Regional Water Supply Plan Update

October 2016

Prepared by the Regional Water Providers Consortium
of the Portland, Oregon, Metropolitan Area

Regional Water Supply Plan Update
2016

Acknowledgements

The 2016 Regional Water Supply Plan Update was completed in-house by Consortium and Consortium member staff. The project was financed and managed by the following Consortium members:

City of Beaverton
Clackamas River Water
City of Forest Grove
City of Gladstone
City of Gresham
City of Hillsboro
City of Lake Oswego
Metro
City of Milwaukie
Oak Lodge Water District
City of Portland
Raleigh Water District
Rockwood Water People's Utility District
City of Sandy
City of Sherwood
South Fork Water Board
Sunrise Water Authority
City of Tigard
City of Tualatin
Tualatin Valley Water District
West Slope Water District

• • • • • • • • •

The Consortium greatly appreciates the efforts of staff and the Regional Water Supply Plan Update Committee for their contributions to this plan. Although many people contributed, the Consortium would like to extend special thanks to the following people for their time and commitment to this project.

David Winship, City of Beaverton
Kari Duncan, City of Lake Oswego
Mike Rosenberger, Rockwood Water People's Utility District
Kristel Fesler, City of Hillsboro
Niki Iverson, City of Hillsboro
Nick Augustus, Tualatin Valley Water District
Carrie Pak, Tualatin Valley Water District
Wade Hathhorn, Sunrise Water Authority
Mike Whiteley, City of Gresham
Sara Petrocine, City of Portland
Hossein Parandvash, City of Portland
Lindsey Berman, Consortium Staff
Rebecca Geisen, Consortium Staff
Patricia Burk, Consortium Staff

Kari Hallenburg of Hallenburg Communications served
as the technical writer for this project.

Table of Contents

Introduction 1

Chapter 1. **Water Supply** 7

Chapter 2. **Water Demand Trend Analysis** 19

Chapter 3. **Conservation Program** 27

Chapter 4. **Emergency Preparedness** 39

Chapter 5. **Regional Interconnections** 53

Chapter 6. **Source Water Protection** 61

Chapter 7. **Regulatory Changes** 73

Chapter 8. **Future Challenges and Opportunities** 83

Conclusion 97

Appendix A: Analysis of Trend in Water Demand in the Retail Service Areas of the Regional Water Providers Consortium Members 99

Introduction

Overview 1
History 2
2004 RWSP Update 4
2016 RWSP Update 4
The Consortium Today 5
Public Involvement 6

Overview

The Regional Water Providers Consortium (Consortium) serves as a collaborative and coordinating organization to improve the planning and management of municipal water supplies in the greater Portland, Oregon, metropolitan region.

Regional Water Providers Consortium Members

City of Beaverton
Clackamas River Water
City of Forest Grove
City of Gladstone
City of Gresham
City of Hillsboro
City of Lake Oswego
Metro
City of Milwaukie
Oak Lodge Water District
City of Portland
Raleigh Water District
Rockwood Water PUD
City of Sandy
City of Sherwood
South Fork Water Board
Sunrise Water Authority
City of Tigard
City of Tualatin
Tualatin Valley Water District
West Slope Water District

Formed in 1997, the Consortium serves most water providers and their customers in Multnomah, Clackamas, and Washington counties. The Consortium is made up of 20 water providers and the regional government, Metro. Together, these entities provide about 90 percent of the Portland metropolitan area's drinking water.

Since its inception, the Consortium's key projects and activities have involved 1) studying and analyzing future water supplies in the region, 2) developing regional water system resiliency, and 3) providing a water conservation program that members can leverage as part of their water supply planning efforts. By working together, Consortium members not only achieve economies of scale but also ensure that the region has a long-term, reliable, efficient, and safe water supply for years to come.

The Consortium was formed to oversee the implementation of the Regional Water Supply Plan (RWSP), which was first compiled in 1996 by the region's water providers. The RWSP provides a comprehensive, integrated framework of technical information, resource strategies, and implementation actions to meet the water supply needs of the Portland metropolitan area to the year 2050. The RWSP is based on more than a dozen background documents and studies and includes policy objectives, regional water demands, an evaluation of existing and future water source options, conservation programs, transmission opportunities, and a set of resource strategies to meet future needs.

History

Prior to the development of the RWSP, water providers operated primarily independently and in their own interests. In the early 1990s, providers recognized that many issues applied to the region as a whole and that all parties would benefit by addressing them in a coordinated and collaborative manner. Some of those issues included:

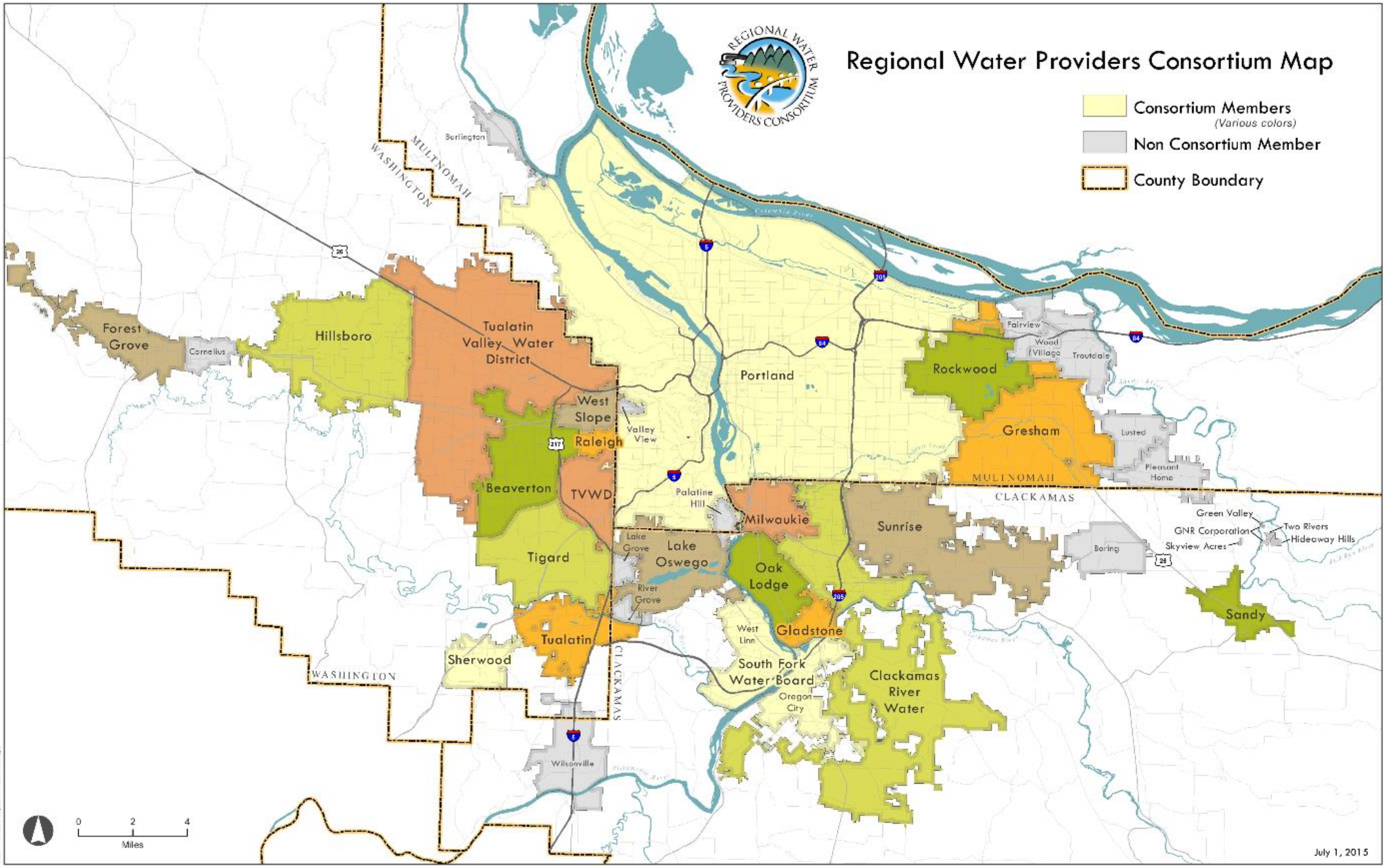
- formation of the regional government Metro and the potential for regional water planning to be conducted under Metro's charter
- access to new water rights and water right extensions
- regulatory changes
- population growth
- increased water demands
- in-stream water rights
- rising costs for new supplies

Twenty-seven water providers came together under an intergovernmental agreement (IGA) to fund and develop the RWSP. In 1996, the final RWSP was presented for consideration by all of the involved water providers, and the Consortium was formed through a new IGA.

By early 1997, the RWSP was endorsed by 26 water providers and Metro. The RWSP became a part of Metro's Regional Framework Plan and now serves to promote coordination between land use planning and water supply planning, fulfilling Metro's charter to address water supply and storage for the region.

The plan represented a new era of cooperation and collaboration among the region's municipal water providers. It is important to note that the RWSP does not require any mandatory action by any participant. The plan is notable for being one of the first regional water supply plans developed using an integrated resource planning process that looks at a wide range of traditional and innovative supply-side and demand-side (conservation) resources to develop long-term resource strategies.

Figure 1. Regional Water Providers Consortium map.



2004 RWSP Update

The Consortium IGA states that the RWSP be updated every 5–10 years. The RWSP was last updated in 2004. The two-year effort included an updated regional water demand forecast, assessment of changes in water supply conditions and sources, the evaluation and integration of a regional water conservation program, and development of an integrated planning model to assess future water program strategies. The 2004 Update focused on providing guidance for individual supply decisions and provided an outline for regional supply coordination. It reflected the actions and plans of the individual members and presented options for meeting future needs. The update did not prioritize particular source options or transmission linkages.

2016 RWSP Update

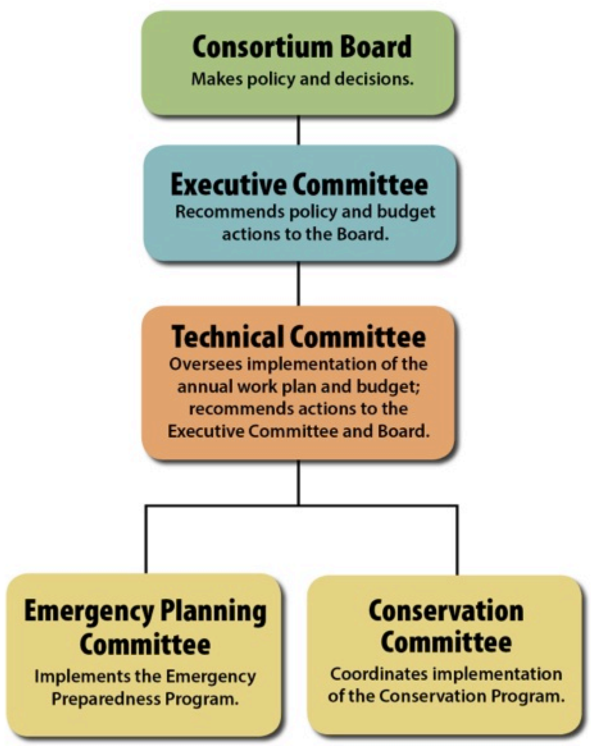
The 2016 RWSP Update is a more modest effort than the 2004 Update. This update consists of a compendium of changes since 2004 and does not include an update of the regional demand forecast or modeling of future water supply strategies. The Consortium Board chose to conduct a minor update to contain costs at a time when budgets were strained and because the existing RWSP is still a viable document. The original RWSP and the 2004 Update were completed primarily by consultants. Consortium and water provider staff members prepared and completed the 2016 Update. This update includes the following chapters:

- **Introduction**: provides the history of the RWSP and formation of the Consortium
- **Water Supply**: identifies major water supply changes over the last 10 years, such as the development of the Willamette River as a regional water source
- **Water Demands Trend Analysis:** looks at how water demands have changed over the last 10 years and the drivers of the downward trend in demand
- **Conservation Program**: highlights the regional water conservation programs that have been implemented by the Consortium and its members
- **Emergency Preparedness**: summarizes the Consortium's emergency preparedness program, which has grown significantly over the last 10 years; describes how it has contributed to the overall resiliency of the regional water system; discusses citizen preparedness; and identifies potential future projects
- **Regional Interconnections**: discusses the work that has been done by the Consortium to identify regional water system interconnections, their importance, and future opportunities
- **Source Water Protection:** discusses the source water protection efforts of members to ensure the long-term health and viability of our region's diverse water sources

- **Regulatory Changes**: identifies the major regulatory changes over the last 10 years and discusses potential future changes to the regulatory landscape
- **Future Challenges and Opportunities:** highlights many of the issues water providers face now and in the future and identifies ways the Consortium can help our region meet those challenges.

