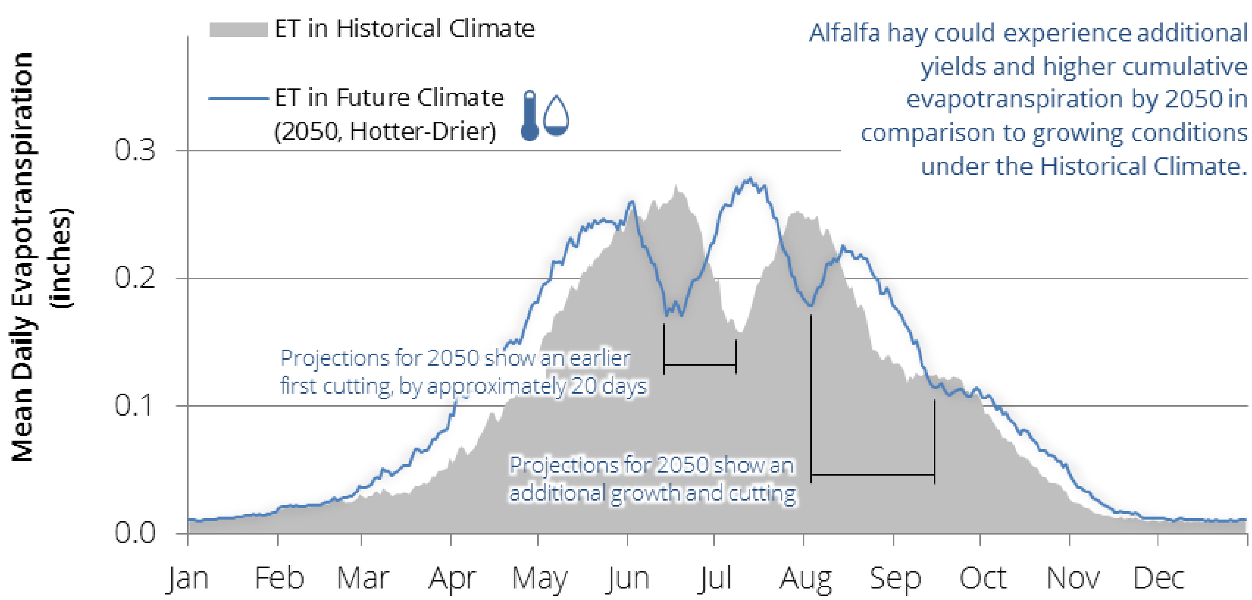
Climate change is expected to increase the demand for irrigation water (NIWR) for several reasons, including:

1. An earlier "spring" and a prolonged growing season that may increase the annual crop water consumption for perennial crops;

2. Greater daily crop water consumption (i.e., higher evapotranspiration) due to higher temperatures, which affects all crops;

3. Increases in crop water demand are expected to outpace the ability of crops to take advantage of natural precipitation. As a result, most locations may experience growth in the NIWR by a larger percentage than the forecasted increases in crop water demand, even for future climate conditions that are considered "wetter."

Figure 2.7 depicts the effects of projected climate changes (Hotter-Drier scenario) on alfalfa hay in in the Klamath River basin, based on data from the Klamath Falls meteorological station. By 2050, the growing season for several perennial crops could begin several weeks earlier, resulting in earlier harvests for crops like alfalfa in comparison to the historical climate. For crops with multiple harvests in a year, an earlier beginning to the growing season can increase the duration of the growing season, potentially resulting in additional yields, but requiring larger volumes of water to sustain the crops for the longer duration.

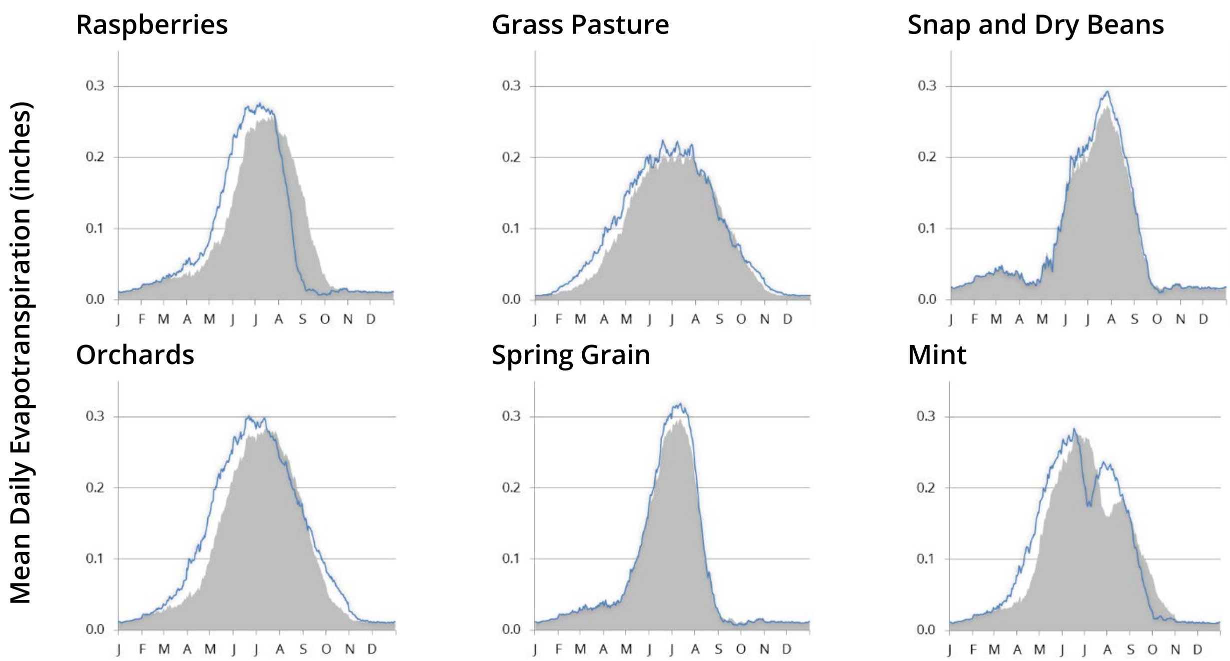


Source: *Huntington et al. 2015*

Figure 2.7. Historical and Future Mean Daily Evaporation (ET) for Alfalfa Hay in the Klamath River Basin (Klamath Falls Station)

Annual crops are projected to experience larger daily evapotranspiration rates that result in larger annual water requirements. Figure 2.8 depicts the effects of projected climate changes (Hotter-Drier scenario) on a selection of annual and perennial crops in the Klamath River basin, based on data from the Klamath Falls meteorological station. Perennial crops (e.g., orchards and mint) to have an earlier green-up, prolonged growing seasons, and additional harvests similar to alfalfa. Annual crops (e.g., Spring Grain, Potatoes) demonstrate higher daily water consumption.

Appendix C describes the methods used to calculate crop consumptive demands (including NIWR) for this study. Appendix G includes the data for crop water demand projections used in this study.



Source: *Huntington et al. 2015*

Figure 2.8. Historical and Future Mean Daily Evaporation (ET) for Selected Crops in the Klamath River Basin (Klamath Falls Station)

Changes in the climate can affect irrigation demands in a complex manner. Increases in temperatures are expected to increase total crop water demands, but increases in precipitation are not necessarily equivalent to projected increases in NIWR. As illustrated in Figure 2.9, current rainfall (i.e., effective precipitation) meets 30 percent of the current crop consumptive demand in Oregon, the balance being met with NIWR.

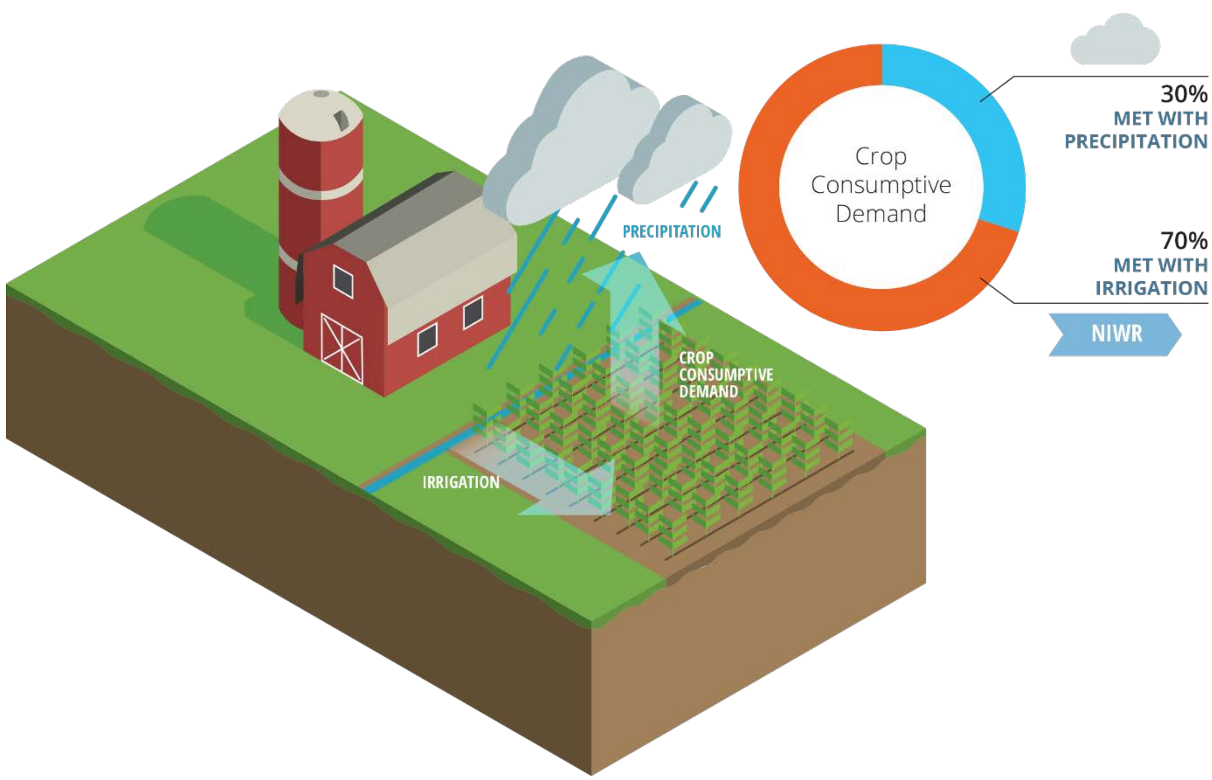


Figure 2.9. Statewide Average Contributions of Precipitation and NIWR to Crop Consumptive Demand, Current Demand

Even for future scenarios that are wetter than the historical climate, the increases in precipitation may not align with geography or timing of crop water needs. Additionally, future precipitation conditions may look different, including changes in the frequency, magnitude, and seasonality of storms. Changes in these factors may influence the fraction of precipitation that becomes available for meeting crop demands (i.e., effective precipitation). For most locations in Oregon, increases in irrigation demands are projected to be larger than changes in effective precipitation, resulting in statewide average percent increases to NIWR that are larger than the percent increases in crop consumptive demands.

The lopsided increases in NIWR, relative to crop consumptive demand, are largest for regions that have historically relied more heavily on effective precipitation for meeting crop consumptive demands, such as Clatsop County. The following figures break out the manner in which crop consumptive demand, effective precipitation, and NIWR change for alfalfa hay in Clatsop County for the five future climate scenarios. Each of these figures are based on recorded historical and simulated future climate conditions for the meteorological station located at the Astoria Regional Airport (OR0328; Huntington et al. 2015).

Table 2.1 presents the separate components used for calculating NIWR for alfalfa hay in Clatsop County, including precipitation, effective precipitation, ET, and NIWR.

Table 2.1. Components of NIWR Calculation for Alfalfa Hay in Clatsop County (Station OR0328)

Annual Quantities for Alfalfa Hay in Clatsop County	Current Scenario (2015)	Future Climate Scenarios (2050)				
		Central Tendency	Hotter Wetter	Hotter Drier	Warmer Drier	Warmer Wetter
Changes in Precipitation						
Precipitation (mm)	1767	1798	1950	1707	1734	1920
Change from Historical Record	*NA*	*2%*	*10%*	*-3%*	*-2%*	*9%*
Changes in Crop Consumptive Demand						
Evapotranspiration (mm)	607	616	620	618	615	615
Change from Historical Record	*NA*	*2%*	*2%*	*2%*	*1%*	*1%*
Sources of Water for Meeting Crop Demand (millimeters)						
Effective Precipitation (mm)	494	474	482	450	466	480
Net Irrigation Water Requirement (NIWR)	113	142	139	168	149	135
Relative Contributions to Crop Consumptive Demand (percent)						
Effective Precipitation	81%	77%	78%	73%	76%	78%
NIWR	19%	23%	22%	27%	24%	22%
Change in NIWR Contribution, relative to 2015	*NA*	*4%*	*4%*	*9%*	*6%*	*3%*

Source: *Huntington et al. 2015*

Table 2.1 displays the effects of future climate scenarios on both precipitation and effective precipitation for the same scenarios provided. Changes in precipitation range from -2 percent reductions to 10 percent increases. By contract, effective precipitation (the amount of precipitation that falls, infiltrates, and is consumed by crops) is projected to decrease under all future climate scenarios. The NIWR is calculated as the remaining portion of crop consumptive, not met by effective precipitation. As shown in Table 2.1, the increase in NIWR is higher than the increase in crop consumptive demand for each scenario.

The concepts demonstrated for alfalfa hay in Clatsop County manifest across Oregon, as illustrated in Figure 2.10. Projected increases in statewide NIWR (between 7 and 14 percent) are higher than projected increases in crop consumptive demands (between 6 and 9 percent). For Central Tendency, Hotter-Wetter, and Warmer-Wetter conditions, all of which are considered wetter than the historical climate, the percent increase in NIWR (10, 10, and 7 percent, respectively) is larger than the corresponding increases in crop consumptive demand (7, 9, and 6 percent, respectively).

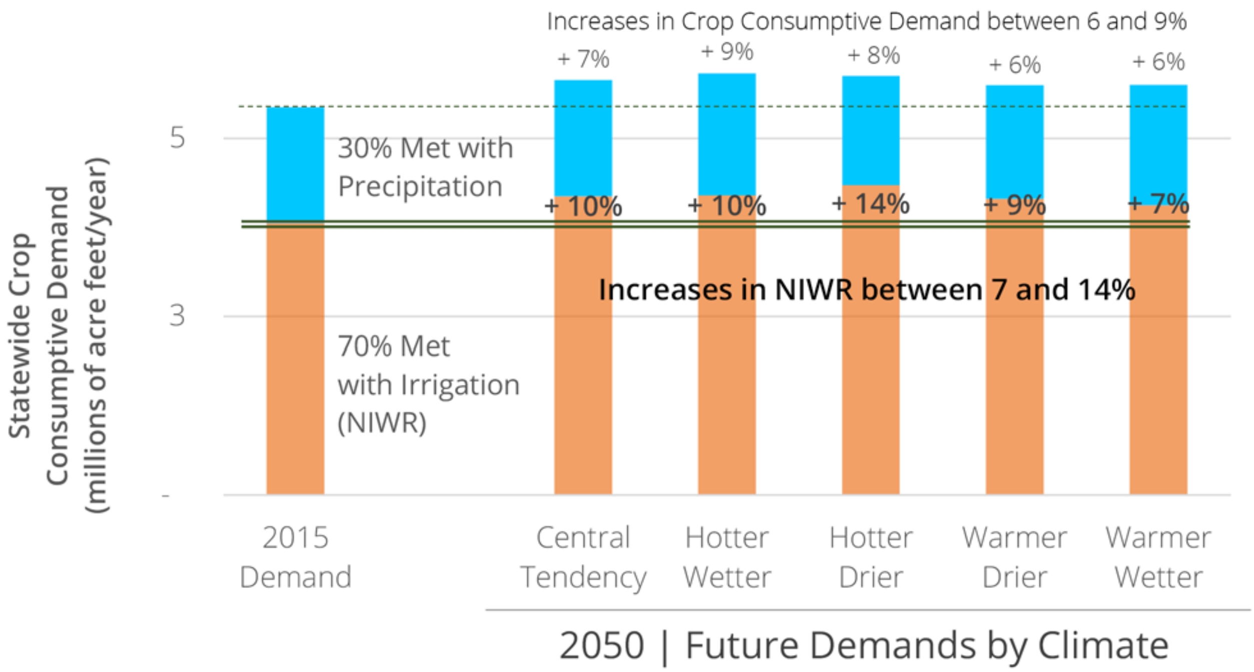


Figure 2.10. Forecasted Changes in NIWR by Climate Scenario

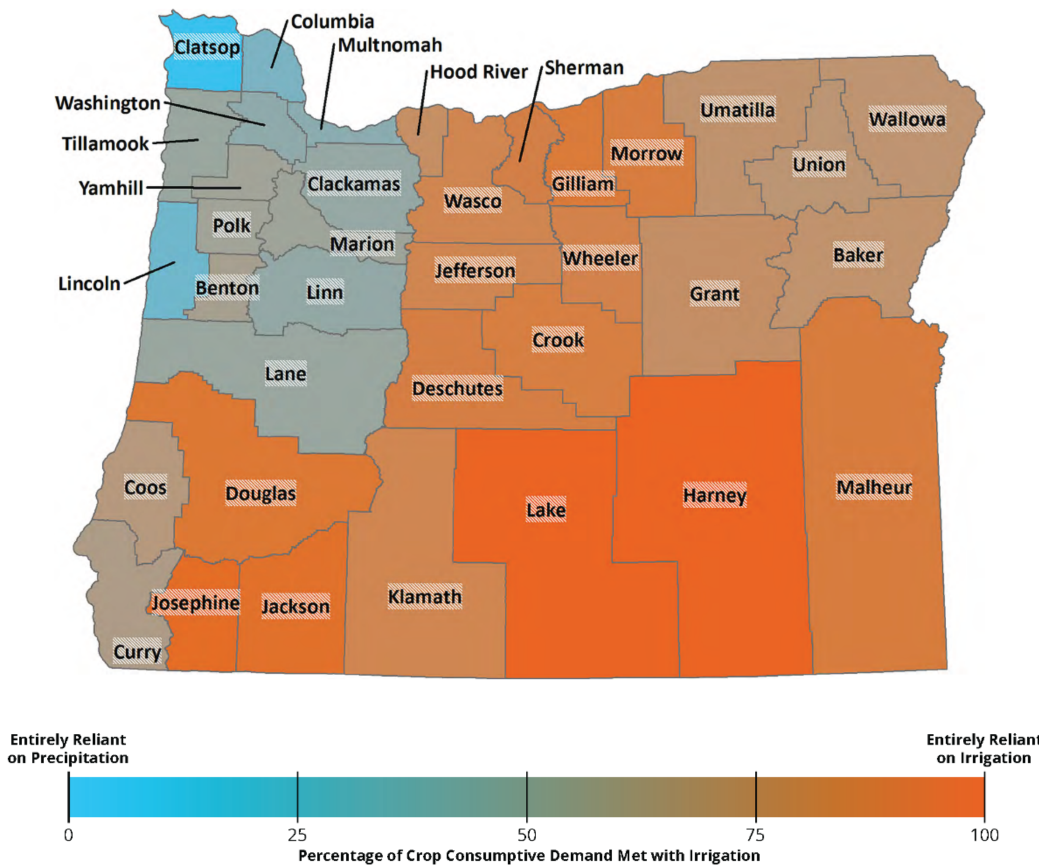
The subsequent figures display the extent to which each of Oregon's counties are reliant on irrigation (NIWR) under the historical climate (Figure 2.11), and how this reliance is anticipated to change under each of the five future climate scenarios (Figure 2.12). For example, Figure 2.11 shows that Clatsop County agriculture is 19 percent dependent upon NIWR (and therefore 81 percent reliant on precipitation). Figure 2.12 indicates that, for the Hotter-Drier scenario, Clatsop County may be 9 percent more reliant on irrigation (meaning that 28 percent of crop consumptive demand would need to be met by NIWR).

Should the timing, form, or quantity of precipitation change in the future, coastal areas and the Willamette Valley – shaded in blue and gray in Figure 2.11 – may need to develop additional supplies to meet their needs.

Increases in reliance on irrigation are most visible and most pronounced for counties with, historically, the highest overall reliance on precipitation. These counties, which are ranked toward the bottom of tables in Figures 2.11 and 2.12, have the highest percentage increases in all future climate scenarios. The Hotter-Drier scenario highlights this sensitivity.

2015 | Current Agricultural Reliance on Irrigation Demand

2015 Water Demand Forecast

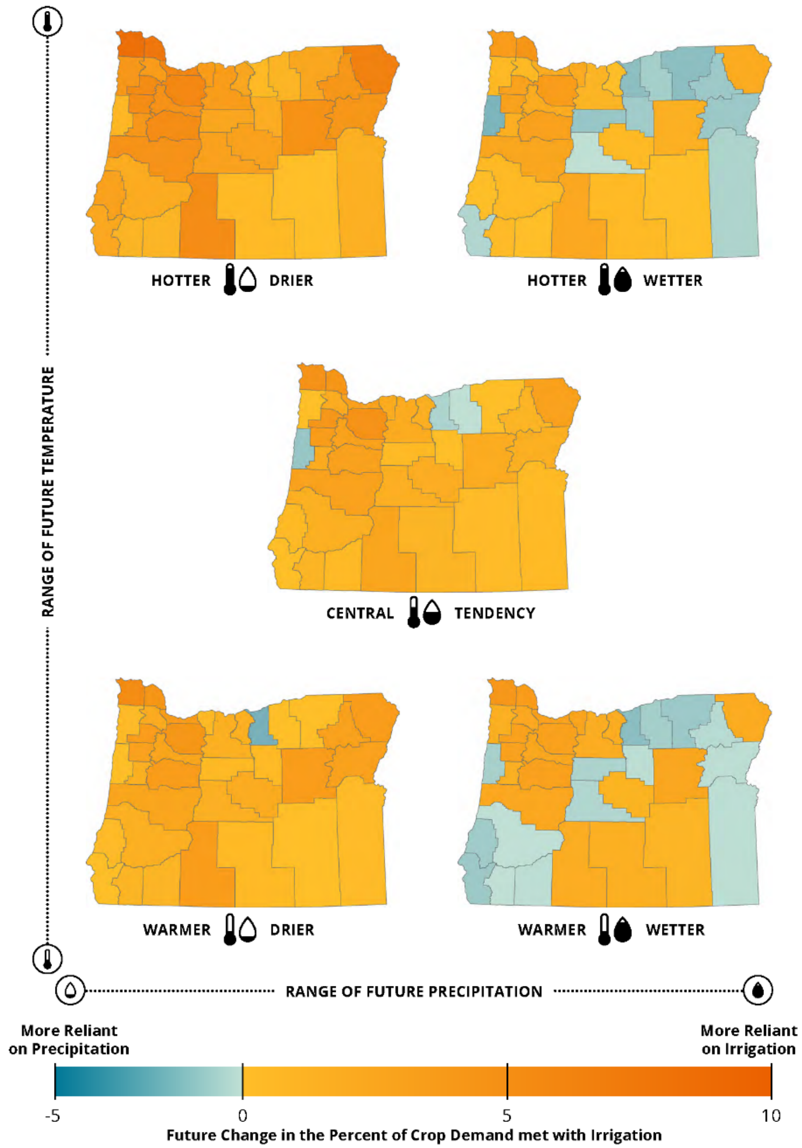


County	Irrigated Acreage	Percent of Crop Consumptive Demand met with Irrigation
Harney	147,650	95%
Lake	153,060	94%
Josephine	7,340	87%
Jackson	56,840	84%
Douglas	14,650	81%
Gilliam	8,820	78%
Malheur	173,780	77%
Morrow	133,830	76%
Crook	72,420	75%
Deschutes	38,650	75%
Sherman	3,080	73%
Wheeler	8,480	72%
Jefferson	54,590	70%
Wasco	30,740	70%
Klamath	231,680	70%
Hood River	16,750	64%
Grant	42,870	63%
Baker	149,560	60%
Umatilla	133,830	60%
Wallowa	41,640	59%
Union	52,400	58%
Coos	9,070	54%
Curry	3,140	52%
Benton	11,980	48%
Polk	20,180	46%
Yamhill	29,510	46%
Marion	100,530	45%
Tillamook	12,890	44%
Lane	22,230	43%
Clackamas	37,490	42%
Linn	35,840	41%
Washington	28,500	39%
Multnomah	9,520	38%
Columbia	4,210	33%
Lincoln	870	30%
Clatsop	2,090	19%
Statewide	**1,900,710**	**70% -average**

Figure 2.11. Current Agricultural Reliance on Irrigation by County

2050 | Future Change in Percent of Agricultural Reliance on Irrigation

2015 Water Demand Forecast



County	Irrigated Acreage	Central Tendency	Hotter Wetter	Hotter Drier	Warmer Drier	Warmer Wetter
		PROJECTED CHANGES BY 2050				
Harney	147,650	+0%	+0%	+1%	+0%	+0%
Lake	153,060	+1%	+1%	+1%	+1%	+0%
Josephine	7,340	+1%	+0%	+2%	+1%	-0%
Jackson	56,840	+1%	+0%	+2%	+1%	-0%
Douglas	14,650	+2%	+1%	+3%	+2%	-0%
Gilliam	8,820	-1%	-1%	+1%	-0%	-2%
Malheur	173,780	+1%	-1%	+2%	+1%	-0%
Morrow	133,830	-0%	-1%	+2%	+0%	-1%
Crook	72,420	+2%	+1%	+4%	+2%	+0%
Deschutes	38,650	+2%	-0%	+4%	+2%	-1%
Sherman	3,080	+2%	+0%	+3%	+2%	+1%
Wheeler	8,480	+0%	-1%	+2%	+1%	-0%
Jefferson	54,590	+1%	-1%	+3%	+1%	-1%
Wasco	30,740	+2%	+1%	+4%	+2%	+1%
Klamath	231,680	+3%	+2%	+6%	+4%	+1%
Hood River	16,750	+2%	+2%	+4%	+1%	+2%
Grant	42,870	+2%	+2%	+5%	+4%	+2%
Baker	149,560	+1%	-1%	+5%	+3%	-0%
Umatilla	133,830	+0%	-1%	+3%	+1%	-1%
Wallowa	41,640	+3%	+2%	+7%	+4%	+1%
Union	52,400	+1%	-1%	+5%	+3%	-0%
Coos	9,070	+1%	+0%	+3%	+1%	-1%
Curry	3,140	+0%	-0%	+3%	+1%	-1%
Benton	11,980	+2%	+2%	+4%	+2%	+0%
Polk	20,180	+3%	+3%	+6%	+3%	+2%
Yamhill	29,510	+4%	+3%	+6%	+4%	+3%
Marion	100,530	+3%	+2%	+5%	+3%	+2%
Tillamook	12,890	+0%	+1%	+4%	+1%	+0%
Lane	22,230	+3%	+3%	+5%	+3%	+1%
Clackamas	37,490	+5%	+4%	+6%	+4%	+2%
Linn	35,840	+3%	+3%	+6%	+4%	+2%
Washington	28,500	+2%	+1%	+4%	+2%	+1%
Multnomah	9,520	+3%	+2%	+6%	+4%	+2%
Columbia	4,210	+4%	+4%	+8%	+4%	+3%
Lincoln	870	-1%	-2%	+2%	+0%	-1%
Clatsop	2,090	+4%	+4%	+9%	+6%	+3%
Statewide	**1,900,710**	**+2%**	**+1%**	**+4%**	**+2%**	**+1%**

Figure 2.12. Future Changes in Percent of Agricultural Reliance on Irrigation

Crop Water Demand Forecast Methodology

This forecast for agricultural water demand uses:

- Acreages of irrigated agricultural land use by county,
- Distributions of crop types by county, and
- Crop and irrigation water demands (i.e., crop consumptive demands and NIWR), which vary by crop and by future climate.