The Consortium Today

The Consortium is guided by a Board of elected officials from the member cities and water agencies. Four committees participate in the work of the Consortium. The Consortium's annual budget is around $900,000 per year and is funded by member-paid dues. A staff of 3.5 FTE works under an agreement with the City of Portland.



The Consortium's work focuses on three main areas:

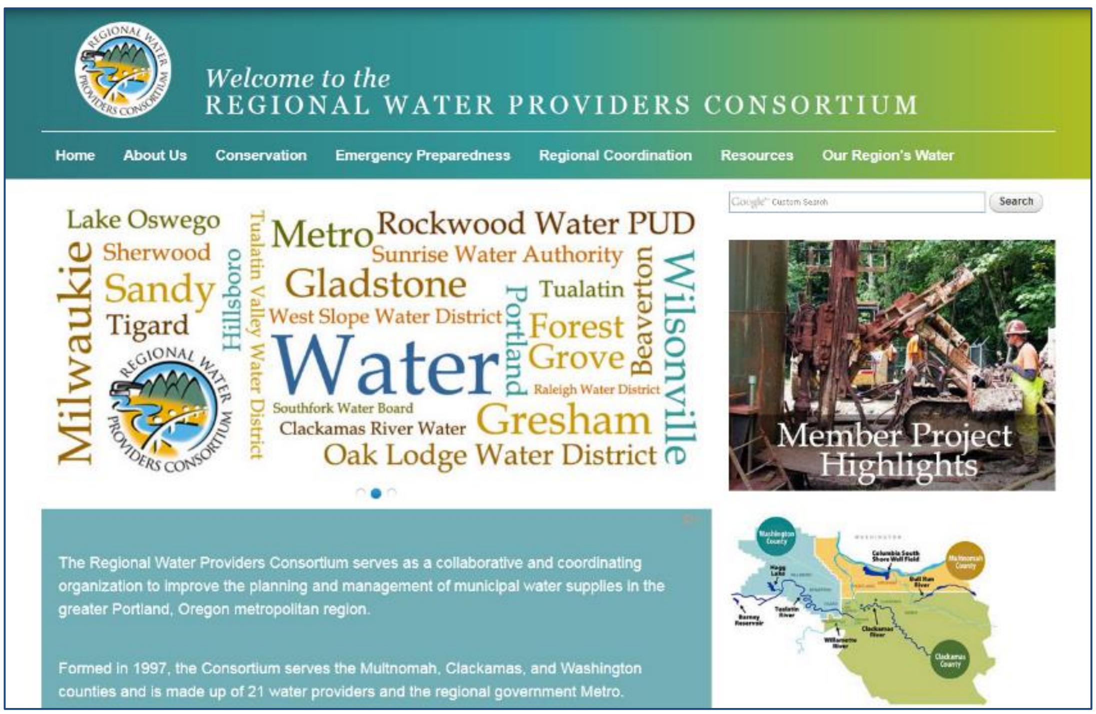
- **Regional coordination**, which includes the study and discussion of water supply issues; forecasting population; and working with Metro, Oregon Water Resources Department, the Oregon legislature, and other governmental bodies and organizations to represent the interests of municipal water providers.
- **Water conservation** program to help people use water more efficiently by using a diverse set of communication and outreach tools such as TV, radio, print media, websites and social media, school programs, events, workshops, and device distribution.
- **Emergency preparedness**, coordination, and collaboration among water providers in the region that includes training, exercises, and grant-funded equipment and studies to improve preparedness, response, and recovery.

A five-year strategic plan identifies three key strategic challenges for the Consortium, establishes strategic goals that form the Consortium's regional strategy, and guides future work. The three key challenges are: 1) meeting water supply needs, 2) emergency preparedness, and 3) building a better regional partnership. The update of the RWSP satisfies one of the goals identified in the strategic plan.

Public Involvement

The original RWSP and the 2004 Update included a significant public outreach effort because of its large scope and impact. The 2016 Update is a minor amendment to the RWSP; it is not a rewrite of the plan nor does it change the policy objectives or resource strategies that are still part of the RWSP. Because of the modest scope of the 2016 Update, the Consortium relied primarily on its website, electronic newsletter, and social media to inform the public about the update and opportunities to review it before the Consortium Board adoption in October 2016. The Consortium's website (www.regionalh2o.org) dedicated a page to the RWSP Update, and it was publicized in several on-line newsletters. The Consortium announced the development of the plan and opportunities for input on Facebook and Twitter.

The 2016 RWSP Update provides a look back at the Consortium's collaborative water supply planning and management of the region's water supplies over the last 10 years and identifies a path forward to provide long-term, reliable, efficient, and safe drinking water into the future. The RWSP Update serves to continue the legacy of integrated water resources planning in the Portland Metropolitan Region.



Chapter 1: Water Supply

Overview ... 7
Water Supply Options Update ... 8
Trask/Tualatin River Basin ... 8
Bull Run/Columbia South Shore Well Field (CSSWF) ... 9
Clackamas River ... 10
Willamette River ... 10
Other Local Sources ... 11
Water Supply Issues ... 12
Climate Change ... 12
Regional Transmission and Interties ... 13
Resiliency ... 14

Overview

Under the original 1996 Regional Water Supply Plan (RWSP), 29 different water supply options were considered for serving the Portland/Vancouver metropolitan area through 2050. Using the policy objectives established under the plan, the various supply options were evaluated based on the following criteria:

- water availability
- environmental impact
- raw water quality
- vulnerability to catastrophic events
- ease of implementation
- treatment requirements
- capital and operating cost

Five source options were selected and further evaluated, which included: Bull Run Dam 3, Clackamas River Diversion, Willamette River Diversion, Columbia River Diversion, and Aquifer Storage and Recovery (ASR). In the 2004 RWSP Update, the Consortium revised the list of issues to reflect changes in regulatory standards and water rights (such as municipal permit extensions) and global climate change concerns and added the expansion of sources to include the Trask/Tualatin and localized groundwater sources. At the time, the availability of the Columbia River was uncertain, and there was opposition by some communities regarding the potential use of the Willamette River. At the same time, however, the city of Wilsonville and the Tualatin Valley Water District (TVWD) made significant investments in the Willamette, and Wilsonville had started to use it as a new source.

In the 2004 Update, the Consortium focused on prioritizing source water development within the three major sub-basins serving the Metro area: Trask/Tualatin River, Bull Run, and Clackamas River. These source priorities are the same today, accompanied by significant interest in the Willamette River and ASR as water sources. This chapter provides updates since 2004 on the status of the region's five major water supply sources:

- Trask/Tualatin River
- Bull Run/Columbia South Shore Well Field (CSSWF)
- Clackamas River
- Willamette River
- ASR/groundwater

Issues and trends associated with each of these sources are described in this chapter and summarized in Table 1 (page 15).

Water Supply Options Update

Trask/Tualatin River Basin

The Trask/Tualatin River Basin has served the members of the Joint Water Commission (JWC) with water supply from stored water holdings in Hagg Lake and Barney Reservoir, along with various natural-flow water (available through water rights) in the Tualatin River Basin. The net storage available for municipal drinking water supply from both stored water facilities totals 28,386 acre-feet (ac-ft). In anticipation of rising demands for the cities of Hillsboro, Beaverton, and TVWD, the 2004 RWSP update identified a long-term plan to expand available storage in Scoggins Reservoir.

Scoggins Dam

Over the last decade, the interested parties spent significant time and resources examining various options to raise Scoggins Dam at Hagg Lake. Since 2004, additional studies indicate that because of the nature of the original construction of the dam, the existing structure requires extensive seismic upgrades and any expansion of storage may require significant improvements up to and including possible replacement of the existing dam.

Additional studies of dam rehabilitation were also tied to federal review and funding, which created uncertainty regarding the feasibility of completing a project in a timely manner. Concerns were also noted about the potential for extended interruption during periods of peak demand. Hillsboro and TVWD each completed an extensive evaluation of water supply options for their communities and determined the Willamette River to be the preferred source alternative to complement existing supply sources. This source option anticipates use of an existing intake along the Willamette River to help provide sufficient supply to meet the long-term needs for those communities.

Without expansion of Scoggins Reservoir, the JWC has set the peak capacity of its Trask/Tualatin River source (along with treatment) at about 100–120 million gallons per day (mgd). Since 2004, the JWC has increased its plant capacity on the Tualatin River from 60 mgd to 75 mgd, and future plans are to expand capacity to 85 mgd by 2019.

Bull Run/Columbia South Shore Well Field (CSSWF)

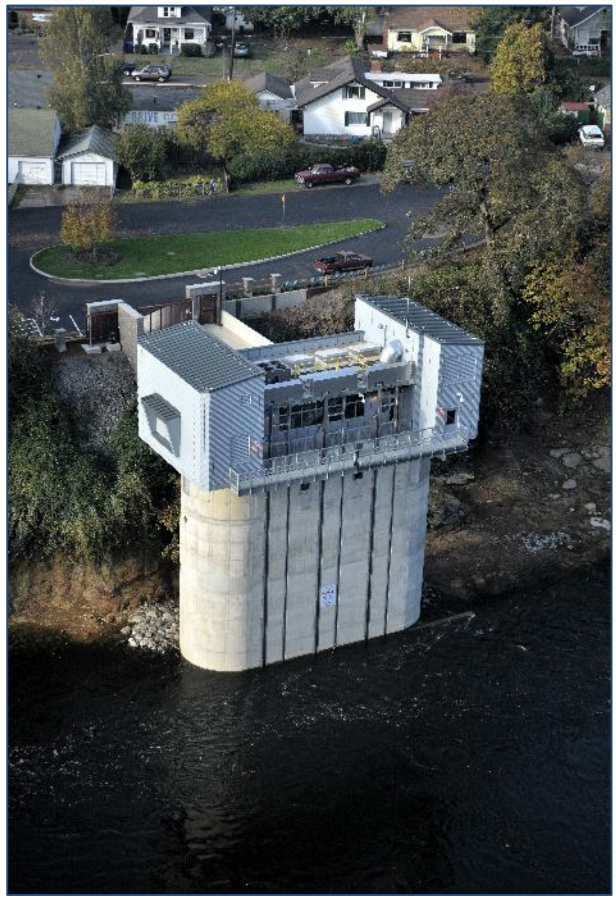
The Bull Run Watershed is the City of Portland's main supply and a key water source for Portland's wholesale customers. The supply is principally composed of two major storage reservoirs (dam 1 and 2) that provide a total useable storage of 30,340 ac-ft. (9,900 MG) with transmission conduits that serve a peak capacity of 209 mgd. In 2004, expansion options for this source included raising dam 2 (adding 6,750 ac-ft), replacing the gates at dam 1 with higher gates (adding 630 ac-ft), and possibly adding a third dam (dam 3) to contribute 58,300 ac-ft of usable storage.