In order to arrive at a final demand volume (acre feet per year) for each county, the total number of irrigated acres per crop was estimated by dividing the number of irrigated acres by the distribution of types of crops throughout a county. The NIWR for each crop was then multiplied by the crop-weighted area for each county to result in a final volume of crop demand per county. These estimates are based on best available data, though approximations had to be made throughout the process. More information about the methods used in this section can be found below and in Appendix D.

Acreages of Irrigated Agricultural Land Use by County and Administrative Basin

The USGS Oregon Water Use Compilation (2010) was used to quantify irrigated acreages by county for this 2015 Water Demand Forecast. The USGS Oregon Water Use Compilation is compiled on a five-year intervals. Among other sources of information, the USDA Census of Agriculture for 2008 was evaluated by the USGS, as input to the 2010 Oregon Water Use Compilation.

Distribution of Crops by County and Administrative Basin

The USGS Oregon Water Use Compilation ceased reporting acreages of specific crops by county after 2005. As a consequence, this forecast uses other sources to describe the distribution of agricultural land use among various crops, based on percentages. Two estimates for the distribution of types of crops by county were used in this forecast:

- USDA 2012 Census of Agriculture (USDA 2014a)
- USDA Cropland Data Layer (CDL) (USDA 2014b)

The USDA Census of Agriculture was selected for describing the distribution of crops within each county. Largely, this selection was made because the full spatial distribution of CDL was beyond the requirements for estimating agricultural land use and because of errors in the CDL that produced poor results for some counties.

The CDL was used for translating county-based agricultural demands into Administrative Basins (Figure 2.13). This was accomplished by taking the intersection of agricultural land in each county and determining what fraction fell into each of the overlaying Administrative Basins. The results of this are included in Appendix A.

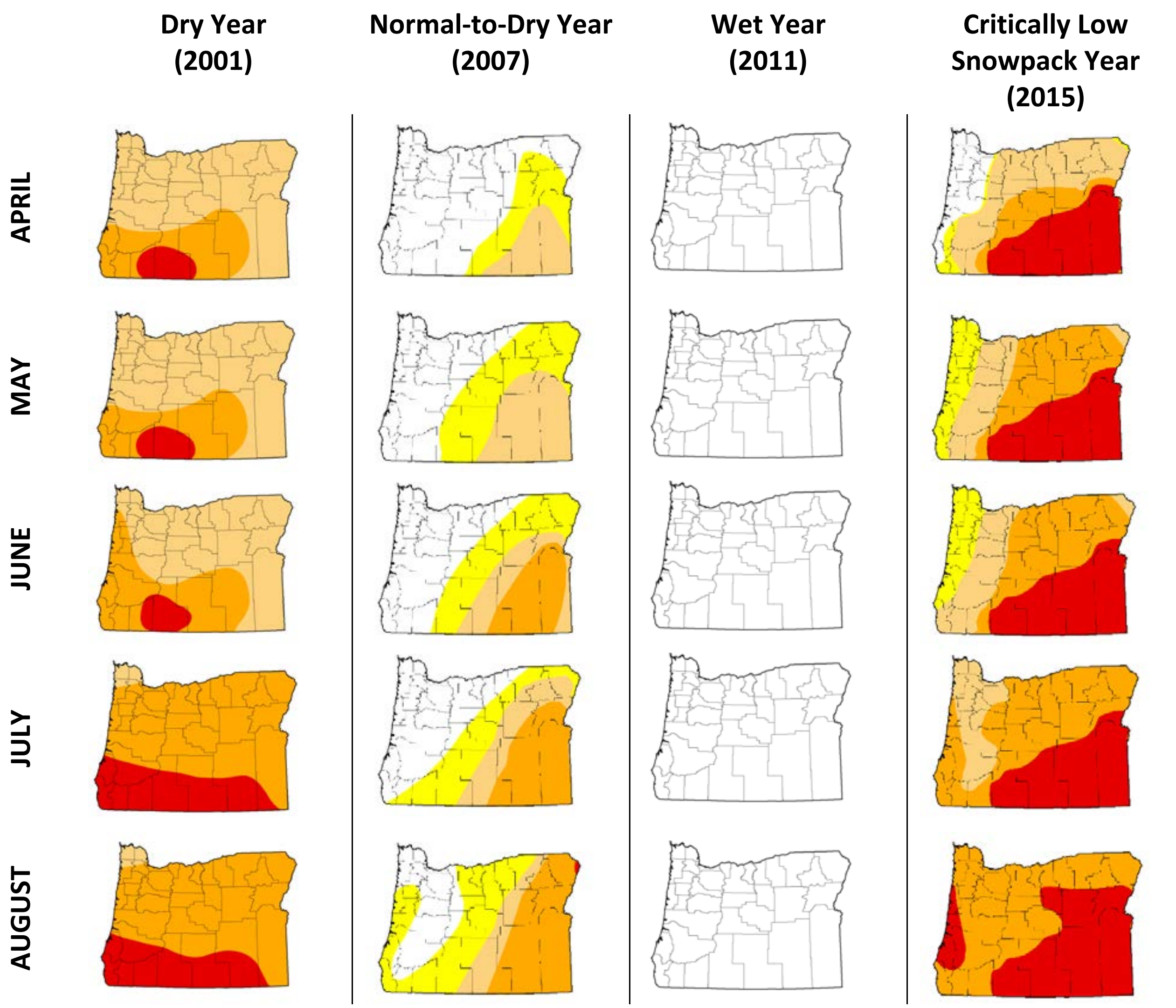
Source: *NAAS Cropland Data Layer (USDA 2014b)*
Notes: *Green shading indicates agricultural land*

Figure 1.13. Oregon's Agricultural Lands, as Detected Through Satellite Imagery

Remaining Uncertainties in the Estimate of Irrigated Acreage and Crop Distribution

The 2008 Water Demand Forecast anticipated a long-term growth in agricultural land use. Both the USGS Oregon Water Use Compilation (2010) and USDA 2012 Census of Agriculture (2014a) indicate a recent decline in irrigated agricultural land in Oregon between 2005 and 2012. Despite this, the previously forecasted increases in agricultural land use may still prove true. Agricultural land use is affected by several factors that vary from year to year, including global demand for crops, the national economy, weather, and water supply availability. Each of these factors affects the acreage of land and selection of crops across Oregon in a different way.

One example of volatility in these factors is the period of national economic downturn in the United States, which occurred during the previous two land use estimates. Another example is depicted in Figure 2.14, which shows, how Oregon's water supply varies across the state during the growing seasons for years with representative dry, wet, and average precipitation. The current year is shown to highlight the variability in conditions that are possible under our current climate regime. The cumulative effect of these factors on long-term agricultural land use was not addressed in this forecast.



Source: United States Drought Monitor (USDA 2015)
Notes: White indicates normal or wet conditions, darker colors indicate increasing severity of drought.

Figure 2.14. Interannual Variability in Water Supply Conditions During the Agricultural Growing Season

Crop and Irrigation Water Demands

This report relies on two methods for estimating current and future NIWR across Oregon:

- The Cuenca estimates (Cuenca 1992), and
- The ETDemands model, which provides more modern techniques for calculating evapotranspiration for historical and projected future climates, and was recently applied for the West-Wide Climate Risk Assessments (Huntington et al. 2015).

WWCRA data were used whenever available; if WWCRA data were not available, the Cuenca estimates were applied. The WWCRA estimates included NIWR for historical climate and the five future climate scenarios used in this forecast. WWCRA estimates of NIWR are available for specific crops at meteorological stations within the Columbia and Klamath river basins. Cuenca estimates of NIWR are available for specific crops in distinct agricultural regions, which are based on areas with generally homogenous climate conditions.

Figure 2.15 displays the counties which use WWCRA data for estimating NIWR (which are associated with the identified meteorological stations), and those which relied on Cuenca estimates. The figure also identifies

WWCRA crop consumptive demand information that is available at other meteorological stations, but which was not applied to the agricultural demand estimate in this forecast.

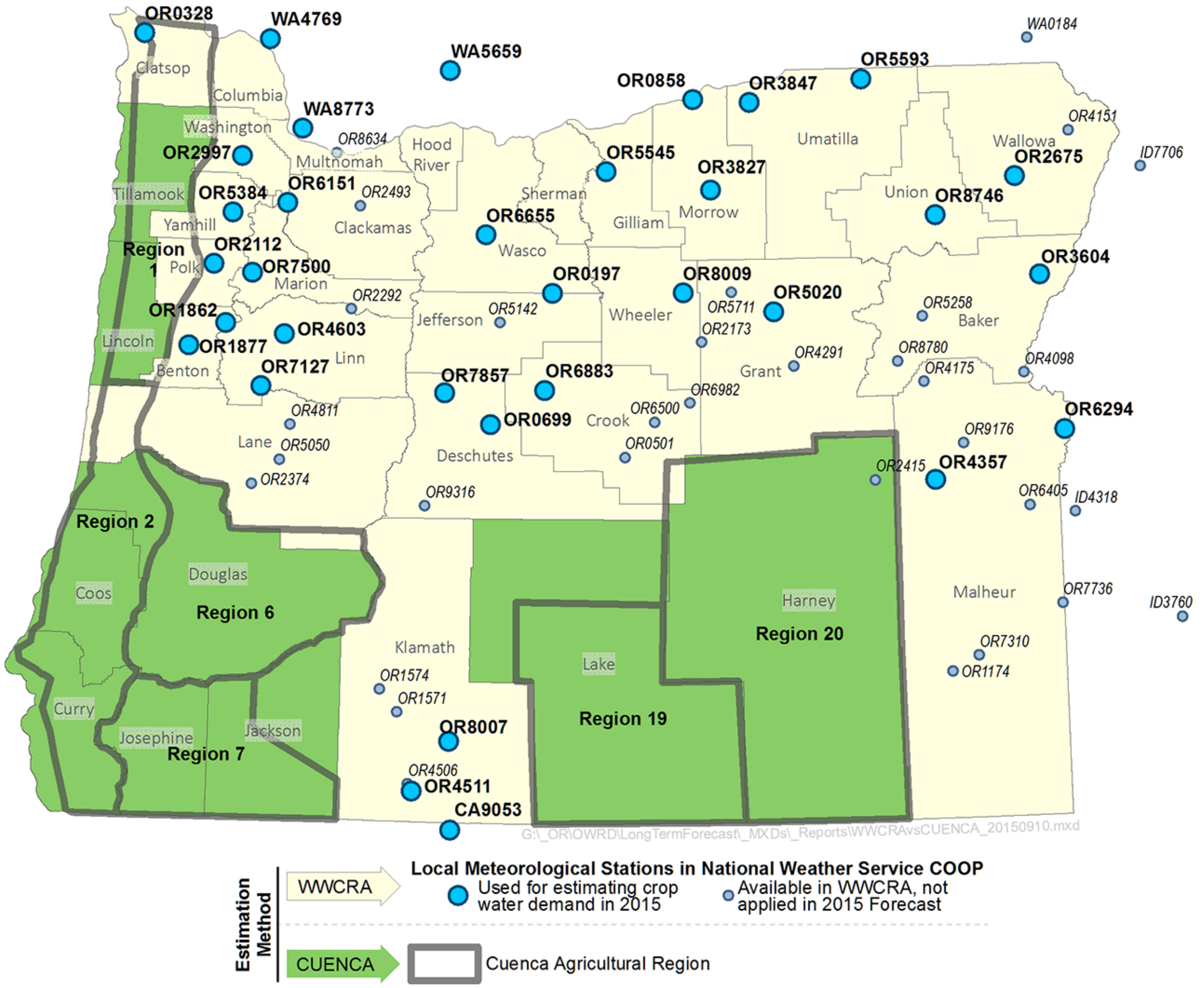


Figure 2.15. Sources of Information Used for Current and Future Crop Water Demand Estimates

As noted earlier, acreages of crops were determined for each county based on the 2010 USGS Oregon Water Use Compilation (total acreages) and the USDA 2012 Census of Agriculture (distributions of crop types). In order to estimate volumes of demand by county, depths of crop demands (i.e., NIWR) were assigned to these acreages. Table 2.2 identifies the meteorological stations or Cuenca Agricultural Regions used to estimate volumes of agricultural demand for each county. Appendix D describes the manner in which crops within each county have been associated with either NIWR estimates from WWCRA or Cuenca crop estimates.

Table 2.2. Sources of Crop Water Demand Estimates, by County

County	Reference Meteorological Station (for WWCRA) or Agricultural Region (from Cuenca)	County	Reference Meteorological Station (for WWCRA) or Agricultural Region (from Cuenca)
Baker	OR8746, OR3604	**Lake**	Cuenca Agricultural Region 19
Benton	OR1862, OR1877, OR5384, OR 2112, WA8773	**Lane**	OR7127, OR4603, OR7500
Clackamas	OR6151, WA8773, OR5384	**Lincoln**	Cuenca Agricultural Region 1
Clatsop	OR0328	**Linn**	OR4603, OR7500, OR5384
Columbia	WA4769	**Malheur**	OR6294, OR4357
Coos	Cuenca Agricultural Region 2	**Marion**	OR7500, OR4603, OR5384, OR2997
Crook	OR6883	**Morrow**	OR7500, OR0858, OR5593
Curry	Cuenca Agricultural Region 2	**Multnomah**	WA8773, OR6151
Deschutes	OR0699	**Polk**	OR2112, OR5384
Douglas	Cuenca Agricultural Region 6	**Sherman**	OR5545, OR0858
Gilliam	OR0858	**Tillamook**	Cuenca Agricultural Region 1
Grant	OR5020	**Umatilla**	OR5593, OR3827, OR0858
Harney	Cuenca Agricultural Region 20	**Union**	OR8746, OR3604
Hood River	WA5659	**Wallowa**	OR2675, OR3604
Jackson	Cuenca Agricultural Region 7	**Wasco**	OR6655, OR0858
Jefferson	OR0197, OR7857	**Washington**	OR2997, WA8773, OR6151
Josephine	Cuenca Agricultural Region 7	**Wheeler**	OR8009
Klamath	OR4511, CA9053, OR8007	**Yamhill**	OR5384, WA8773, OR6151

For counties and crops assigned to WWCRA stations, data were readily available for future agricultural demands at the meteorological stations identified in Figure 2.15. These data are recorded in Appendix G (a database available through OWRD), and encompass three climatic periods, centered on the years 2020, 2050, and 2080. For stations with Cuenca region assignments, a simplified ratio approach was developed to estimate how climate changes projected for neighboring WWCRA stations with similar climates would affect the estimated agricultural demands. The description of the methods for this are reported in Appendix E, and the results are included in Appendix A.

Uncertainties in the Measurement of Net Irrigation Water Demand

It is important to understand the uncertainties surrounding estimates of agricultural water demand. Evapotranspiration is the second largest component of river basin water balances, following precipitation, and is the primary determinant of irrigation water requirements for agricultural crops.

A variety of methods have been developed and applied for estimating Oregon's irrigation requirements. Prior to this forecast report, the current and widely applied estimates of crop evapotranspiration and NIWR were developed at Oregon State University (Cuenca 1992). In the decades since the release of the 1992 publication, several advancements have been made to the estimation of crop water demand. Chiefly, advancements in remote sensing data and computational power have allowed for more comprehensive measurement and simulation of crop water requirements, with greater locational specificity than was previously available.

Additionally, the need to understand how projected changes in climate may influence agricultural water demands has stimulated necessitated the use of more complex representations of crop water use.

As an initial step in defining the uncertainties and consistency between the Cuenca approach and the ETDemands model through analyses of measured ET, developed through remote sensing approaches. The remote sensing approaches transform thermal and reflected spectral imagery from Landsat satellite images into evapotranspiration, using a surface energy balance method. The specific techniques used are referred to as the METRIC process (**M**apping evapotranspiration [**ET**] at high **R**esolution using **I**nternalized **C**alibration). The comparisons among Cuenca, ETDemands, and METRIC methods are provided in Appendix F.

The comparisons among estimated crop water demand methods reveal a noteworthy, and potentially significant, difference between traditional crop water demand estimates used by Cuenca and values measured by remote sensing methods. General agreement was found between the ETDemands Model and the METRIC process, varying by crop but typically being within 20 percent of one another. The Cuenca estimates tended to be lower than those reported by METRIC by more than 20 percent, varying also by crop. The following sections highlight the strengths and weaknesses of each approach.

Recommendations for Reducing Uncertainty in Agricultural Demands

Future estimates of Oregon's agricultural water demands would benefit from being derived in a manner that is consistent for the entire state, and which allows for inspection of crop specific water demand at daily, monthly, growing season and annual scales. The technology used for this report and for the WWCRA studies, the ETDemands model, would provide this additional value. The application of the ETDemands model for this report was limited to specific weather stations on an annual basis, creating a significant effort to assign crops across each county to appropriate representative crops at the available weather stations. A more comprehensive approach could be conducted to **apply the ETDemands model across the state for each crop,** reducing the judgment required for conducting crop water estimates, and making true spatial analysis possible for place-based coordinators with specific land use alternatives.

Although the Cuenca approach has been an effective standard for decades, the ETDemands model presents the following advantages:

- **More current and defensible estimates.** The ETDemands model provides an improved level of credibility through the following:
  - The use of the most current and broadly accepted methodologies for estimating crop water demand.
  - Demonstrable consistency with remote sensing measurements which rely on satellite imagery and have been shown to be accurate measurements of actual evapotranspiration (METRIC processes).
  - Higher specificity regarding crop types are now available for representing the diversity of crops in Oregon.
- **Greater flexibility for planning purposes.** The ETDemands model allows for greater diversity of planning activities in comparison with the traditional approaches, including:
  - The ability to estimate crop demand under climate changes. Traditional methods do not allow for scenario planning with the information available from climate change.
  - Greater specificity about climate, location, and crop types allowed in the ETDemands Model can facilitate a high level of flexibility in understanding how changes in land use or crop blends could affect demands for water.

Use of the *ETDemands* model provides:

- **More defensible crop water demand estimates**
- **Broader flexibility for scenario development and alternative testing**
- **Compatibility with modern techniques for measuring crop water demand (i.e., METRIC)**

- o Not only is the ETDemands approach able to make calculations for historical periods dating to the late 1800s (Allen and Robison 2007) when only air temperature and precipitation were measured, but it can also take advantage of modern weather data systems, such as Agrimet, where a full complement of weather data that affect evapotranspiration and water demands are measured. Having a long time series provides information on long-term variation and evolution of both weather and evapotranspiration demands, for a variety of purposes.

Separate quantification of crop water demands using the METRIC approach would provide additional benefits for Oregon. These include benefits for the following tasks and activities being conducted throughout Oregon.

Application of METRIC for measuring crop water use would provide:

- **Accurate, spatial measurements of actual water use conditions**
- **Broader flexibility for scenario development and alternative testing**
- **Compatibility with modern techniques for measuring crop water demand (i.e., METRIC)**

- **Water balance study or individual farm-planning:** METRIC estimates are useful to assess spatial distribution of evapotranspiration within a county, sub-basin or region, and to identify specific evapotranspiration associated with individual land-use parcels such as agricultural fields. METRIC estimates would also be useful when calculating water balances used in groundwater and hydrologic studies, or in conjunction with water use records to determine the water balance for a particular region.

- **Water allocation model:** METRIC-based evapotranspiration estimates can improve crop coefficient values that are used in to estimate the sensitivity of Oregon's agricultural water demand to future climate changes. If both METRIC and a model such as ETDemands were available for a watershed, they could also be used to estimate sensitivity of crops to inter-annual changes in weather conditions. Oregon's current Water Availability Model utilizes area specific crop coefficients that would benefit from such improvements.[1]

- **Place-based water resources coordination:** The METRIC model is considered up to 96 percent accurate in estimating crop water consumption over a full growing season, and therefore provides a cost-effective way to monitor and address water needs at the field-scale. This information can become essential for both long-term and short-term planning efforts. For instance, the high reliability of the information lends a defensible way to quantify water volumes for transfers. Additionally, the computational flexibility and accuracy allow for the development of much more extensive land use planning alternative descriptions.

[1]For more information on the Water Availability Model, see: http://www.oregon.gov/owrd/SW/docs/SW02_002.pdf.

CHAPTER 3

MUNICIPAL, DOMESTIC, AND INDUSTRIAL WATER DEMAND FORECAST

M&I demand reflects water needs to support the state's growing urban centers and domestic well users throughout the state's unincorporated areas. This chapter describes the information and methods used to estimate M&I water demands in Oregon through 2050 and presents a summary of the forecast. The forecast addresses the M&I water demand represented by three categories of water use:

- Municipal service water use, which includes domestic and industrial uses within urban growth boundaries, represents the largest component of M&I water demand. It consists of water uses for 242 incorporated cities and other municipal-type water suppliers throughout Oregon.
- Unincorporated water use includes the portions of Oregon's 36 counties that lie outside of urban growth boundaries. Municipal service and domestic well water use are forecasted from reported and projected populations, and estimated per capita demands.
- Self-supplied industrial water use represents industrial and commercial water users that are separate from municipal systems and who hold their own water rights. Self-supplied industrial demands are reported for each of Oregon's 36 counties, using information about the water rights held by industrial water users.

Summary of M&I Demands

Oregon's M&I water demands are anticipated to increase 20 percent by 2050, resulting primarily from a projected 40 percent increase in population (approximately 1.5 million additional residents). Ongoing and planned conservation measures are expected to reduce per capita water demand for many communities. However, the weighted average per capita M&I water demand for Oregon is projected to remain about the same as current conditions, increasing approximately 0.7 percent, from 109 to 110 gallons per day (0.1225 to 0.1234 acre feet per year) per capita. **Industrial and commercial demands served by municipal water systems are included in the projection of per capita demand**. Self-supplied industrial demands served from separate and individual water rights are not projected to increase. Figure 3.1 illustrates the magnitude of changes in the scale and composition of M&I water demand, as they are forecasted in this report.

Population was found to be a more important driver of future water demands than changes in community per capita demands. Most population growth is forecasted to occur in Oregon's large urban areas, with central Oregon projecting the highest percentage growth through 2050. Conversely, rural and unincorporated areas are expected either to remain stable in population or to experience some decline.

The counties with the highest projected volumetric increase in M&I water demand by 2050 are:

(1) Washington, (2) Deschutes, (3) Multnomah, (4) Clackamas, and (5) Lane.

The M&I demands for some counties are forecasted to increase more than the statewide average of 20 percent. The counties with the highest forecasted increases in M&I water demand by 2050 are:

(1) Deschutes, 54 percent; (2) Washington, 50 percent; (3) Polk, 47 percent; (4) Yamhill, 43 percent; and (5) Jefferson, 35 percent.

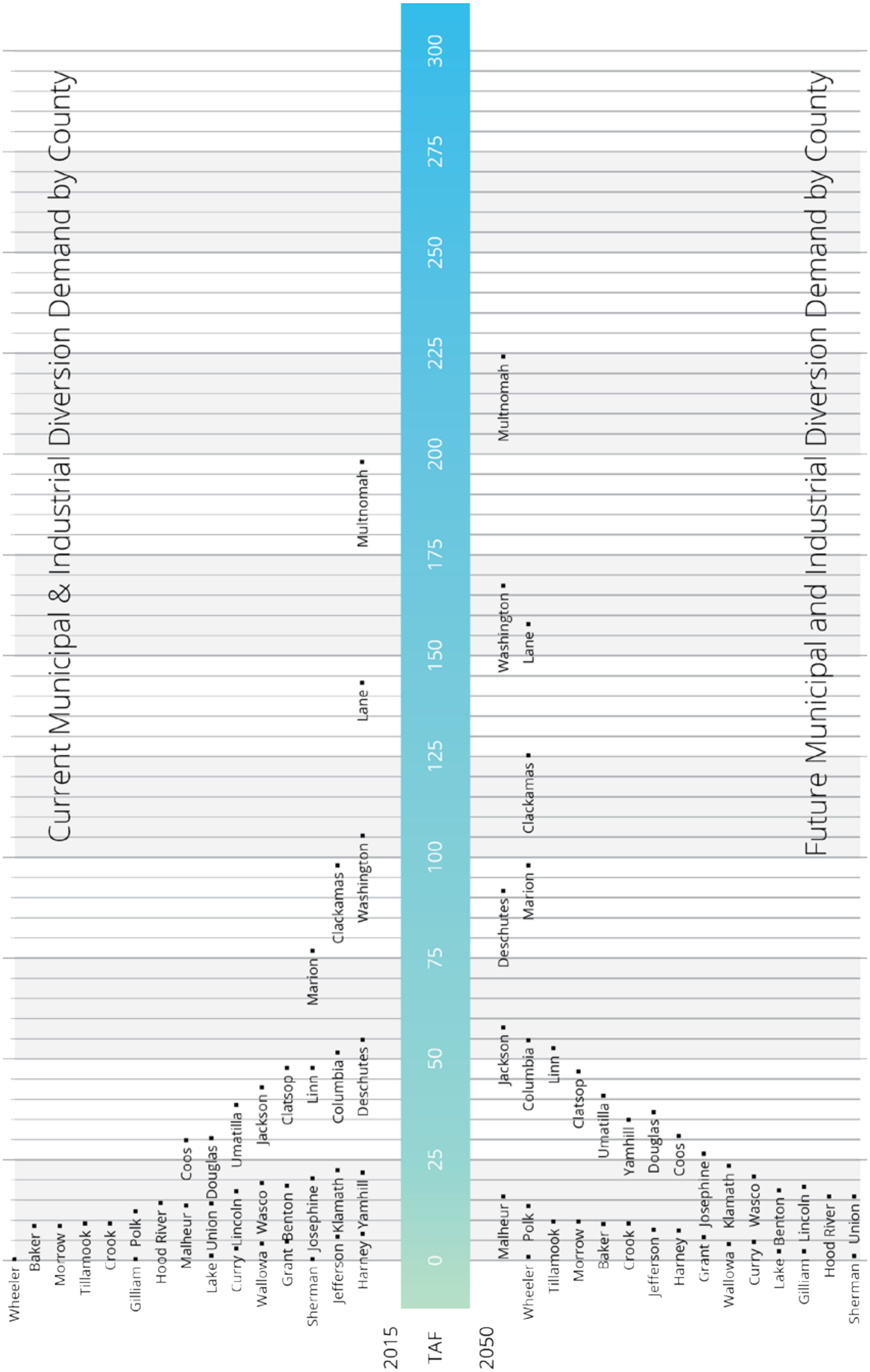


Figure 3.1. Comparison of Current and Future M&I Diversion Demand by County

Key Findings for Municipal and Industrial Water Demands

- Population growth is a more influential driver of future M&I water demand than per capita use rates. Statewide, per capita demands have declined over the past seven years, attributable to efforts by water utilities to improve water accounting, increased conservation efforts by the public, and development of WMCPs. The implementation of these policies and programs is expected to be completed in the near-term and, therefore, additional savings in per capita demand have not been projected for the future.