Bull Run Dam 1

Planned rehabilitation of existing facilities has been completed. Due to reduced overall and per capita demands, no additional storage has been added to the Bull Run system since 2004. Portland has initiated a supply system master plan process to determine, among other things, if additional supply for the Portland system is likely to be needed in the next 20 years.

Portland has a second water source in the Columbia South Shore Well Field (CSSWF), which serves as a summertime augmentation source and emergency backup supply. Several improvements have been made since 2004 to the well field that have expanded capacity from 90 mgd (over 30 days) to 92 mgd (over 90 days). Portland's Water Management and Conservation Plan identifies plans to create additional well capacity of 138.7 mgd (over 90 days) by 2028.

Clackamas River



Clackamas River Intake

The Clackamas River serves as the water source for four major treatment plants owned by South Fork Water Board (SFWB), Clackamas River Water (CRW), North Clackamas County Water Commission (NCCWC), and the City of Lake Oswego. Among these parties, existing water rights total 373 cubic feet per second (cfs) of which about 122 cfs are junior in priority date to minimum in-stream flows. In 2004, the various plants had a combined treatment capacity of 76 mgd: NCCWC, 10 mgd; City of Lake Oswego, 16 mgd; CRW, 30 mgd; and SFWB, 20 mgd. Since then, the NCCWC has added 10 mgd to its plant, and the cities of Lake Oswego and Tigard have joined in a partnership to build out their plant, adding 22 mgd of capacity. South Fork also added 10 mgd to its plant and has plans to add another 23.7 mgd in the future. The combined total would bring the future capacity of this source to 141.7 mgd.

Willamette River

In 2004, the Tualatin Valley Water District (TVWD) and the City of Wilsonville held rights on the river of 130 mgd and 19.4 mgd, respectively. The two providers built shared treatment capacity of 15 mgd, and TVWD added intake capacity to allow for its entire right to be diverted at that location in the future. TVWD later turned its water right over to the Willamette River Water Coalition (WRWC), and it is now

Sherwood

shared by TVWD and the cities of Sherwood, Tigard, and Tualatin. TVWD also sold its original 5 mgd treatment capacity to the City of Sherwood.

Today, a number of other agencies have started work on improvements to increase the use of the Willamette River as a future water source. The cities of Beaverton and Hillsboro each have added rights of 21.7 and 36.2 mgd, respectively. TVWD and the City of Hillsboro have formally joined to develop as much as 95 mgd of new treatment capacity and are constructing water supply facilities as part of the Willamette Water Supply Program (WWSP), with 56.5 mgd of that capacity going to TVWD and the other 36.2 mgd to the City of Hillsboro. Beaverton is also considering joining the WWSP. Wilsonville and Sherwood are investigating separate treatment plant expansions ranging from approximately 5 mgd to 10 mgd within the next 5 to 10 years. In addition, negotiations are in progress for developing an intergovernmental agreement for overseeing the management of a new regional water supply system that includes the cities of Wilsonville, Sherwood, Beaverton, Hillsboro, Tigard, Tualatin, and TVWD. These parties, with the exception of Tualatin, are currently completing a joint Water Treatment Plant Master Plan for future treatment facilities.

Other Local Sources

A variety of "local sources" based on ground and surface water rights were identified in the 2004 RWSP Update. Of the 106.6 mgd in total rights reported, 34.5 mgd were designated as installed capacity and, of that capacity, 29.9 mgd was associated with groundwater wells. Some portion of this groundwater capacity was reported as planned aquifer storage and recovery (ASR) programs. The largest active ASR program at the time was being developed by the City of Beaverton with an operating capacity of 4 mgd under a joint limited license (LL 002) with Tualatin Valley Water District for 500 MG of storage capacity. Tigard, Tualatin, and Clackamas River Water also reported ASR pilot programs totaling 850 MG of storage.

Since 2004, many water providers have developed ASR or groundwater supplies or added capacity. See Table 1 for a summary of these changes.

Looking forward, Rockwood Water PUD and Gresham have plans to add another 10 mgd and 5 mgd in groundwater capacity, and Sunrise plans to add another 6.5 mgd in ASR capacity. Hillsboro is planning a future 2 mgd (100 MG) ASR pilot program and may also develop a joint well with one of the JWC partners.

Rockwood Water PUD Well

Water Supply Issues

In the 2004 RWSP Update, the major issues affecting source options were regulatory changes, water rights, water availability and management, and climate change. While these remain issues today, water providers face an additional challenge. In 2004, there was limited understanding or awareness of the critical impacts that a large earthquake would have on water supply in the Portland metro region. The Oregon Resiliency Plan, published by the state in 2013, documented the vulnerability of water supplies in light of an improved understanding of the significance of the Cascadia Subduction Zone. This section discusses current climate change research related to water supply, regional transmission and interties and resiliency.

Climate Change

In 2014, the U.S. Global Change Research Program published a comprehensive assessment of projected climate change impacts for the United States. Regarding water resources in the Pacific Northwest, the report concludes that "changes in the timing of streamflow related to changing snowmelt have been observed and will continue, reducing the supply of water for many competing demands and causing far reaching ecological and socioeconomic consequences."[1]

In particular, the report notes that temperatures have increased across the region that includes Oregon, Washington, and Idaho by an average of 1.3 °F from 1895 to 2011. Temperatures are projected to increase in this region from 3.3 °F to 9.3 °F by 2070–2099 depending on the level of ongoing greenhouse gas emissions that occurs going forward.[2]

[1] Mote, P.A.K., et al., 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, 487–513.

[2] Ibid., p. 489.

The largest hydrologic responses to these projected changes are anticipated in surface water basins with significant annual accumulations of snow where warming is anticipated to increase winter flows and advance the timing of spring melt.[3] There has not yet been significant research into potential impacts to local groundwater resources; however, groundwater supply is typically less sensitive to seasonal variability in precipitation.

The regional water sources most vulnerable to these changes are those that are fed by significant amounts snowpack, most notably the Clackamas Basin. By contrast, the Bull Run and Trask/Tualatin River basins are rain-dominated and therefore somewhat less vulnerable to this particular projected climate change impact. All local systems will likely face the challenge of anticipated vegetation changes in regional watersheds and an increased frequency of wildfires.

Anticipating and planning for projected climate change impacts require ongoing study of expected hydrologic effects and a close watch on consumption trends and projections. Although population continues to increase in the region, per capita consumption, and, in many cases, total consumption continue to decline. To date and for the near-term, the effect of greater water use efficiency is expected to continue to outpace the effects of climate on available supply for Portland.

Regional Transmission and Interties

The region's principal water supply strategy described in the 2004 RWSP Update focused on local basin development for the Tualatin River, Bull Run, and Clackamas River sources. At the time, the main regional transmission capacities were the City of Portland's wholesale network, which included the Washington County supply line, and various other wholesale delivery features. The Joint Water Commission also had constructed a significant transmission and delivery system to serve TVWD and the cities of Hillsboro, Forest Grove, and Beaverton from its plant along the Tualatin River. In the Clackamas River Basin area, the four major water suppliers developed separate long-term supply plans for each of the treatment plants: South Fork, CRW, NCCWC, and the City of Lake Oswego. South Fork and the NCCWC, along with CRW, constructed an important intertie between their facilities.

Since 2004, there have been few significant improvements to the regional-scale system. The cities of Lake Oswego and Tigard are constructing shared plant improvements and, in the process, have constructed a new raw-water transmission line that passes beneath the Willamette River between the intake along the Clackamas River and the new treatment plant in West Linn. Members of the Clackamas River Water Providers are examining the old raw-water line that served these facilities as a possible emergency intertie across the Willamette River.

[3] Ibid., p.489.

The pipeline could allow finished water from cities of Tigard or Lake Oswego to pass back across the Willamette River to a connection point in the City of Gladstone, which in turn could be fed back to the NCCWC.

The current plans for expanding the use of the Willamette River must address the need for a significant new transmission line to supply finished water to TVWD, Hillsboro, and other members of the Willamette Water Supply Program. Those plans will include various intertie improvements between TVWD, Hillsboro, and the other participating members. Together, these projects present transmission opportunities and the option for future interconnections with regional supply sources.[4]

Resiliency

As mentioned, much has been learned about the impacts of a Cascadia Subduction Zone earthquake on water systems and other infrastructure. As a result, several of the larger water providers are conducting seismic assessments as part of their water system master plans. Information from these studies is being shared to benefit the region. Many water providers are also including seismic upgrades as part of infrastructure improvements or when constructing new facilities. Focusing on system backbone and water supply to critical facilities drives much of the planning. As discussed in Chapters 4 and 5, water providers are engaged in regional emergency planning coordination and improving regional interconnections to increase overall resilience of our regional water supply network.

[4] Parandvash, G. Hossein, and Chang, Heejan. 2016. "Analysis of Long-term Climate Change on Per Capita Water Demand in Urban Versus Suburban Areas in the Portland Metropolitan Area, USA." *Journal of Hydrology* **538**:574–586.

Table 1: Source Option Expansion and Development (2004, 2015, 2016–2035).

2004 RWSP Update				
Trask/Tualatin	**Bull Run/CSSWF**	**Clackamas River**	**Willamette River**	**ASR/Groundwater**
Scoggins Reservoir: 13,500 ac-ft (13,095 ac-ft net available) Barney Reservoir: 18,000 ac-ft (14,139 ac-ft net available) Water Rights: 74 mgd (115 cfs) available at WTP[1] JWC WTP: 70 mgd (peak capacity)	Reservoirs 1 & 2: 30,400 ac-ft (9,900 MG) Conduit Capacity: 210 mgd Option for Dam 3: possible addition of 58,300 ac-ft (172 mgd) CSSWF: 90 mgd (30 days)	Lake Oswego: 38 mgd (16 mgd WTP) South Fork Water Board: 53.7 mgd (20 mgd WTP) NCCWC: 40 mgd (10 mgd WTP) › CRW: 40 mgd (30 mgd WTP)	Wilsonville: 19.4 mgd (10 mgd WTP) TVWD: 130 mgd	**Groundwater** Rockwood PUD: 11.1 mgd Lake Oswego: 0.5 mgd Sunrise: 3.5 mgd Powell Valley: 8 mgd[2] Sherwood: 3.3 mgd Beaverton: 3 mgd Tigard: 0.6 mgd Sherwood: 3.3 mgd **ASR** Shown as: Storage Volume (Recovery Rate) Tigard: 250 MG (1.4 mgd) Portland: 1,000 MG (12 mgd) Beaverton: 500 MG (3 mgd) CRW: 100 MG (1 mgd)

ac-ft: acre feet
ASR: aquifer storage and recovery
CRW: Clackamas River Water District
CSSWF: Columbia South Shore Well Field
JWC: Joint Water Commission
mgd: million gallons per day
NCCWC: North Clackamas County Water Commission
TVWD: Tualatin Valley Water District
WRWC: Willamette River Water Coalition
WTP: water treatment plant

[1] Substantial portions of the water rights for natural flow are unavailable during periods of low flow (summer)
[2] Powell Valley wells were acquired by Portland Water Bureau in 2005