- Overall M&I demand is expected to increase through the forecast period at a similar pace to population growth. Statewide population growth has slowed in comparison to the rates of growth projected during the 2008 Water Demand Forecast. This slow-down in population growth coincided with a downturn in the state's economy, but growth has begun to rebound with improved economic conditions.

- Oregon's population is projected to continue migrating from rural or unincorporated areas to urban areas. Urban areas have higher per capita demands than unincorporated areas and, therefore any continued migration would be expected to increase the average per capita demand of the state.

Important Assumptions in Estimating Municipal and Industrial Water Demands

- **The per capita demands in this report are not the average use of each resident.** Instead, the per capita demand reported herein includes industrial and commercial uses that are served by the municipal water provider. Thus, urban water providers with more commercial and industrial water uses may have higher per capita demands than rural water providers that mostly serve residential customers. Commercial and industrial uses are expected to change proportionally with increases or decreases in populations.

- **Changes in population by 2050 were primarily based on forecasts obtained from the Portland State University (PSU) Population Research Center (PRC)**, which produces a periodic population forecast for Oregon. The most recently completed forecast extends to 2050, and the 2065 update is partially underway. Where these values were not available, the Oregon Office of Economic Analysis (OEA) long-term county forecasts were used.

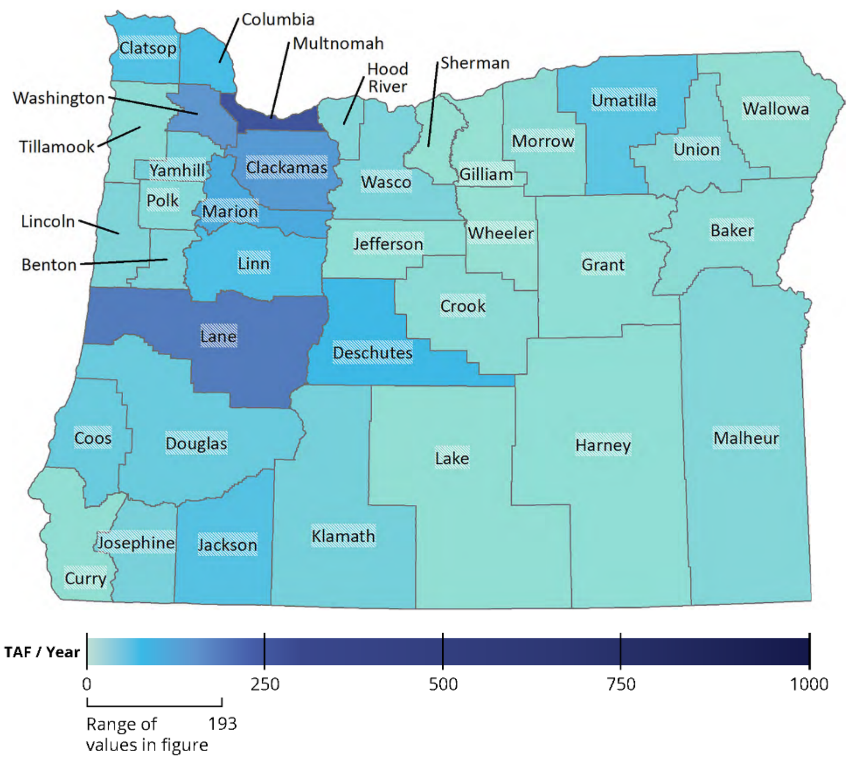
- **Changes in per capita demand were estimated from 50 of the most recent WMCPs from communities across Oregon**. In many cases, representative communities were used to assign per capita demands to communities without recent WMCPs.

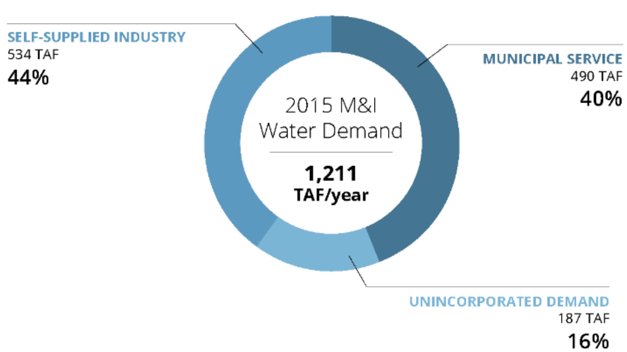
Municipal and Industrial Water Demands by County and Administrative Basin

The subsequent pages of this report include companion figures and tables that display estimates of current M&I (including municipal service, domestic well, and self-supplied industrial) water demand in Oregon by county and by Administrative Basin. Future demands are presented as a change, relative to current demand.

2015 Water Demand Forecast

2015 | Current Municipal & Industrial Diversion Demand by County





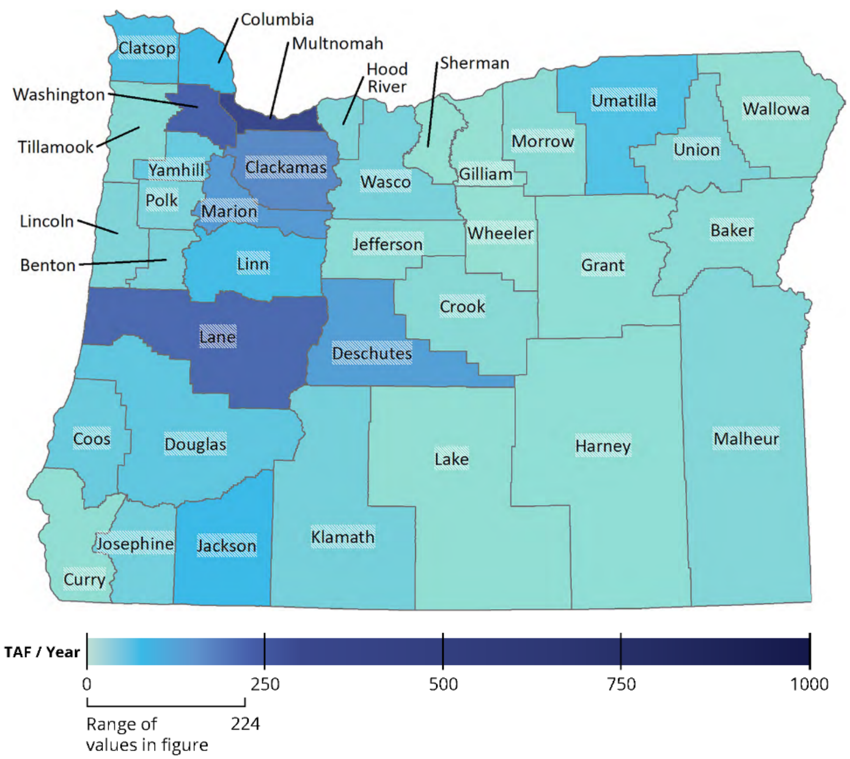
County	Population	Total 2015 M&I Demand (TAF/yr)	Demand by Water Use Category (TAF/yr)		
			Municipal Service	Unincorporated Demand	Self-Supplied Industry
Multnomah	768,600	193	118.4	3.8	70.7
Washington	570,700	112	53.3	50.6	7.6
Clackamas	393,200	98	33.8	28.7	35.5
Lane	361,500	138	52.8	6.6	78.7
Marion	331,600	78	38.8	5.5	33.6
Jackson	211,300	44	28.8	11.8	3.4
Deschutes	170,600	60	28.5	12.2	19.0
Linn	122,000	48	13.8	3.4	30.4
Douglas	110,100	31	9.6	4.0	17.7
Yamhill	104,500	23	14.1	5.3	4.0
Benton	88,000	19	10.0	2.8	6.0
Josephine	83,900	21	8.2	8.2	4.9
Polk	80,200	13	6.0	3.8	2.7
Umatilla	78,900	39	13.8	4.1	21.2
Klamath	67,000	23	10.8	4.8	7.8
Coos	63,100	30	4.5	1.7	24.0
Columbia	51,300	52	5.3	4.3	42.0
Lincoln	47,600	17	3.7	1.7	11.3
Clatsop	37,600	47	4.8	2.6	39.3
Malheur	32,000	14	4.3	3.4	6.6
Union	27,000	15	4.4	1.2	8.9
Wasco	26,000	19	4.3	1.9	12.5
Tillamook	25,700	9	1.4	1.3	6.0
Hood River	23,700	14	1.7	2.7	9.5
Jefferson	22,800	6	2.2	3.0	0.3
Curry	22,500	4	1.7	0.4	1.4
Crook	21,100	10	2.1	1.8	5.9
Baker	16,200	8	2.6	1.1	3.9
Morrow	11,700	8	2.0	0.8	4.9
Lake	7,900	3	0.6	1.3	1.3
Harney	7,400	7	1.0	0.7	4.9
Grant	7,400	5	0.9	0.5	3.8
Wallowa	7,100	4	1.1	0.5	2.7
Gilliam	2,000	1.4	0.5	0.1	0.8
Sherman	1,700	1.0	0.4	0.2	0.4
Wheeler	1,400	0.2	0.1	0.1	0.0
TOTAL	**4,005,600**	**1,211**	**490**	**187**	**534**

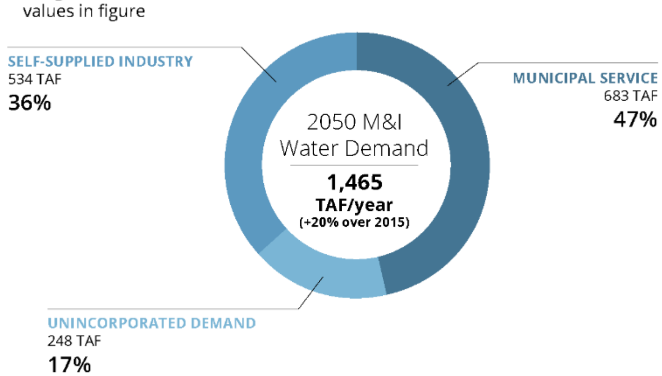
To convert TAF/yr to MGD, multiply the values in TAF by 0.89

Figure 3.2. Current M&I Diversion Demand by County

2050 | Future Municipal & Industrial Diversion Demand by County

2015 Water Demand Forecast





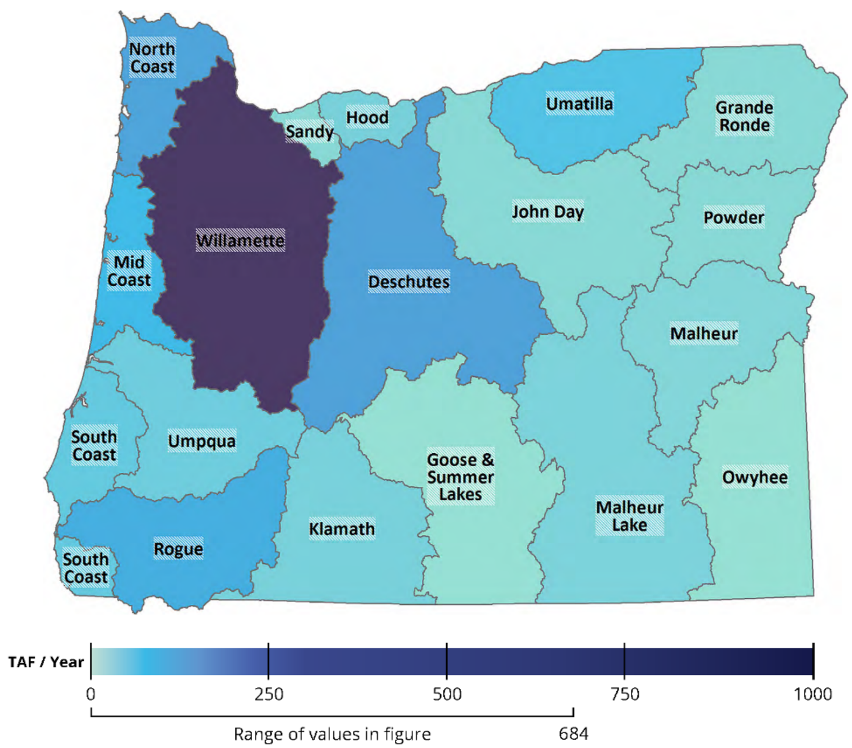
County	Population	Total 2050 M&I Demand (TAF/yr)	Demand by Water Use Category (TAF/yr)		
			Municipal Service	Unincorporated Demand	Self-Supplied Industry
Multnomah	960,900	224	148.1	4.8	70.7
Washington	874,400	167	81.7	77.5	7.6
Clackamas	561,000	125	48.2	40.9	35.5
Marion	476,100	97	55.7	7.8	33.6
Lane	469,100	157	72.8	5.9	78.7
Deschutes	304,000	92	55.2	17.7	19.0
Jackson	280,900	58	41.7	12.7	3.4
Linn	163,500	53	18.5	4.5	30.4
Yamhill	159,500	34	21.5	8.0	4.0
Douglas	143,500	36	14.0	4.4	17.7
Polk	128,500	18	9.6	6.1	2.7
Josephine	111,100	27	13.2	8.5	4.9
Umatilla	108,900	46	19.1	5.7	21.2
Benton	108,300	22	12.3	3.4	6.0
Klamath	71,200	24	11.6	5.0	7.8
Columbia	69,100	55	7.1	5.8	42.0
Coos	63,800	31	5.2	1.3	24.0
Lincoln	55,400	18	4.3	2.0	11.3
Clatsop	40,900	47	5.2	2.8	39.3
Hood River	34,900	16	2.5	4.0	9.5
Malheur	34,700	15	4.6	3.7	6.6
Union	34,200	16	5.6	1.5	8.9
Wasco	33,400	21	5.6	2.4	12.5
Jefferson	30,800	7	3.4	3.7	0.3
Tillamook	30,700	9	1.6	1.5	6.0
Curry	27,200	4	2.2	0.4	1.4
Crook	25,200	11	2.6	2.1	5.9
Baker	16,300	7.6	2.6	1.1	3.9
Morrow	15,500	8.7	2.7	1.1	4.9
Lake	7,900	3.1	0.6	1.2	1.3
Harney	7,000	6.5	0.9	0.7	4.9
Wallowa	6,600	4.2	1.0	0.5	2.7
Grant	6,200	5.0	0.8	0.4	3.8
Gilliam	2,600	1.6	0.7	0.1	0.8
Sherman	1,800	1.0	0.4	0.2	0.4
Wheeler	1,300	0.2	0.1	0.1	0.0
TOTAL	**5,466,300**	**1,465**	**683**	**248**	**534**

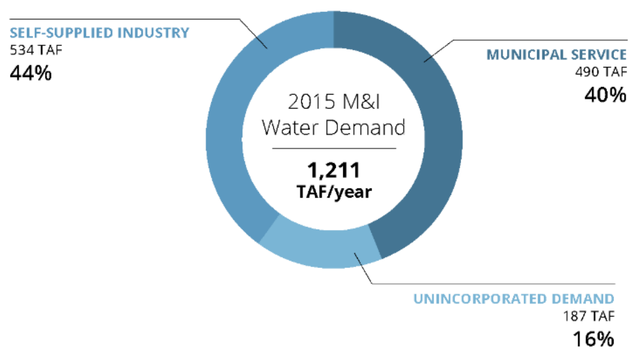
To convert TAF/yr to MGD, multiply the values in TAF by 0.89

Figure 3.3. Future M&I Diversion Demand by County

2015 | Current Municipal & Industrial Diversion Demand by Administrative Basin

2015 Water Demand Forecast





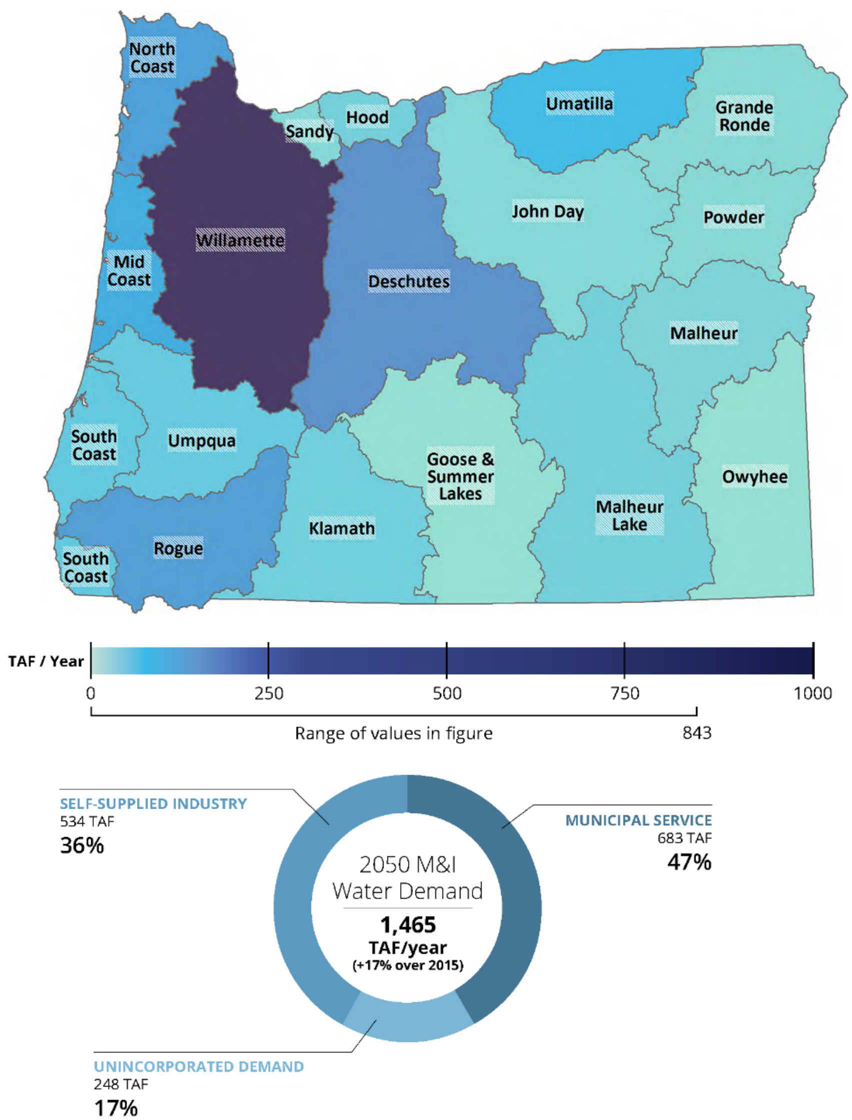
Administrative Basin	Population	Total 2015 M&I Demand (TAF/yr)	Demand by Water Use Category (TAF/yr)		
			Municipal Service	Unincorporated Demand	Self-Supplied Industry
Willamette	2,574,700	684.1	316.1	84.2	283.8
Mid Coast	312,800	54.8	21.5	17.3	16.0
Rogue	293,300	69.1	42.2	18.7	8.2
Deschutes	228,400	86.5	39.3	19.7	27.5
Umpqua	99,800	28.9	7.5	6.0	15.4
North Coast	81,300	84.6	10.8	6.4	67.4
Umatilla	80,800	45.5	13.7	6.1	25.7
South Coast	79,200	35.4	4.9	3.5	27.0
Klamath	61,600	22.4	10.3	5.2	6.9
Malheur Lake	59,800	20.1	8.4	6.5	5.2
Sandy	47,000	9.4	4.3	3.9	1.2
Malheur	29,200	14.3	3.9	3.7	6.7
John Day	23,600	9.8	3.0	2.1	4.7
Powder	15,500	10.2	2.6	1.2	6.4
Grande Ronde	7,600	11.0	1.0	0.9	9.1
Hood	7,300	22.5	0.5	1.0	21.0
Owyhee	2,400	0.6	0.3	0.3	0.0
Goose & Summer Lakes	1,400	1.9	0.1	0.3	1.5
TOTAL	**4,005,600**	**1,211**	**490**	**187**	**534**

To convert TAF/yr to MGD, multiply the values in TAF by 0.89

Figure 3.4. Current M&I Diversion Demand by Administrative Basin

2050 | Future Municipal & Industrial Diversion Demand by Administrative Basin

2015 Water Demand Forecast



Administrative Basin	Population	Total 2050 M&I Demand (TAF/yr)	Demand by Water Use Category (TAF/yr)		
			Municipal Service	Unincorporated Demand	Self-Supplied Industry
Willamette	3,580,200	842.9	436.8	122.3	283.8
Mid Coast	413,200	67.7	28.3	23.4	16.0
Rogue	400,400	91.8	62.4	21.2	8.2
Deschutes	345,500	117.1	64.6	25.0	27.5
Umpqua	127,000	33.3	11.0	6.9	15.4
Umatilla	114,300	53.9	19.3	8.9	25.7
North Coast	90,900	86.8	12.0	7.4	67.4
South Coast	76,500	35.5	5.7	2.8	27.0
Malheur Lake	75,800	24.3	10.6	8.5	5.2
Klamath	71,900	25.1	12.1	6.1	6.9
Sandy	57,900	11.4	5.3	4.9	1.2
John Day	38,400	13.0	4.9	3.4	4.7
Malheur	37,000	16.5	5.0	4.8	6.7
Powder	15,500	10.2	2.6	1.2	6.4
Hood	9,300	23.0	0.7	1.3	21.0
Grande Ronde	7,600	11.1	1.1	0.9	9.1
Owyhee	3,000	0.8	0.4	0.4	0.0
Goose & Summer Lakes	1,800	1.9	0.1	0.3	1.5
TOTAL	**5,466,300**	**1,465**	**683**	**248**	**534**

To convert TAF/yr to MGD, multiply the values in TAF by 0.89

Figure 3.5. Future M&I Diversion Demand by Administrative Basin

Incorporated and Unincorporated Municipal Water Demand

This forecast projects changes in municipal demand from forecasts of population and anticipated changes in per capita demand. Population data were evaluated for 242 Urban Growth Boundaries (UGBs) throughout Oregon, and for all 36 counties in Oregon.

The following sections describe the methods for estimating population, per capita demands, and subsequently the M&I demands of communities throughout Oregon. Appendix B provides more detailed break-out tables that identify the information being used within each UGB and each county area outside of the UGBs.

Estimates of Population

The 2015 Water Demand Forecast relied on the following for estimates of current and future population:

- 2010 U.S. Census (U.S. Census Bureau 2011)
- Portland State University-Population Research Center (PSU-PRC), Coordinated Population Forecast http://www.pdx.edu/prc/opfp (2015)
- Oregon's Office of Economic Analysis (OEA), Long Term County Forecast (2010-2050), http://www.oregon.gov/DAS/OEA/Pages/demographic.aspx (2013)

For the purposes of comparison, the 2008 Forecast relied on the following information:

- 2000 U.S. Census
- PSU-PRC, 2007 Oregon Population Report
- Oregon's OEA Long Term County Forecast (2000-2040)
- Oregon's Department of Human Services Drinking Water Services Public Water Systems database (methodology development for population on domestic wells)

The 2010 U.S. Census and Oregon Office of Economic Analysis allowed for a direct comparison and updates to the projections from the 2008 Forecast. A comparison of the Oregon Statewide population numbers can be found in Table 3.1.

Table 3.1. Comparison of Oregon Statewide Population Projection Differences between the 2008 and 2015 Water Demand Forecasts

Year	2008 Forecast	2015 Forecast	% Difference
2015	4,183,333	4,001,600	-4.3
2050	6,129,463	5,588,500	-8.8

The census and PSU-PRC forecasts of populations were summarized at five-year increments between 2010 and 2050 for each of the incorporated communities of Oregon. Population estimates from incorporated communities were then subtracted from county-based population forecasts from Oregon's OEA to produce unincorporated population numbers for each of the 36 counties, for each five-year period. The unincorporated population numbers for each county are analogous to the population that receives water from domestic wells.

In general, current projections for population growth are slower than were projected in 2008. WMCPs have largely attributed the slowdown in population growth to the downturn in the state and national economy in the late 2000s. Figure 3.6 depicts the distribution of population among counties and Administrative Basins that are used for the Current Demand Scenario (2015) and for the 2050 Demand Scenario (2050). Counties projecting the most population growth are Washington (1), Multnomah (2), Clackamas (3), Marion (4), and Deschutes (5). Basins projecting the most population growth are the Willamette (1), Deschutes (2), Rogue (3), Mid Coast (4), and Umatilla (5). Counties projecting a population loss are Harney, Grant, Wallowa, and Wheeler County.