2016 RWSP Update				
Trask/Tualatin	**Bull Run/CSSWF**	**Clackamas River**	**Willamette River**	**ASR/Groundwater**
Scoggins Reservoir: 13,500 ac-ft (4,399 MG) Barney Reservoir: 14,886 ac-ft (4,851 MG) Water Rights: 125 mgd (194 cfs)[1] JWC WTP: 75 mgd (peak capacity), divided - Hillsboro: 33.75 mgd - Forest Grove: 10.0 mgd - Beaverton: 18.75 mgd - TVWD: 12.5 mgd JWC added 20 MG of finished water storage at Fern Hill Reservoir (40 MG total) Hillsboro added 10 MG at Crandall Reservoir	Reservoirs 1 and 2: unchanged Conduit capacity: 209 mgd Option for Dam 3: suspended Eliminated uncovered reservoirs at Mt. Tabor (added 50 MG to Powell Butte and 10 MG to Kelly Butte) CSSWF: 92 mgd (90 days)	Lake Oswego: 38 mgd (32 mgd WTP) South Fork Water Board: 53.7 mgd (30 mgd WTP) NCCWC: 40 mgd (20 mgd WTP) CRW: unchanged	**Water Rights** Wilsonville: 19.4 mgd WRWC: 130 mgd Hillsboro: 36.2 mgd Beaverton: 21.7 mgd **WTP Capacity** Wilsonville/Sherwood: 15 mgd WTP Planning for WWSP WTP is underway	**Groundwater** Rockwood PUD: 13.7 mgd Lake Oswego: 0.5 mgd Sunrise: 3.5 mgd Powell Valley: 7.4 mgd[2] TVWD: 3 mgd Beaverton: 3 mgd Tigard: 0.6 mgd Gresham: 5 mgd **ASR** Shown as: Storage Volume (Recovery Rate) Tigard: 250 MG (4.0 mgd) Portland: 1,000 MG (12 mgd) Beaverton: 500 MG (5 mgd) Tualatin: 0.5 mgd TVWD: 700 MG (5 mgd) Sunrise: 600 MG (1.5 mgd)

ac-ft: acre feet
ASR: aquifer storage and recovery
CRW: Clackamas River Water District
CSSWF: Columbia South Shore Well Field
JWC: Joint Water Commission
mgd: million gallons per day
NCCWC: North Clackamas County Water Commission
TVWD: Tualatin Valley Water District
WRWC: Willamette River Water Coalition
WTP: water treatment plant

[1] Substantial portions of the water rights for natural flow are unavailable during periods of low flow (summer)
[2] Powell Valley wells were acquired by Portland Water Bureau in 2005

2016–2035 (20-year plan)				
Trask/Tualatin	**Bull Run/CSSWF**	**Clackamas River**	**Willamette River**	**ASR/Groundwater**
Scoggins Reservoir: unchanged Barney Reservoir: unchanged Water Rights: unchanged JWC WTP: 85 mgd (peak capacity), divided - Hillsboro: 41.75 mgd - Forest Grove: 10.0 mgd - Beaverton: 18.75 mgd - TVWD: 14.5 mgd	Reservoirs 1 and 2: unchanged Conduit capacity: unchanged Eliminate uncovered reservoir Washington Park 4 CSSWF: 41 mgd (90 days)	Lake Oswego/Tigard: 38 mgd (32 mgd WTP) South Fork Water Board: 53.7 mgd (53.7 mgd WTP) NCCWC: 40 mgd (20 mgd WTP) CRW: unchanged	**Water Rights** Unchanged **WTP Capacity** Wilsonville/Sherwood: 20-25 mgd WTP WWSP WTP: approx. 65 mgd, divided - TVWD: approx. 40 mgd - Hillsboro: approx. 20 mgd - Beaverton: approx. 5 mgd	**Groundwater** Rockwood PUD: 23.7 mgd Lake Oswego: 0.5 mgd Sunrise: 3.5 mgd Powell Valley: 10.2 mgd[2] Tualatin: 0.5 mgd TVWD: 3.0 mgd Beaverton: 3.0 mgd Gresham: 10 mgd **ASR** Shown as: Storage Volume (Recovery Rate) Tigard: 250 MG (4.0 mgd) Portland: 1,000 MG (12 mgd) Beaverton: 800 MG (9 mgd) Tualatin: 0.5 mgd TVWD: 700 MG (5 mgd) Hillsboro: 100 MG (2 mgd) Sunrise: 600 MG (8 mgd)

ac-ft: acre feet
ASR: aquifer storage and recovery
CRW: Clackamas River Water District
CSSWF: Columbia South Shore Well Field
JWC: Joint Water Commission
mgd: million gallons per day
NCCWC: North Clackamas County Water Commission
TVWD: Tualatin Valley Water District
WRWC: Willamette River Water Coalition
WTP: water treatment plant

[1] Substantial portions of the water rights for natural flow are unavailable during periods of low flow (summer)
[2] Powell Valley wells were acquired by Portland Water Bureau in 2005

Chapter 2: Water Demand Trend Analysis

Overview 19
Level One Analysis 20
Exploring the Nature of the Trend 21
Level One Analysis Findings 21
Level Two Analysis 21
Level Two Analysis Findings 22
Conclusion 23

Overview

The Regional Water Providers Consortium (RWPC) conducted a study to look at how water demands have changed in the last 10 years and what factors have contributed to that change. The study analyzed the trend in water demand and whether conservation-related actions had a bearing on the trend. Two levels of analysis were conducted. The first looked at the overall trend among water providers and the second looked at the factors contributing to the overall trend based on a more detailed analysis of a few water providers. The complete "Analysis of Trend in Water Demand in the Retail Service Areas of the Regional Water Providers Consortium Members" is located in Appendix A.

The analysis shows that demand was generally decreasing during the period evaluated and decreases in per capita demand outpaced increases in demand due to population growth over the study period. The primary driver for decline is likely due to the price of water.

What is "trend analysis"?

The "trend" in measurement of a variable is the general direction of the changes in that variable over time. For example, the price of an item in the market may fluctuate over a short period of time, but the general direction of the price over a longer period of time might be increasing, decreasing, or constant.

In analyzing data for trend, three things are considered.

1. Whether the data show trend at all. The data may fluctuate over time, but the general direction is neither up nor down.
2. The direction of trend. The data show that the general direction is up or down (positive or negative).
3. The intensity of trend. The steepness of the general direction of the trend, as shown by the data. For example, if the trend is positive (increasing), the steepness refers to how fast it changes — does the price double or quadruple, etc., over the long run?
4. All three aspects of trend can be tested and measure by statistical models.

Level One Analysis

The goal of the Level One analysis was to examine the overall trend in the demand for water in the retail service areas of a representative sample of Consortium members and to determine the nature and intensity of the trend.

The participating Consortium members belong to different service areas with varying population sizes and, therefore, different levels of demand. For this analysis, Consortium members were asked to provide water consumption and production data for their retail service area for the 2004–2013 period.

The water consumption data consist of annual billed consumption by residential and nonresidential retail customers. Nonresidential customers include commercial, industrial, institutional, and any other customer not considered residential. The production data consist of annual, winter, summer, and peak day demands, which include retail consumption and unaccounted-for-unbilled water.

Eleven of the Consortium members provided complete sets of consumption data, and 14 members provided complete sets of production data. Population figures (estimated by Portland State University Population Research Center for the retail service areas) and the demand data were used to develop various consumption and production metrics for the purpose of the trend analysis.

Full details on data and metrics as well as the methodology used for the Level One Analysis can be found in Appendix A.

Water production and water consumption

"Water production" refers to the amount of water a water provider makes available through the water system. The system typically consists of a water treatment plant(s), pipes, pumps, etc. Production is usually measured by a master meter at the point of transmission, which is where the water is delivered into the big pipes that carry the water to the points where it is distributed to neighborhoods and eventually to customers.

"Water consumption" refers to the water that is actually consumed by customers in households, businesses, etc. Consumption is measured by individual meters installed on the properties that receive water. Consumption records are tracked and stored in the billing system of the water provider. The difference in the amounts of water produced and consumed is usually includes leaks in the system, water used for system flushing, water used for fire extinguishing, and unauthorized water use.

Exploring the Nature of the Trend

Figures 1 and 2 (page 24) show the annual and average day per capita consumption by the retail residential customer class of the participating Consortium members. Trend lines are fitted to the graphs to assist in the visual assessment of the direction of the trend. Figure 1 shows that for 9 of the 11 providers that had residential data available, the annual consumption has a visible downward trend. Figure 2, on the other hand, shows a visible downward trend in the average day per capita consumption for 10 of the same 11 providers. The indication is that, for the majority of providers (10 out of 11), reduction in per capita residential consumption outpaces the increase in demand as a result of population growth.

A regression model was used to measure the intensity and the statistical significance of the trend in the various consumption and production metrics. Appendix A provides a detailed discussion of the statistical analysis of the nature and intensity of the water demand trend.

Level One Analysis Findings

1. For the majority of the participating Consortium members that had data available, per capita water demand in the region generally decreased between 2004 and 2013.
2. In the majority of the cases, the decline in per capita water demand outpaced the growth in demand due to population increases.
3. The rate of decline in per capita residential and nonresidential water consumption was the same for most members, with a few exceptions. Hillsboro showed a greater rate of decline in residential per capita consumption than other Consortium members. Tigard, Sandy, and Wilsonville had greater rates of decline in nonresidential per capita consumption than other members. Overall, however, this trend appears to indicate that the factors that impacted per capita demand affected residential and nonresidential to about the same degree.
4. The decreasing water demands of the participating Consortium members could be a result of changes in factors that are related to conservation, economy, weather, price of water, and land use. Some of these factors are examined in the Level Two analysis.

Level Two Analysis

Retail service area populations were used to compute daily per capita water production. Using per capita figures controls for the effect of population growth on demand. Econometric demand models were developed to explain the variations in daily per capita demand due to factors such as weather, seasonality, economy, and price of water.

The participants also provided data on annual revenue per million gallons. The revenue data are used as a proxy for the price of water in the econometric models. The participating water providers have different rate structures, and rates may not be the same for all customer classes.

The retail production used in this analysis includes water consumed by all customer classes and the unaccounted-for water.

The circuitous cause-and-effect relationship between price and demand that exists for water utilities is a factor to be considered in this analysis. When faced with falling demand as a result of factors other than price, water utilities tend to recover costs by increasing rates while keeping revenue neutral. The increase in rates could put additional downward pressure on demand, which could lead to another round of rate increases.

The effect of non-price factors on demand such as conservation programs, plumbing code changes, changes in conservation attitude, and changes in land use, are usually long-term in nature and continuous. As a result, the trend in demand reflects the trend in the price of water as well as the trend in non-price factors and the trend in the price of related services such as sewer. The estimated effect of price in the demand model, therefore, includes the effect of some other factors as well.

Appendix A provides complete details on data and metrics as well as the methodology used for the Level Two Analysis.

Level Two Analysis Findings

1. The price of water[5] has increased for all five of the Level Two Analysis participants over the 2004–2013 period.
2. For most providers, the price of water had the most significant effect on declining demand.[6]
3. Weather and short-term economic cycles[7] during the study period do not appear to have had a significant effect on declining demand.

---

[5] The inflation-adjusted revenue per million gallons was used as a proxy for the price of water.

[6] This is not the case in Tualatin, where the price increase has been smaller and therefore has had a smaller impact on demand.

[7] As represented by the annual unemployment rate in the Portland Metropolitan Statistical Area (MSA).

4. The effect of price on the intensity of trend in demand could be partly attributable to conservation and water-efficiency-related factors, land use, price of sewer, and other factors that affect water demand in the long-term that are not represented in the demand models.

Table 1 provides the changes in trend intensity as a result of adjusting per capita demand metrics for weather, economy, and price effect for the retail service areas in this analysis.

Conclusion

Both levels of analysis in this study indicate that within the past 10 years the per capita demand has been on the decline in the region. For most water providers, the trend in total demand has been decreasing as well. The Level 2 analysis shows that, for the most part, the decreasing trend in the per capita consumption can be attributed to increasing trend in price of water along with impact of conservation and land use.

The current levels of analyses cannot tell us what will happen to total demand in the next 10 years. The "Residential End Uses of Water, Version 2," published April 2016 by the Water Research Foundation (DeOreo et al.),[8] shows that per capita demand by all customer classes continues to fall in the future, certainly beyond the next 10 years. Trend in total demand, however, depends on the customer class mix of the service area. Service areas with strong demand by the nonresidential class could experience increasing trend in total demand in the future when the economy is in the upswing. New high-water-user commercial, industrial, and institutional customers could reverse the impact of decreasing per capita use as well. Prognosis of the nature of trend in total demand in the future needs more research and analysis that is best conducted by the individual water providers in the region.

[8] DeOreo, William, B., Dziegielewski, Benedykt, Kiefer, Jack, and Sawyer, P.C. 2016. "Residential End Uses of Water." Water Research Foundation, Denver, Colorado. Available at http://www.waterrf.org/PublicReportLibrary/4309A.pdf

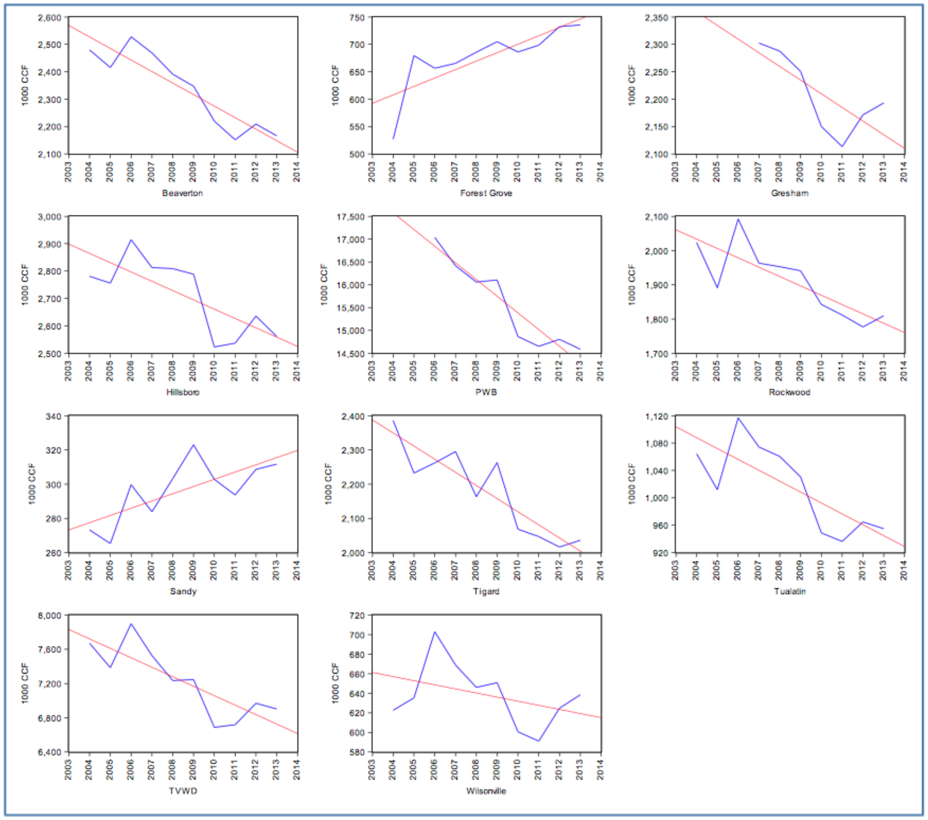


Figure 1. Annual water consumption by the residential class of the participating Consortium members 2004–2013. For 9 of the 11 providers that had residential data available, the annual consumption has a visible downward trend.

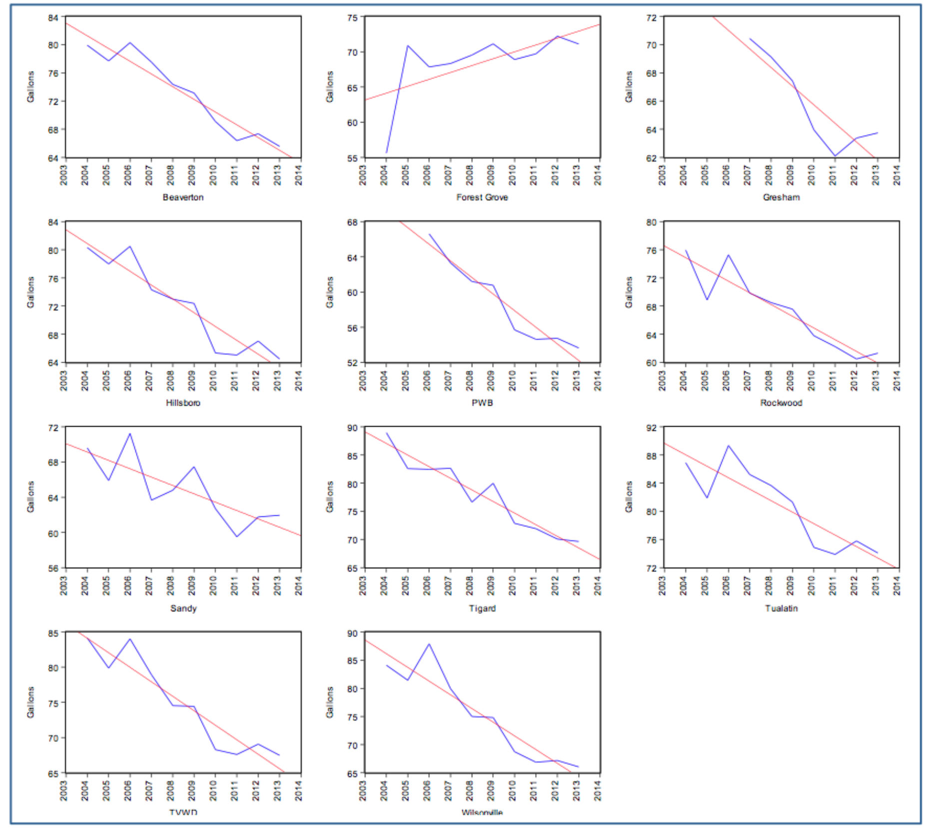


Figure 2. Average day per capita consumption by the residential class of the participating Consortium members 2004–2013. Ten of the 11 providers show a downward trend in the average day per capita consumption.

Table 1. Changes in trend intensity as a result of adjusting per capita demand metrics for weather, economy, and price effect, 2004–2013.

Demand Metrics and Status		Gresham			PWB			Tigard			Tualatin			TVWD		
		Rate of Change	Prob.	Diff. Relative to Unadjusted (a)	Rate of Change	Prob.	Diff. Relative to Unadjusted (a)	Rate of Change	Prob.	Diff. Relative to Unadjusted (a)	Rate of Change	Prob.	Diff. Relative to Unadjusted (a)	Rate of Change	Prob.	Diff. Relative to Unadjusted (a)
Annual	Unadjusted	-2.3%	0.000		-1.0%	0.066		-3.2%	0.000		-1.9%	0.028		-4.1%	0.000	
	Adjusted for weather	-2.2%	0.000	Not Sig	-0.8%	0.055	Not Sig	-2.8%	0.000	Not Sig	-1.8%	0.029	Not Sig	-3.9%	0.000	Not Sig
	Adjusted for economy	-2.2%	0.000	Not Sig	-0.9%	0.079	Not Sig	-3.2%	0.000	Not Sig	-1.7%	0.004	Not Sig	-3.7%	0.000	Not Sig
	Adjusted for price	-0.1%	0.834	Sig	3.7%	0.000	Sig	-0.9%	0.330	Sig	-1.7%	0.050	Not Sig	-1.8%	0.022	Sig
	Adjusted for all	0.1%	0.769	Sig	3.9%	0.000	Sig	-0.6%	0.535	Sig	-1.7%	0.002	Not Sig	-1.2%	0.015	Sig
Winter	Unadjusted	-2.1%	0.000		-0.6%	0.181		-2.7%	0.000		0.8%	0.410		-3.7%	0.000	
	Adjusted for weather	-2.1%	0.000	Not Sig	-0.7%	0.140	Not Sig	-2.6%	0.000	Not Sig	0.8%	0.407	Not Sig	-3.7%	0.000	Not Sig
	Adjusted for economy	-2.0%	0.000	Not Sig	-0.5%	0.255	Not Sig	-2.7%	0.000	Not Sig	1.0%	0.152	Not Sig	-3.2%	0.001	Not Sig
	Adjusted for price	-0.8%	0.021	Sig	3.2%	0.000	Sig	-1.4%	0.036	Sig	0.5%	0.575	Not Sig	-1.8%	0.001	Sig
	Adjusted for all	-0.8%	0.002	Sig	3.3%	0.000	Sig	-1.4%	0.040	Sig	0.7%	0.283	Not Sig	-1.3%	0.062	Sig
Summer	Unadjusted	-2.7%	0.000		-1.3%	0.031		-3.5%	0.000		-3.0%	0.003		-4.4%	0.000	
	Adjusted for weather	-2.6%	0.000	Not Sig	-1.1%	0.026	Not Sig	-3.0%	0.000	Not Sig	-2.8%	0.001	Not Sig	-4.2%	0.000	Not Sig
	Adjusted for economy	-2.7%	0.000	Not Sig	-1.2%	0.038	Not Sig	-3.5%	0.000	Not Sig	-2.8%	0.000	Not Sig	-4.2%	0.000	Not Sig
	Adjusted for price	-0.1%	0.754	Sig	3.4%	0.000	Sig	-1.0%	0.271	Sig	-2.6%	0.009	Not Sig	-2.2%	0.011	Sig
	Adjusted for all	0.1%	0.810	Sig	3.7%	0.000	Sig	-0.5%	0.480	Sig	-2.2%	0.001	Not Sig	-1.7%	0.001	Sig
Seasonal	Unadjusted	-4.0%	0.001		-2.9%	0.081		-4.3%	0.005		-6.4%	0.004		-5.1%	0.003	
	Adjusted for weather	-3.4%	0.002	Not Sig	-2.1%	0.090	Not Sig	-3.3%	0.005	Not Sig	-6.1%	0.002	Not Sig	-4.6%	0.001	Not Sig
	Adjusted for economy	-4.0%	0.001	Not Sig	-2.9%	0.085	Not Sig	-4.3%	0.005	Not Sig	-6.4%	0.002	Not Sig	-5.1%	0.004	Not Sig
	Adjusted for price	1.3%	0.194	Sig	4.0%	0.032	Sig	-0.5%	0.741	Sig	-5.4%	0.008	Not Sig	-2.7%	0.054	Sig
	Adjusted for all	1.8%	0.105	Sig	4.8%	0.007	Sig	0.5%	0.706	Sig	-5.0%	0.003	Not Sig	-2.2%	0.043	Sig

Highlighted cells indicate trend intensities that are not statistically significant at 90% confidence level.
(a) Wald test was used to test the significance of change in the intensity of trend.

See Table Note, page 26.