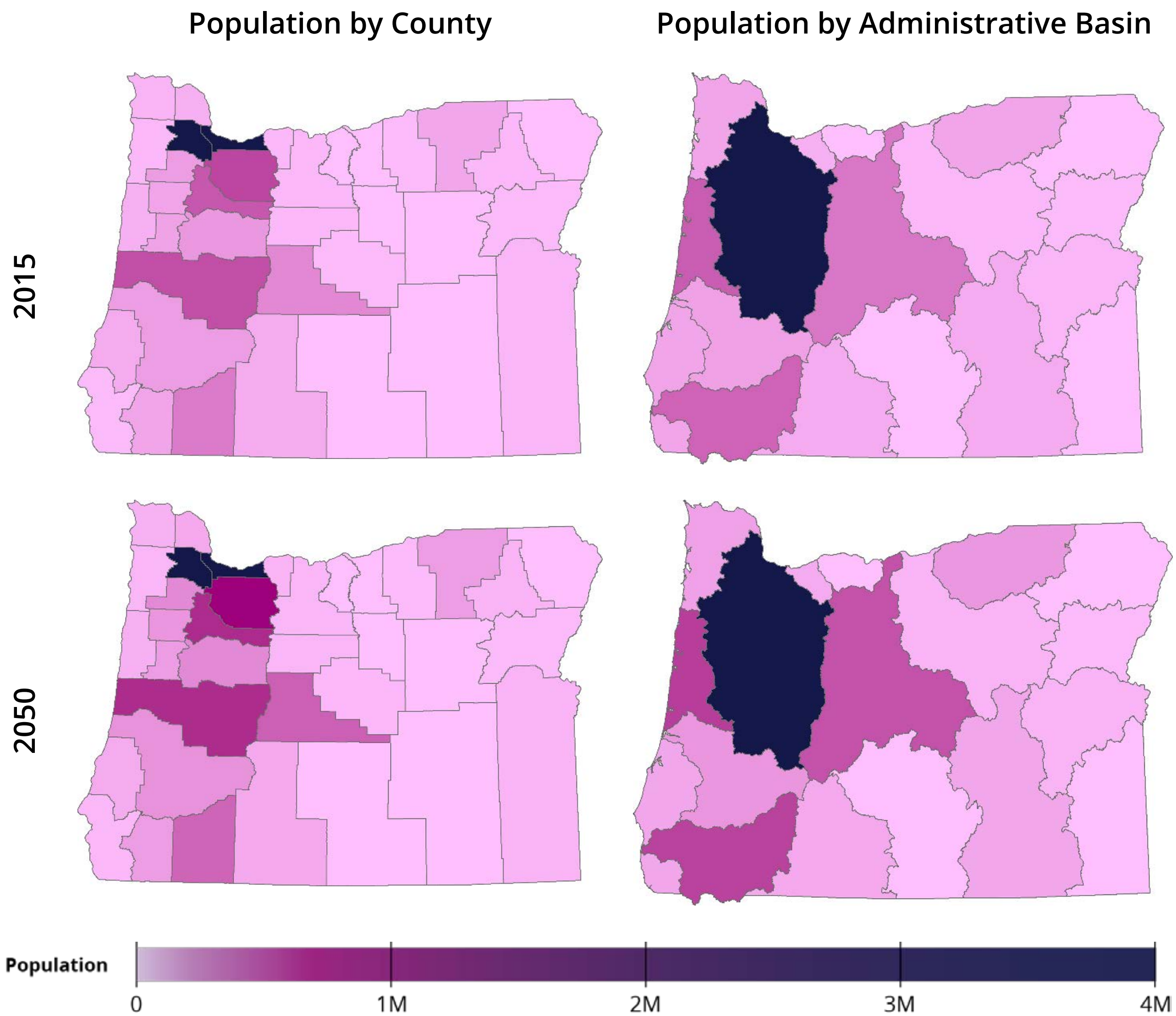
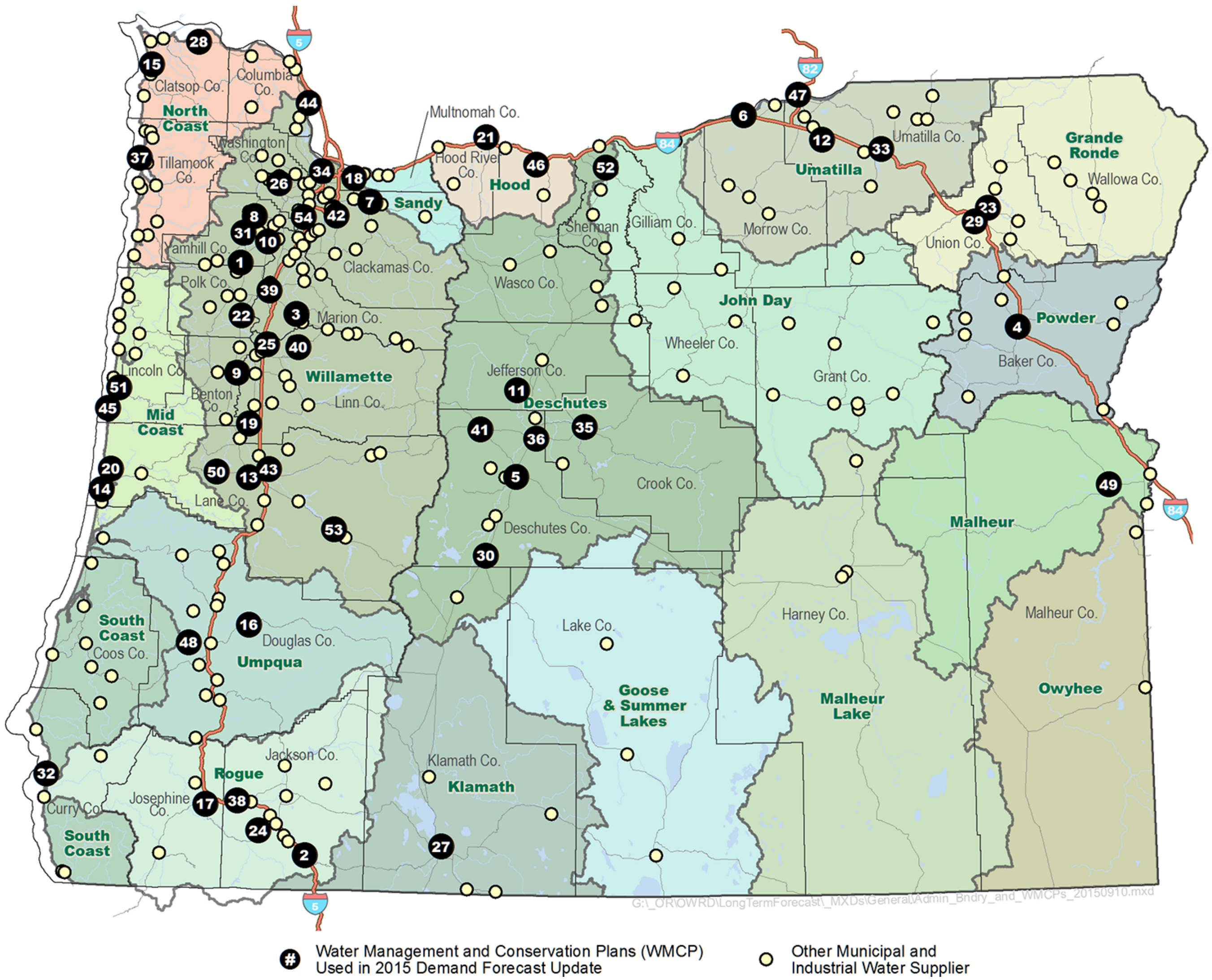


Figure 3.6. Population Growth by County and Administrative Basin, 2015 to 2050



ID	WMCP
1	Amity
2	Ashland
3	Aumsville
4	Baker City
5	Bend
6	Boardman
7	Boring Water District
8	Carlton
9	Corvallis
10	Dayton
11	Deschutes Valley Water District
12	Echo
13	Eugene Water & Electric Board
14	Florence
15	Gearhart
16	Glide Water Association
17	Grants Pass
18	Gresham & Rockwood PUD
19	Harrisburg
20	Heceta Water PUD
21	Hood River
22	Independence
23	Island City
24	Jacksonville
25	Jefferson
26	Joint Water Commission
27	Klamath Falls
28	Knappa Water Association
29	La Grande
30	La Pine
31	McMinnville Water & Light
32	Nesika Beach-Ophir Water District
33	Pendleton
34	Portland Water Bureau
35	Prineville
36	Redmond
37	Rockaway Beach
38	Rogue River
39	Salem
40	Scio
41	Sisters
42	South Fork Water Board
43	Springfield Utility Board & RWD
44	St. Helens
45	SW Lincoln County Water District
46	The Dalles
47	Umatillia
48	Umpqua Basin Water Association
49	Vale
50	Veneta
51	Waldport
52	Wasco
53	Westfir
54	Wilsonville

Figure 3.7. Water Management and Conservation Plans Applied to the 2015 Water Demand Forecast

Estimations of Per Capita Demand

This forecast relies on 54 recent WMCPs (identified in Figure 3.7) to estimate current and projected future per capita water demand within each of Oregon's 242 UGBs, and OUGB.

The selected WMCPs were evaluated for descriptions of demographics, mixture of commercial/industrial uses, and water use characteristics (including current and future per capita demands). For several WMCPs, comparisons of per capita water use were provided for neighboring municipalities; these comparisons were cited and used. For communities not directly referenced in the selected WMCPs, similarities between communities were used to identify an appropriate municipality to use as a proxy.

In a limited number of cases, WMCPs contained descriptions of overlapping service areas and conflicting information about per capita demand. In such instances, estimates from the more local WMCP (at the city or town scale) were preferred over the more regionally based numbers.

Notably, the Echo WMCP per capita demand (minus golf course usage) was used broadly as a proxy for cities northeast of the Cascades with less than 5,000 inhabitants, and for OUGBs in north-central and northeast counties.

Table 3.3 lists WMCPs that were used to estimate per capita water demands in the UGBs and OUGBs for each county. Appendix B provides a comprehensive list of per capita water demand details related to each UGB and OUGB, and provides notes on the assessment of each WMCP for use among the UGBs and OUGBs.

Changes in per capita municipal demand result from reductions due to conservation practices at a local level, and shifts in populations to areas with higher projected per capita demands (e.g., migration of populations from OUGBs to UGBs, which have higher total per capita demands due to the inclusion of commercial and industrial use needs). It was assumed that as urban areas grow in population, commercial and industrial demands would also increase at roughly the same pace to support the economy and serve the influx of people. Specifically looking at average domestic/residential usage, per capita demands in urban areas are typically lower than their rural counterparts due to differences in property size and configuration, such as space for lawns, gardens, pools, or animals. Also, differences in water service billing rates can have an impact on human behavior and choices about conservation and landscaping.

Generally, many of the WMCPs observed decreasing per capita demands during the past decade because of ongoing conservation initiatives, stricter building codes and requirements, the recent economic downturn, and maintenance activities that have reduced losses in the distribution system. These reductions have generally plateaued in recent years and per capita demands are generally expected to remain constant into the foreseeable future.

Forecasted changes in per capita demand are small or imperceptible when viewed at the county and Administrative Basin level. For the state of Oregon as a whole, the net change in per capita demand by 2050 is an increase of approximately 0.7 percent.

Table3.3: Assignment of Proxy Per Capita Water Demands to Counties in Oregon without Recent WMCPs

County	WMCPs Referenced
Baker	Baker City 2008
Benton	Corvallis 2012; Scio 2014
Clackamas	South Fork Water Board 2011; Boring 2014; Wilsonville 2013
Clatsop	Gearhart 2012
Columbia	St. Helens 2013
Coos	Nesika Beach-Ophir Water District 2012
Crook	Echo 2012; Prineville 2011
Curry	Nesika Beach-Ophir Water District 2012
Deschutes	Bend 2011; La Pine 2014; Redmond 2013; Sisters 2011
Douglas	Umpqua Basin Water Association 2013; Glide 2012; Springfield Utility Board & Rainbow Water Dist. 2012
Gilliam	Echo 2012
Grant	Echo 2012
Harney	Baker City 2008
Hood River	Hood River 2013; Echo 2012
Jackson	Ashland 2013; Grants Pass 2013; Jacksonville 2014; La Pine 2014; Rogue River 2015
Jefferson	La Pine 2014 ; Redmond 2013
Josephine	Grants Pass 2013; Jacksonville 2014; Rogue River 2015
Klamath	Klamath Falls 2012; La Pine 2014
Lake	Klamath Falls -2012; La Pine -2014
Lane	Eugene Water and Electric Board 2012; Florence 2010; Heceta Water Public Utility District 2014; Springfield Utility Board & Rainbow Water District 2012; Veneta 2012; Westfir 2013
Lincoln	Southwest Lincoln County Water District 2014; Waldport 2014
Linn	Corvallis 2012; Jefferson 2014; Harrisburg 2014 ; Scio 2014
Malheur	Baker City 2008; Echo 2012; Pendleton 2013; Vale 2015
Marion	Aumsville 2014; Jefferson 2014; Salem 2014; Wilsonville 2013
Morrow	Boardman 2012; The Dalles 2014; Echo 2012
Multnomah	Gresham 2013; Portland Water Bureau 2010
Polk	Aumsville 2014; Wilsonville 2013; Independence 2015
Sherman	Wasco 2014
Tillamook	Gearhart 2012; Knappa Water Association 2013
Umatilla	Echo 2012; Pendleton 2013
Union	Echo 2012; La Grande 2010; Island City 2011
Wallowa	Echo 2012; La Grande 2010
Wasco	The Dalles 2014; Echo 2012
Washington	Carlton 2015; Joint Water Commission 2010; Wilsonville 2013
Wheeler	Echo 2012
Yamhill	Carlton 2015; Dayton 2013; McMinnville 2014; Amity 2014

Self-Supplied Industrial Demand

Self-supplied industrial water demands correspond to more than 1,800 existing water rights, which represent a significant quantity and volume of allocated water for some watersheds. This forecast retains the estimates for self-supplied industrial demands conducted in 2008, which were based upon water rights records for such users, by county (Appendix B) (OWRD 2008).

Projections of changes in applications for water use permits for self-supplied industrial do not exist and, therefore, demands for self-supplied industrial use were held constant for the purpose of this water demand forecast. Anecdotally, about 100 water use applications have been filed and permits approved in Oregon for self-supplied industrial and commercial use since the 2008 Forecast. The water use permits range from 0.016 cfs to 5.57 cfs. Most requests were for groundwater and the locations geographically dispersed. The largest requests were for heating and cooling projects in Klamath, Lake, Harney, and Lane Counties. The types of organizations filing these requests ranged from agricultural farms, to server farms, lumber and energy companies, hospitals, schools, churches, and local and state government.

It is more difficult to track the departure or closure of self-supplied industries in Oregon since 2008. Presumably, the economic recession that followed the 2008 Water Demand Forecast took its toll on such industries. However, the water right certificates and water use permits pertaining to these industries may linger on the record, even after years of non-use. A more thorough investigation conducted through the OWRD water use reporting program may improve the understanding of net changes in self-supplied industrial water use. Only a small portion of existing water rights require reporting of water use, however this percentage is increasing as new rights are issued. As of 2014, 69 percent of non-governmental water users with reporting requirements filed water use reports. As compliance with water use reporting increases, OWRD records and assessments of self-supplied industrial use will improve.

This forecast of water demand could be improved through a developed understanding of industrial water use, the volume and timing of water diversions, the fraction of diversions that are consumed versus returned to surface and groundwater sources, and projections for new industrial water uses or water users.

Methodology for the Municipal and Industrial Demand Forecasts

Since the 2008 Water Demand Forecast, the information developed and reported in WMCPs has become more standardized and reliable, particularly in the reporting of per capita demand. These improvements allowed the 2015 Water Demand Forecast to accurately use municipal communities as the smallest spatial unit of water demand estimates. Such improved information allows for the assignment of per capita demands to each of the incorporated and unincorporated areas within Oregon's 36 counties. It also allows for greater transparency into how per capita demand estimates are applied to specific locations, and greater ease in updating as conditions change or as new information becomes available.

Applying census block information from the U.S. Census to distribute population among the 18 Administrative Basins resulted in different forecasted population numbers than the county-by-county approach. A goal of this forecast was to balance the population forecast numbers so the county-by-county totals would match the Administrative Basins totals. The methodology used to achieve this was to review the assumptions and census block assignments from the 2008 Forecast and develop population factors for each Administrative Basin to apply to the updated county-by-county population forecast. While this reduced the error in population differences, there are still some slight discrepancies that could be addressed in the future.