Table Note: Table 1 contains results of two sets of analyses on various demand metrics of each water provider based on two different statistical tests. In one, the intensity (steepness) of the trend in the metrics is measured and showed whether the intensity is statistically significant. For instance, for Gresham the intensity of trend in the Unadjusted annual demand metric is –2.3% and is statistically significant as indicated by Prob. 0.00 (not highlighted). Also the trend intensity in the Adjusted for Price matric is –0.1%, which is not statistically significant as reflected by Prob. 0.834 (highlighted). The second set of analysis tests whether the intensity of trend in the Adjusted metrics relative to unadjusted changes statically significantly. Again for Gresham the trend intensity changes from –2.3% for Unadjusted to –2.2% for Adjusted for weather. Wald Test shows that this change is not statistically significant. This means that weather did not have an effect on trend intensity in the demand metric over the 2004–2013 period. This does not mean that weather did not have any effect on demand in any year, only that it did not determine the trend intensity. By the same token, the change from –2.3% to –0.1% for Adjusted for price turns out to be statistically significant, which means price does impact trend. The "Difference Relative to Unadjusted" column shows the results of those tests.

Chapter 3: Conservation Program

Overview 27
History of Conservation 28
Current Consortium Conservation Programs 28
- Multimedia Campaign 29
- Program Branding 29
- Community Events and Workshops 29
- Youth Education 29
- Partnerships 30
- Spanish Language Outreach 30
- Property Manager Outreach 30
- Trade Ally Collaboration and Outreach 31
- Educational Materials 31
- Conservation Devices 31
- Conserveh2o.org Website 31

Consortium Member Conservation Survey 32
- Consortium Members Conservation Programs 32
- Survey Summary 34

10 Years of Public Outreach: Changes and Lessons 35
Conservation Resources for Water Providers 37
Looking Forward 37

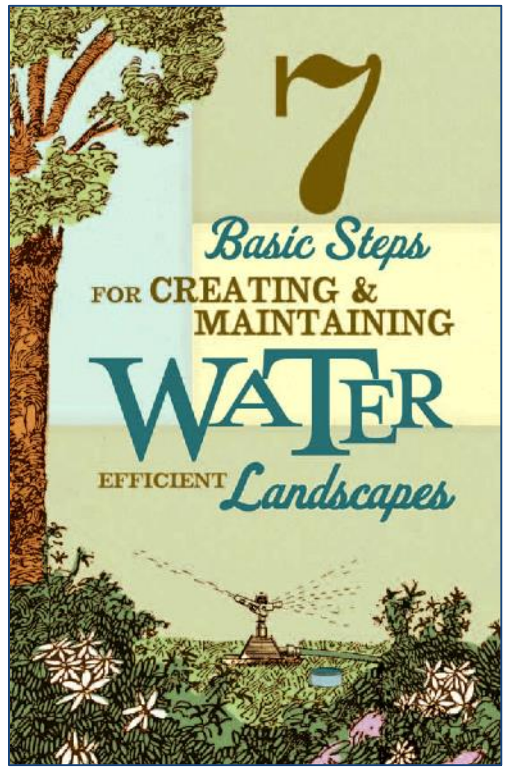
Overview

Water conservation is a key strategy in the region's efforts to meet water supply needs, meet state requirements, and provide a unified voice in water conservation in a regional media market.

Municipal water providers applying for new water rights or water right extensions are required by Oregon Administrative Rule 690-086 (Division 86) to prepare a Water Management and Conservation Plan (WMCP) to demonstrate how the water provider will manage and conserve water supplies to meet present and future needs. Consortium programs help providers meet the public information and technical assistance program requirements of Division 86.

History of Conservation

Because conservation is considered a "supply" source, it has been subjected to the same level of analysis as other water supply sources in the region. The 1996 RWSP used a comprehensive framework to examine water conservation to ensure that all viable conservation technologies and management practices were considered and their savings quantified. The Regional Water Providers Consortium evaluated more than 150 conservation programs from a list developed from conservation literature, other water utilities, and experts. They selected 24 programs, which were refined to include outdoor programs only. Provider input was solicited, and the final conservation programs were ranked against key criteria such as economic viability, customer acceptance, technological maturity, and regional match. The 2004 Update included an additional analysis of programs. Providers selected the programs that best suited to their entities, and the Consortium offered a common set of programs throughout the region for conservation education, outreach, and workshops.



The regionally implemented conservation programs were:

- Residential Information, Education, and Awareness
- Property Manager Workshops
- Trade Ally Irrigation and Landscape Workshops

The original RWSP did not recommend indoor conservation programs, but the current conservation program has been expanded to include an indoor program.

Current Consortium Conservation Programs

Current Consortium conservation programs continue to build on the priorities identified in the 1996 and 2004 plans and, at the recommendation of members, have been expanded to include both outdoor and indoor water conservation information.

The Consortium provides a fully integrated yet diverse range of educational conservation outreach programs designed to serve a population that includes residential customers, multifamily property managers, trade ally members (irrigation and landscape specialists), natural resource organizations, elementary school teachers and students, Latino residents, landscape and garden nurseries, and garden enthusiasts.

Multimedia Campaign

The Consortium's media campaign incorporates outdoor water conservation summer messaging during summer months and indoor water conservation messaging in the winter. The current campaign includes television and radio ads, television news stories, and on-air interviews. Print media and TriMet transit ads were part of the outreach campaign until 2016 when there was a shift in program priorities and budget. The Consortium also maintains a social media presence.

Program Branding

A program branding effort established a consistent visual style for all printed materials, device packaging, and the conservation website, as well as a uniform message and "voice" for the region.

Community Events and Workshops

The Consortium expanded community outreach efforts by developing educational workshops, presentations, and community events focused on water conservation education targeting trade allies, multifamily property managers, elementary grade students, and the general public.

Youth Education

Educational and interactive water conservation school assembly programs have been created for grades K–5 throughout the tri-county region. Of the four different water conservation school assembly programs that have been created, two are still in use. These educational assembly programs reach approximately 4,000 students each year. The Consortium developed and distributed posters, stickers, bookmarks, and activity books designed specifically for this audience.

The Consortium co-sponsors the Children's Clean Water Festival with several other community partners. The festival is a free, day-long environmental education event that engages about 1,400 fourth- and fifth-grade students from throughout the region. The festival includes more than 40 hands-on, water-focused activities, classroom presentations, and stage shows that reinforce and support school science curriculum.

Partnerships

The Consortium developed partnerships and continues to collaborate with natural resource organizations and businesses that share similar interests in water efficiency. Consortium partnerships include the following organizations in delivering water-wise presentations, workshops, webinars, events, and general water-efficiency information: Energy Trust of Oregon, Portland General Electric (PGE), Multifamily NW, Oregon Landscape Contractors Association (OLCA), *The Landlord Times,* Irrigation Association, Alliance for Water Efficiency, the State of Oregon's Landscape Contractors Board, and the U.S. Environmental Protection Agency's WaterSense product labeling program.

Spanish Language Outreach

The Consortium conducts outreach to the Latino community by developing an annual media campaign that includes print articles, television ads and television news stories in Spanish. The Consortium also sponsored several water-wise workshops in Spanish at the OLCA EXPO with continuing education hours (CEH) available.

Property Manager Outreach

The Consortium conducted targeted outreach to multifamily property managers through water-wise workshops, presentations, events, and webinars. Since 2004, the Consortium's participation in property manager-focused workshops and events increased significantly from 2 to 10 annually due in part to the opportunity for attendees to earn CEHs through partner agencies. The Consortium created and distributed a brochure titled "Water Conservation Guide for Multifamily Property Managers" and also distributed its other outdoor-focused print materials and indoor water-conservation devices to workshop and event attendees.

Trade Ally Collaboration and Outreach

The Consortium conducted targeted outreach to trade ally partners such as landscape contractors, irrigation specialists, and landscape architects and designers through water-wise workshops, classroom presentations, and events. In many cases, attendees were able to earn CEHs through partner agencies and the State's Landscape Contractors Board at these events. The Consortium distributed its outdoor-focused print materials and water-conservation devices to this audience. The Consortium also co-sponsored several water-wise Spanish trainings with CEHs. Outreach to this audience has more than tripled in the past 10 years in terms of number of workshops held and number of participants.

Educational Materials

The Consortium created a comprehensive and diverse set of more than 30 educational materials to be distributed to the public, including homeowners, multifamily property managers, trade industry representatives, schools, and children. Most materials are available to download from the Consortium's website.

Conservation Devices

The Consortium's selection of indoor and outdoor water-conservation devices include high efficiency showerheads, toilet leak detection dye tabs, faucet aerators, and watering gauges. These devices are available free to the public throughout the year through Consortium community events. The Consortium also conducts on-line promotions featured on the Consortium website and social media channels as well as workshops for member customers. Conservation devices are packaged in Consortium-branded materials.

Conserveh2o.org Website

The website includes interactive water-efficiency tools, instructional videos, water-wise plant gallery, kids' page and games, social media (Twitter), and other conservation-related content.

The Consortium's conservation strategy links all programs through the website and reinforces the branding of the Consortium as an organization that implements cost-effective regional water conservation measures designed to encourage efficient use of the region's water supply. As a result of the contributions and buyin of regional water providers, the Consortium delivers a diverse and economical menu of regional water conservation programs.

Consortium Member Conservation Survey

In early 2015, the Consortium conducted a survey of its members to:

- identify conservation programs that Consortium members have implemented since 2004
- identify Consortium member's current conservation programs
- identify current Consortium conservation programs that members are using to fulfill their state-required water management and conservation plan (Division 86) requirements

A summary of the survey responses follows.

Consortium Members Conservation Programs

Eighty-one percent the providers responded to the survey.

Of the survey participants, 73 percent reported that they have less than one full-time equivalent (FTE) dedicated to supporting their conservation programs. Fourteen percent have staffing levels at one FTE, and 13 percent have more than one FTE.

Sixty-five percent reported that their current conservation materials and services budgets are less than $50,000 per year. Seventy-one percent indicated that their entity uses some type of rate structure that promotes conservation, although the structure varies from provider to provider.

All survey respondents reported that their conservation programs serve residential customers. Eighty-five percent reported that their programs target multifamily customers, and 54 percent reported that their programs target commercial industrial customers.

In the 2004 update of the Regional Water Supply Plan, Consortium members identified a variety of programs to be implemented at the regional level, such as residential information and education, and multifamily property manager and trade ally workshops. At that time, some members planned to implement additional conservation programs on their own. As Table 1 below indicates, Consortium members implemented all but three of the programs in the past 10 years, and many members continue to implement some of these programs today.

Table 1. Conservation programs implemented by Consortium members.

Programs Consortium Members Have Implemented (non-Consortium)	Implemented in the Past 10 Years	Implementing Now
Residential Customers		
Toilet Rebate Program	[a]	10
Washing Machine Rebate Program	5	3
ET Controller Retrofit and Weather-based Irrigation Controller Programs[b]	6	4
Weather-based Irrigation Controller Rebate Program	4	2
Indoor Audits	5	1
Sub-metering	1	0
Multifamily Customers[c]		
Sub-metering	0	0
Commercial and Industrial Customers		
Large Landscape Audits	4	3
ET Controller Retrofit and Weather-based Irrigation Controller Rebate Program	4	4
Indoor Audits	4	3
Outdoor Ordinance (requires preapproval of landscape plans for new construction)	0	0
Eliminate Single-pass Cooling	2	2
Sub-metering	1	0
General Public/Nonspecific Customer Class		
Waterless Urinal Rebate Program	1	1
Multistream Rotator Hose Nozzle Rebate Program	4	3

Table 1. Continued

Programs Consortium Members Have Implemented (non-Consortium)	Implemented in the Past 10 Years	Implementing Now
Non-residential Irrigation Sub-metering	1	1
Community Events and Workshops (i.e., conservation-focused workshops, tabling events)	11	7
Youth Education (i.e., school assembly programs, classroom presentations)	10	7
Printed Educational Outreach (i.e., brochures, displays, other printed materials)	11	8
Conservation Device and Kit Distribution	11	8

[a] Toilet rebates (from the last 10 years) were inadvertently left out of the survey; however, current toilet rebate information has been included.

[b] ET Controller

[c] Multifamily customers: A handful of water providers are providing some additional incentives to their multifamily customers.

Survey Summary

Approximately 86 percent of survey respondents have incorporated the following Consortium conservation programs into their WMCPs to meet Division 86 requirements: multimedia campaign, events and workshops, school assembly programs, trade ally programs, printed outreach materials, conservation devices, and the conserveh2o.org website.

Seventy-one percent of members reported they included School Assembly Programs in their WMCPs, and 57 percent included the Trade Ally Programs.

Note: *The lower number for the Trade Ally Program is likely to be misleading because the majority of the Consortium's Events and Workshops are currently geared to Trade Ally audiences and Multifamily Property Managers. In hindsight, the Trade Ally and Events and Workshops categories should have been combined into one category in this survey question.*

The information in Table 1 generally mirrors the information garnered from survey participants when they were asked to rank elements of the Consortium's current conservation programs (Table 2). Members identified the outdoor-focused English television campaign as their top priority. Several other elements of the multimedia campaign followed closely, such as the indoor-focused and outdoor-focused Spanish television campaign and the summer radio campaign. Two aspects of the multimedia campaign — annual print media and the TriMet transit ad campaign — ranked the lowest, which mirrors the decisions that were made in early 2015 to cut these elements from the Conservation program starting in the 2016–2017 fiscal year.

The School Assembly Program and Community Events and Workshops both ranked relatively low, as shown in Table 2. The low placement of the School Assembly Program reflects the fact that many providers already offer School Assembly Programs to schools in partnership with the Consortium, so the one "free" show per year offered through the Consortium is not especially important to these providers. Community Events and Workshops, while ranked low, are still considered important and valuable to Consortium members in helping meet Division 86 requirements. The Community Events and Workshop category represents the predominant form of outreach to the Trade Ally groups.

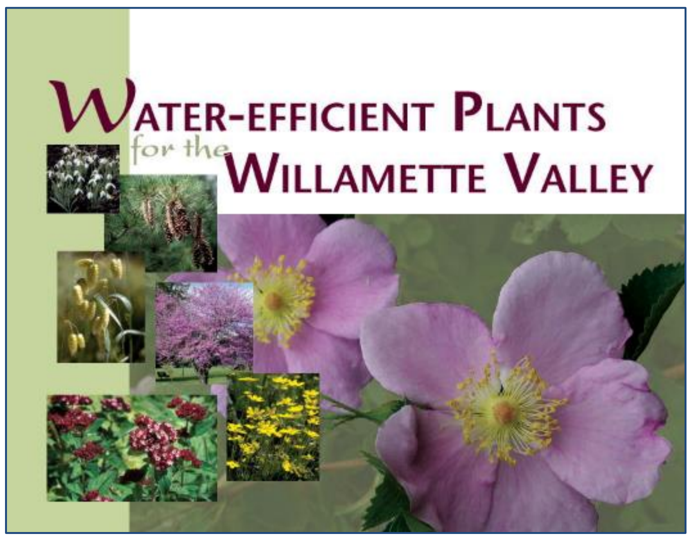
Table 2: Survey rankings.

Consortium Conservation Program Elements	Ranked 1–10 in Order of Importance (1 = highest, 10 = lowest)
Outdoor-focused English television campaign	4.00
Conserveh2o.org website	4.36
Consortium printed outreach materials	4.93
Indoor-focused English television campaign	5.79
Outdoor-focused Spanish television campaign	5.86
Radio campaign (summer only)	5.93
Conservation devices	6.07
School assembly program	6.36
Community events and workshops	6.50
Annual print media	7.71
TriMet transit ad campaign	8.50

10 Years of Public Outreach: Changes and Lessons

Over the past 10 years, awareness of the importance of water as a valuable, but limited, resource has increased, both globally and regionally. The Consortium's outreach has evolved from focusing on conveying a general awareness of the importance of conservation to promoting specific conservation "actions" such as watering one inch a week. The program has grown into a diverse and integrated multi-media program with a much greater reach to customers. For example, the website has grown exponentially with an increase in page views from 59,000 in 2004 to 245,000 in 2015. Latino outreach has also been added to broaden the conservation messaging to Spanish-speakers. Partnerships have also been cultivated with trade-ally, energy and multifamily property partners. The use of social media has also extended the Consortium's reach to a more diverse audience.

Conservation actions supported by the Consortium include a variety of changes inside the home, from installing high-efficiency faucet aerators and showerheads to investing in high-efficiency appliances such as toilets, washing machines, and dishwashers. Outdoor conservation actions promoted by the Consortium include transitioning landscapes with large areas of turf to designs with smaller areas of turf or that incorporate turf alternatives and encouraging property owners to install water-wise gardens. While it is difficult to quantify the effect of these actions, the message is reaching customers as evidenced by the increase in the use of the weekly watering number (now 1200 subscribers) and the distribution of more than 12,000 water gauges by the Consortium and thousands more by water providers in the last 10 years. Many Consortium members provide rebate incentives, which have further encouraged the public's shifting behavior relating to water conservation.



Over this 10-year period, Consortium staff learned that shifting public engagement from conservation *awareness* to conservation *action* is best accomplished by phasing in outreach efforts. These efforts began by developing simple and uniform water conservation messaging for the region and followed that with step-by-step guidelines and tips that were easy to understand, easy to access, and simple to apply. A set of education and outreach materials was developed for the region that included informational brochures and booklets, interactive tools such as the

Weekly Watering Number, e-newsletters, and Consortium-branded conservation devices.

The Consortium conducted targeted water-wise trainings and workshops designed for irrigation and landscape industry members and multifamily property managers that included information on irrigation trends and technologies, water-saving devices and appliances, and seven basic steps to water efficient gardening. Workshop participants received CEHs, rebate information, educational materials, conservation devices, and staff/resource support for attending these trainings and workshops.

Conservation Resources for Water Providers

The Consortium occasionally receives requests for programs that fall outside of the Consortium's regional interest. When this occurs, the Consortium provides a forum for members to identify other members interested in partnering with them on outside efforts. These partnerships often include non-Consortium organizations or entities that have similar goals.

Looking Forward

- The Consortium will continue to build on its programmatic strengths such as its regional multimedia campaign and website.
- The Consortium will continue to provide a forum for regional water providers to exchange and share information about their respective programs, new technologies, and emerging conservation trends.
- The Consortium will continue to develop conservation-related resources to meet the needs of its members and to achieve economies of scale.
- The Consortium will work together to develop a regional communication plan for use during water shortages.

The Consortium's strength is in using its collective resources to provide a consistent and integrated regional multimedia conservation message. By providing a strong conservation foundation, the Consortium supports individual member programs and gives them the flexibility to augment their conservation efforts with programs that fit their specific needs.

The 2016 RWSP Update did not include the evaluation of any new conservation measures, however there are emerging technologies that are available to increase water savings potential. They include:

- software products that track real-time water use and provide customers with educational messages and resources to decrease water use
- automated metering infrastructure or smart meters (providing hourly, real-time reports on community water consumption)
- other quantifiable tracking/incentive-based programs.

The benefits of a sustained, long-term regional approach to conservation include providing water managers with another tool in the development of water demand strategies that may delay costly infrastructure projects. Conservation also makes a water system more resilient by stretching water supplies during periods of peak demand when systems are operating at peak capacity. Conservation supports other important values such as fish and wildlife habitat, recreation, and meeting the challenges of climate change. Lastly, conservation programs help customers to feel connected to their water supply by assisting them in using it more efficiently. The next generation of consumers is likely to be more aware of the importance of water conservation and general sustainability practices. Consequently, they will have high expectations of their water providers' water- conservation expertise.

The Portland metro region is fortunate to have an adequate and diverse water supply, but it is incumbent on local water providers to continue to efficiently manage water supplies and to educate their customers to use this resource wisely as the region's population grows. By sustaining a robust conservation program, our region is better prepared to manage its valuable water resources for generations to come.

Chapter 4: Emergency Preparedness

Overview ... 39
Emergency Planning Committee ... 40
Policy Framework ... 41
  Consortium Strategic Plan ... 41
  The Oregon Resilience Plan ... 42
Regulatory Framework ... 43
Regional Collaboration ... 43
Mutual Aid ... 44
Consortium Projects ... 45
  Regional Equipment and Grants ... 45
  Emergency Water Treatment and Distribution Plan ... 46
  Regional Interconnections ... 47
  Training and Exercises ... 47
Coordination and Outreach ... 49
  Emergency Contact List ... 49
  Website ... 49
  Drinking Water Advisory Tool ... 50
Future Projects ... 50
  Public Messaging ... 50
  Regional Interconnections Geodatabase Update and Exercise ... 51
  Seismic Risk Assessment ... 51
  Interoperable Communications ... 52
  Drought Planning ... 52
  The Oregon Resilience Plan ... 52

Overview

Emergency preparedness, one of the key policy objectives of the Regional Water Supply Plan (RWSP), is the process of minimizing "the magnitude, frequency, and duration of water service interruptions due to natural or human-caused events, such as earthquakes, landslides, volcanic eruptions, floods, spills, fires, sabotage, etc." In the 2004 RWSP Update, terrorism was added to the policy objective to acknowledge the changing landscape around infrastructure protection. The Consortium's Five-Year Strategic Plan includes emergency preparedness as one of three key goals of the Consortium, and it includes addressing the need for better coordination and communication among providers and establishes emergency planning objectives for the Consortium.

The Consortium's role in emergency planning and coordination dates from 2001 when the Consortium Emergency Planning Committee (EPC) was formed. The program has grown and evolved in the subsequent years. Fiscal year (FY) 2015–16 marked a significant shift in priority and funding for emergency preparedness when the Consortium reallocated staff resources and funding to expand the program.

The EPC's primary objectives are to:

- improve coordination and communication among water providers
- provide training opportunities
- identify and secure funding for projects and equipment, and
- identify ways to improve interconnections

The Consortium has broadened its scope to include customer preparedness. The work of the EPC has had a positive effect on the ability of Consortium members to better prepare for, respond to, and recover from emergencies. This chapter describes the Consortium's work in emergency preparedness since the 2004 RWSP Update and outlines the program's future objectives.

Emergency Planning Committee

The EPC is composed of staff members from each of the participating Consortium member agencies working in the area of or interested in emergency management. Participation is voluntary.

The role of the EPC is to:

- provide guidance to Consortium staff on the development of the Consortium's annual work plan and budget
- assist with implementation of the annual work plan
- provide input on the Emergency Preparedness Strategy during updates of the Consortium's Strategic Plan
- help plan and implement exercises and drills sponsored by the Consortium
- participate in Consortium-sponsored exercises, trainings, and drills as desired

- share information with other committee members on work already accomplished in this area that may be beneficial to them
- identify funding priorities when grant money is available
- foster regional coordination by participating in regional preparedness and coordination efforts and plans

Policy Framework

This section describes the policies that have framed the Consortium's work in emergency preparedness.