All municipalities in Oregon holding water rights are required to report their actual monthly water use to the state. As of 2014, 90 percent of cities who hold water rights comply with this requirement.[1] This information allows the public to track changes in municipal water use, identify trends, and estimate future water use as well. As part of its place-based coordination efforts, OWRD's work in municipal demand could include a break-down

[1] To access reported water use, see http://apps.wrd.state.or.us/apps/wr/wateruse_query/.

by character of use (e.g.; domestic, industrial). This would allow for a more accurate description of changes in demand for potentially smaller planning units.

The information available for this 2015 Water Demand Forecast includes refinements in the resolution provided for localizing population and per capita demand. However, this report is subject to similar types of uncertainties and limitations as the 2008 Water Demand Forecast. Uncertainty exists in several of the drivers that affect future water demand, including the economy, growth and shifts in population, climate, conservation values, utility system maintenance, regulations, and future investments in infrastructure. A description of how these identified drivers affect water demand, and the uncertainty surrounding them, is provided below.

Economics and Population

The PSU-PRC population forecasts estimate changes in population based on traditional demographic approaches, while also incorporating feedback on localized impacts of economics through workshops and outreach. This can provide a more rigorous approach than that used in the county population estimates provided by the Oregon OEA. However, the PSU-PRC updates 50-year population forecasts for Oregon on a four- to five- year cycle, updating one-third of the state at a time. At the time of this report, the forecast through 2065 was not available for the entire state. Therefore, population estimates for the 2015 Water Demand Forecast look through the 2050 horizon, the last full year in the OEA population forecast. The population numbers in this Demand Update could be further refined upon completion of PSU-PRC's 2065 forecast.

Comparison of the forecasts made in 2008 and in 2015, shows clear and significant uncertainties in the future population of Oregon and its communities. The prevailing thought about why this occurred was due to the downturn in the economic climate. Communities engaged in place-based planning are encouraged to consider the potential impact of uncertainty in population forecasts and their local economies. One potential area of focus might be the predicted influx of population from other states, resulting from a warming climate. Researchers at PSU in Oregon are working to predict and describe the potential scale of this climate migration over the next several years and decades. Communities are encouraged to consider including these numbers in future demand forecasts as they become available.

Climate

Consensus exists among the scientific community that changes in climate are occurring, and that those changes will lead to generally warmer conditions within the Pacific Northwest. Further, these changes in warming will likely affect the balance between supplies and demands in Oregon through a change in the timing and form of precipitation, in the timing and quantity of natural runoff, increases in open water evaporation, decreased ability to recharge aquifers, potential changes in the severity of flooding and droughts, and prolonged growing seasons for irrigated plants (including urban landscaping). The effect of climate change on M&I water demand could be estimated through the evaluation of how the range of potential future climates would affect outdoor demands.

Despite the scientific consensus that the climate is changing, uncertainties exist in the timing and extent of projected changes. The extent of uncertainties complicates processes for evaluating water management risks that have traditionally relied upon a singular, historical-basis for calculating potential variability in water supplies. The methods for considering climate change for place-based planning continue to evolve with the science of projecting future climate, but many recent local and regional planning efforts rely on the characterization of uncertainty through scenario planning that consider multiple possibilities for the future climate.

An assessment of how M&I demands could be influenced by climate changes was not conducted for the 2015 Water Demand Forecast. However, information developed in support of Chapter 2 does provide estimates for how water demand for irrigated turf grass and other trees could change over the coming century. Estimates of future consumptive and NIWR demands for turf grass and other crops are available in Appendix G, and are described in detail in Appendix C. Water management entities with an understanding of their outdoor demands could use this information to estimate their sensitivity to climate change.

Conservation

Many municipal water providers in Oregon offer incentives and/or assistance to help water users conserve. 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, weather-based irrigation controllers, and manual hose bib timers. 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 the Western U.S. due, 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.

Distribution System Maintenance

Another source of uncertainty exists in the management of municipal water distribution networks. Some municipal water providers have a large amount of unaccounted-for water that artificially increases their reported per capita demands. For example, a municipal water provider 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.

This page left blank intentionally.

CHAPTER 4

REFERENCES

Allen, R.G., and C.E. Brockway. 1983. Estimating Consumptive Irrigation Requirements for Crops in Idaho, Research Technical Completion Report, Idaho Water and Energy Resources Research Institute, University Idaho, Moscow, ID, 130 p.

Allen, R.G., L.S. Pereira, D. Raes, and M. Smith. 1998. "Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements," Irrigation and Drainage Paper 56, Food and Agriculture Organization of the United Nations, Rome, 300 p.

Allen, R.G., L.S. Pereira, M. Smith, D. Raes, and J.L. Wright. 2005a. "FAO-56 Dual Crop Coefficient Method for Estimating Evaporation from Soil and Application Extensions," Journal of Irrigation and Drainage Engineering, ASCE, 131(1):2–13.

Allen, R.G. and C.W. Robison. 2007, 2009 (rev.). "Evapotranspiration and Consumptive Irrigation Water Requirements for Idaho," University of Idaho Report, 222 p. Available at http://www.kimberly.uidaho.edu/ETIdaho/.

Allen, R.G. and J.L. Wright. 2009. "Estimation of evaporation and evapotranspiration during nongrowing season using a dual crop coefficient," Proceedings of the ASCE-EWRI World Environmental and Water Resources Congress, Kansas City, Missouri, May 17–21, 2009, pp. 4158-4171.

ASCE-EWRI (Environmental and Water Resources Institute of the American Society of Civil Engineers). 2005. The ASCE Standardized Reference Evapotranspiration Equation, Report 0-7844-0805-X, ASCE Task Committee on Standardization of Reference Evapotranspiration, Reston, Virginia., American Soc. Civil Engineers. Available at http://www.kimberly.uidaho.edu/water/asceewri/.

Campbell, W.D. 2013. "Spatial Analysis of Climate and Winegrape Production in Winegrape Growing Regions of Oregon, United States of America." Dissertations and Theses. Paper 1442.

Cuenca, R.H., 1992. Oregon crop water use and irrigation requirements: Corvallis, Oregon State University, Department of Bioresource Engineering, Extension Miscellaneous 8530, 184 p.

Doorenbos, J., and W.O. Pruitt. 1977. "Crop Water Requirements," Irrigation and Drainage Paper No. 24, Food and Agriculture Organization of the United Nations, Rome.

Hamlet, A.F., M.M. Elsner, G.S. Mauger, S.Y. Lee, I.M. Tohver, and R.A. Norheim. 2013. An overview of the Columbia Basin Climate Change Scenarios Project 187 Approach, methods, and summary of key results. Atmosphere-Ocean 51(4):1– 24.

Huntington, J.L., and R. Allen. 2010. Evapotranspiration and Net Irrigation Water Requirements for Nevada, Nevada State Engineer's Office Publication, 266 p.

Huntington et al. (Huntington, J.L., Gangopadhyay, S., Spears, M., Allen, R. King, D., Morton, C., Harrison, A., McEvoy, D., and A. Joros). 2015. West-Wide Climate Risk Assessments: Irrigation Demand and Reservoir Evaporation Projections. U.S. Bureau of Reclamation, Technical memorandum No. 68-68210-2014-01, 196p., 841 app. Available at http://www.usbr.gov/WaterSMART/wcra/.

IPCC (Intergovernmental Panel on Climate Change). 2007. Climate Change 2007: Synthesis Report. Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Islam, Adlul, Lajpat R. Ahuja, Luis A. Garcia, Liwang Ma, Anapalli S. Saseendran, and Thomas J. Trout. 2012. Modeling the impacts of climate change on irrigated corn production in the Central Great Plains, Agricultural Water Management, 110, issue C, p. 94–108.

Jones, G.V. 2005. Climate change in the western United States grape growing regions. *Acta Horticulturae* (ISHS), 689:41-60. Available at http://www.sou.edu/assets/envirostudies/gjones_docs/GJones-ActaHorticulturae05.pdf.

Kimball, B.A., and B.S. Idso. 1983. Increasing atmospheric CO2: Effects on crop yield, water use, and climate. Agricultural Water Management 7(1):55–72.

Kruijt B., J.P.M. Witte, C.M.J. Jacobs, T. Kroon. 2008. Effects of rising atmospheric CO2 on evapotranspiration and soil moisture: A practical approach for the Netherlands, Journal of Hydrology, 349(3-4):257–267.

Manabe, S., and R.T. Wetherald. 1987. Large-scale changes of soil wetness induced by an increase in atmospheric carbon dioxide. Journal of the Atmospheric Sciences 45(5):1211–1235.

Maurer, E.P., A.W. Wood, J.C. Adam, D.P. Lettenmaier, and B. Nijssen. 2002. "A Long-Term Hydrologically-Based Data Set of Land Surface Fluxes and States for the Conterminous United States," Journal of Climate 15(22):3237–3251.

Maurer, E.P., L. Brekke, T. Pruitt, and P.B. Duffy. 2007. "Fine-resolution climate projections enhance regional climate change impact studies," Eos Trans. AGU 88(47):504

Maurer, E.P., L. Brekke, T. Pruitt, B. Thrasher, J. Long, P. Duffy, M. Dettinger, D. Cayan, and J. Arnold. 2013. An enhanced archive facilitating climate impacts and adaptation analysis, Bulletin of the American Meteorological Society, DOI: 10.1175/BAMS-D-13-00126.1.

Mote, P., A.K. Snover, S. Capalbo, S.D. Eigenbrode, P. Glick, J. Littell, R. Raymondi, and S. Reeder, 2014: Ch. 21: Northwest**.** Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 495-521.

Mote, P.W., J. Bethel, S.M. Capalbo, M.M. Dalton, S.E. Eigenbrode, P. Glick, L. Houston, J.S. Littell, K. Lynn, R.R. Raymondi, W.S. Reeder, and A.K. Snover, 2013: Climate Change in the Northwest, Brief Summary.

OEA (Oregon Office of Economic Analysis). 2013. Forecasts of Oregon's County Populations and Components of Change, 2010 – 2050. Accessed June, 2015. Available at http://www.oregon.gov/DAS/OEA/demographic.shtml.

OWRD (Oregon Water Resources Department). 2008. Statewide Water Needs Assessment: Oregon Water Supply and Conservation Initiative. Available at http://www.oregon.gov/owrd/law/docs/owsci/owrd_demand_assessment_report_final_september_2008.pdf.

______. 2015. OWRD Water Rights GIS Data. Accessed June, 2015. Available at http://apps.wrd.state.or.us/apps/gis/wr/Default.aspx.

PSU-PRC (Portland State University Population Research Center). 2015. Coordinated Population Forecasts for Region 1. Accessed June, 2015. Available at http://www.pdx.edu/prc/region-1-documents.

Reclamation (U.S. Department of the Interior, Bureau of Reclamation). 2011. West-wide Climate Risk Assessments: Bias-Corrected and Spatially Downscaled Surface Water Projections, Technical Service Center, Denver, Colorado, March.

Rosenberg, N.J. 1981. The increasing CO2 concentration in the atmosphere and its implication on agricultural productivity. I: Effects on photosynthesis, transpiration and water use efficiency. Climatic Change 3(3):265–279.

USGS (U.S. Geological Survey). 2010. Oregon Water Use Compilation. National Water Information System: Web Interface. Available at: http://waterdata.usgs.gov/or/nwis/water_use/

U.S. Census Bureau. 2011. Oregon Census Data 2010 TIGER file. U.S. Department of Commerce U.S. Census Bureau Geography Division. Available at https://www.census.gov/geo/maps-data/data/tiger-data.html.

USDA (U.S. Department of Agriculture). 2014a. 2012 Census of Agriculture, State and County Data. May. Available at http://www.agcensus.usda.gov/Publications/2012/.

Wood, A.W., E.P. Maurer, A. Kumar, and D.P. Lettenmaier. 2002. “Long-range experimental hydrologic forecasting for the Eastern United States,” Journal of Geophysical Research-Atmospheres 107(D20), 4429, DOI: 10.1029/ 2001JD000659.

Wright, J.L. 1981. “Crop Coefficients for Estimates of Daily Crop Evapotranspiration,” Irrigation Scheduling for Water and Energy Conservation in the 80s, ASAE, St. Joseph, Michigan, pp. 18–26.

______. 1982. “New evapotranspiration crop coefficients,” Journal of Irrigation and Drainage Engineering 108(1):57–74.

______. 1991. “Using weighing lysimeters to develop evapotranspiration crop coefficients,” pages 191–199 in: R.G. Allen, T.A. Howell, W.O. Pruitt, I.A. Walter, and M.E. Jensen (eds.). Proc. of the International Symposium on Lysimetry, July 23–25, Honolulu, Hawaii, ASCE, 345 E. 47th St., New York, NY 10017-2398.

This page left blank intentionally.

Despite Oregon's reputation as a relatively "wet" state, water users across its varied landscape face real challenges in balancing out-of-stream and instream needs. Oregon's water resource challenges are expected to intensify over time, driven by increases in population, changes in the climate, and responsive shifts in land uses and technologies. In combination, these drivers will alter the availability and quality of water supplies as well as the nature and quantity of water demands across Oregon.

As its central purpose, this water demand forecast seeks to start a conversation about the changing water demands throughout Oregon. Understanding the drivers and uncertainties around water demand helps to frame discussions the Oregon Water Resources Department hopes to engage in with the help of water managers and users statewide.

Oregon Water Resources Department
725 Summer Street NE, Suite A
Salem, OR 97301

Rachel LovellFord
Technical Lead
2015 Water Demand Forecast
(503) 986-0836
Rachel.M.LovellFord@wrd.state.or.us

Alyssa Mucken
Integrated Water Resources
Strategy Coordinator
(503) 986-0911
Alyssa.M.Mucken@wrd.state.or.us

Kim Ogren
Senior Water Resources
Development Advisor
(503) 986-0913
Kim.L.Ogren@wrd.state.or.us

MWH Global
806 SW Broadway, Suite 200
Portland, OR 97205

Jeffrey Payne
(503) 220-5460
jeff.payne@mwhglobal.com