Consortium Strategic Plan

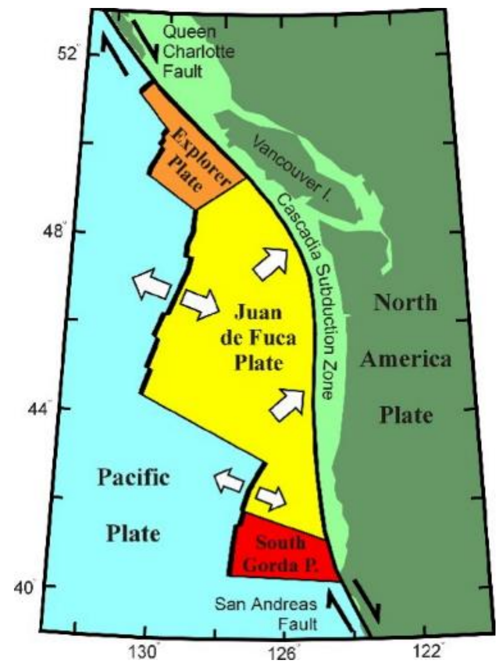
Emergency preparedness is one of the three key strategies in the Consortium's Five-Year Strategic Plan. The region is vulnerable to many types of events that could severely limit or impair water service to all or parts of the area. Examples of water system vulnerabilities include:

- wind and ice storms
- earthquake
- heavy rain and flooding
- landslides
- mudflows
- fire
- volcanic eruptions
- contamination, accidental or intentional
- power outages
- accidents
- breaks or system failures
- terrorism
- vandalism
- climate change
- drought

The Strategic Plan outlines strategic goals in emergency preparedness that serve as the basis for the Consortium's work plan and budget for emergency preparedness. The Strategic Plan is updated every five years to reflect the Consortium Board's priorities.

The Oregon Resilience Plan

House Resolution 3 (HR 3), adopted in April 2011, directed the Oregon Seismic Safety Policy Advisory Commission (OSSPAC) "to lead and coordinate preparation of an Oregon Resilience Plan (ORP) that reviews policy options, summarizes relevant reports and studies by state agencies, and makes recommendations on policy direction to protect lives and keep commerce flowing during and after a Cascadia earthquake and tsunami." OSSPAC assembled eight task groups comprising volunteer subject-matter experts from government, universities, the private sector, and the general public.



The water/wastewater task group was asked to:

- Determine the probable impact of a magnitude 9.0 Cascadia earthquake and tsunami and estimate the time required to restore functions in that sector if that earthquake were to strike under current conditions.
- Define acceptable timeframes to restore water and wastewater functions after a future Cascadia earthquake in order to fulfill expected resilient performance.
- Recommend changes in practices and policies that, if implemented during the next 50 years, will allow Oregon to reach the desired resilience targets.

The water/wastewater task group formulated twelve water-specific recommendations.

The ORP was completed in February 2013 and presented to the Oregon Legislature. During the 2013 session, the Legislature passed Senate Bill 33 (SB 33), which formed the Governor's Task Force on Resilience Plan implementation. The Task Force reviewed the 140 recommendations in the ORP and identified the most critical for the legislature to consider for the 2015–2017 biennium. One of the recommendations was to create a position of State Resilience Officer. In 2015, House Bill 2270 (HB 2270) was passed, which establishes the position of State Resilience Officer to oversee the implementation of the ORP. The task force also made a recommendation to improve public preparedness education as well as two water-sector-specific recommendations:

- Require water systems to complete a seismic-risk assessment and mitigation plan as part of the existing requirement for periodic updates to water system master plans.
- Encourage firefighting agencies and water providers to establish joint standards for use in planning the firefighting response to a large seismic event.

In 2014, the Consortium Board adopted a resolution to back the implementation of the ORP recommendations by supporting relevant legislation and rulemaking and by incorporating ORP recommendations into Consortium plans and programs. Several water providers are currently conducting seismic risk assessments as part of their updates to their water system master plans.

Regulatory Framework

Following 9/11, awareness of the risk to critical infrastructure from terrorism heightened significantly. In response to this increased threat, President George W. Bush signed the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (Bioterrorism Act).

The Bioterrorism Act requires community drinking water systems that serve populations of more than 3,300 persons to conduct a vulnerability assessment to identify potential susceptibilities in the event of a terrorist attack or other intentional acts. Based on the results of the vulnerability assessment, water providers then prepare or revise an emergency response plan to defend against adversarial actions that might substantially disrupt the ability of a system to provide a safe and reliable supply of drinking water. Both the assessment and plan are submitted to the Environmental Protection Agency Administrator.

Shortly after, the state of Oregon adopted administrative rules (OAR 333-061-0064) that require water providers to maintain and update a current emergency response plan. The plans must be reviewed and updated at least every five years.

Regional Collaboration

Much of the Consortium's early work in emergency preparedness focused on establishing relationships, training and working together, and sharing resources among water providers. Regional collaboration with non-Consortium partners and disciplines has more recently become an important focus for the group. As a result, multidisciplinary preparedness has improved in the region. The Consortium is an active participant in the recently formed Regional Disaster Preparedness Organization (RDPO) and a signatory to the RDPO intergovernmental agreement in 2015.

The RDPO is a partnership of government agencies, nongovernmental organizations, and private-sector stakeholders in the Portland Metropolitan

Region that collaborate to increase the region's resilience to disasters. The metropolitan region spans Clackamas, Columbia, Multnomah, and Washington Counties in Oregon, and Clark County in Washington.

The RDPO formed in 2012 out of a desire to build on and unify the emergency preparedness efforts of several groups in the Portland Metropolitan Region, including the Regional Emergency Management Group established in 1993, the Urban Areas Security Initiative Program, originally funded in 2003, and several discipline-specific coordination groups.

The mission of the RDPO is to build and maintain regional disaster-preparedness capabilities in the Portland Metropolitan Region through strategic and coordinated planning, training and exercises, and investment in technology and specialized equipment. The RDPO also directs the Urban Area Security Initiative grant program and is comprises sector-specific working groups that help identify and prioritize grant-funded equipment and projects that support the overall strategic plan for the region.

Consortium staff participates in the Public Works working group and is a member of the steering committee that guides the strategic direction of the RDPO.

The Consortium also maintains relationships with water agencies in Washington that own emergency water distribution systems (EWDS). The EWDS is a compact and portable manifold system made up of valves, connecting hoses, a circulation tank, and water bladders designed to dispense potable water into water bags. They were first developed and procured in the Seattle area, and nine EWDS now reside in the Portland Metro area. Water providers from both Oregon and Washington have participated in drills and training exercises on using EWDS.

Mutual Aid

One of the Consortium's strategic goals is for all water providers to have mutual-aid agreements in place with neighboring water providers. Instead of creating its own mutual-aid agreement, the Consortium has relied on and promoted other regional agreements such as the Cooperative Public Agencies of Washington County Intergovernmental Agreement, the Managing Oregon Resources Efficiently (MORE) Intergovernmental Agreement, and the Oregon Water/Wastewater

Agency Response Network (ORWARN). ORWARN was created in Oregon in 2007 and establishes a framework for providing mutual aid specifically among water and wastewater providers within Oregon. Modeled after other WARNs around the country, ORWARN facilitates rapid, short-term deployment of emergency services in the form of personnel, equipment, and materials that are required to restore critical operations to utilities that have sustained damage from natural or man-made events.

The Consortium actively promotes ORWARN among its members and participates in ORWARN conferences and drills. All Consortium members, with the exception of one, belong to ORWARN.

Consortium Projects

Regional Equipment and Grants

The Consortium, through its members, has successfully acquired more than $1.2 million in Urban Area Security Initiative (UASI) grants for regional water treatment and distribution equipment, portable pipe systems, and a regional water system interconnections study. Through its participation in the RDPO (previously called the UASI Public Works Group), Consortium staff has helped prioritize regional water provider needs, identify gaps, and secure funding for its members. As a result of the Consortium's coordinated efforts and planning, it is recognized as a regional leader, which lends credibility to our respective projects. To date, the region's water providers have purchased or acquired through grants the equipment listed in Table 1. The Consortium also acquired two UASI grants totaling $190,000 for a regional interconnections study (discussed in Chapter 5).

Table 1. Emergency equipment acquired by region water providers (**orange** indicates equipment purchased with UASI funds).

Owner/Housing Agency	Type of Equipment
Beaverton, City of	Emergency Water Distribution System
Clackamas River Water	Emergency Water Distribution System (Consortium Funded)
	Mobile Water Treatment System
	Portable Piping System
Gresham, City of	Emergency Water Distribution System
Hillsboro, City of	Portable Piping System
Joint Water Commission (JWC) City of Hillsboro	Emergency Water Distribution System
Lake Oswego, City of	Mobile Water Treatment System
Milwaukie, City of	Mobile Water Treatment System (2016)
Portland Water Bureau	Emergency Water Distribution System
	Emergency Water Distribution System
	Mobile Water Treatment System
Tualatin Valley Water District	Emergency Water Distribution System
	Emergency Water Distribution System

Emergency Water Treatment and Distribution Plan

In 2009, after the procurement of the first four emergency water distribution systems, the Consortium prepared an Emergency Water Distribution Plan to identify resources and strategies for water providers to use to respond rapidly to a significant disruption in drinking water supplies. The plan includes operational information and guidelines for activating, deploying, and maintaining the emergency water distribution systems (EWDS), mobile water treatment plants, and portable piping systems located around the region.

The Consortium updated the plan in 2011 and again in 2015 to include other regional water supply equipment and operational information and lessons learned through drills.

The Emergency Water Distribution Plan also includes recommendations for public communication concerning water supply disruptions and the use of the emergency water distribution and treatment systems. The plan establishes protocols for the prioritization of resources and levels of response.

Regional Interconnections

Interconnections among water providers have always been considered a critical component of a resilient regional water system. Although most water providers in the region have access to some emergency source of water, limitations on the capacity and infrastructure exist. In 2000, the Consortium completed the Regional Transmission and Storage Strategy to develop long and short-term visions for regional transmission and storage and to identify the institutional arrangements needed to facilitate these visions. This strategy provided the basis for thinking about the best way to develop regional projects to enhance resiliency.

Details on regional interconnections and the Interconnection Map and Evaluation Project, which identifies pathways for routing water in emergency situations, can be found in Chapter 5: Interconnections.

Training and Exercises

Providing training and exercises to enhance regional water providers' expertise in responding to and recovering from an emergency is one of the Consortium's strategic goals in the area of emergency preparedness. Part of this involves training on the use of regional equipment, testing the capabilities of the regional interconnections geodatabase, and enhancing water providers' knowledge of and experience in responding to and recovering from an emergency. The Consortium has planned and facilitated a number of exercises and trainings using assorted water-related scenarios to provide a variety of learning opportunities.

Since the 2004 RWSP Update, the Consortium has conducted the exercises and trainings listed in Table 2.

Table 2. Emergency exercises and training conducted by the Consortium since 2004.

Date	Exercise/Training
September 2004	**ICS Training** for Public Information Officers
February 2005	**Tabletop exercise** to: • evaluate the process used to coordinate, communicate, make key decisions, and implement policy during a regional water emergency • improve coordination and communication among regional partners • identify impact of a large-scale power outage; determine water service interconnections • improve understanding of joint information center The scenario involved loss of power to substations feeding several water treatment plants and Portland Water Bureau's groundwater pump station. The exercise included 107 attendees from 30 agencies.
May 2007	Regional **workshop** on interconnections (discussed in the Regional Interconnections section)
August 2009	**Train-the-trainer** event for the newly acquired emergency water distribution systems (EWDS)
May 2010	**Drill** for water providers using the emergency water distribution systems; involved setup, sanitation, distribution and demobilization of systems, and sharing operational information
September 2010	**Demonstration** of EWDS for city and county emergency managers, elected officials, and other partners
May 2011	**Tabletop exercise** to test capabilities of the ArcGIS interconnections geodatabase. Objectives were to: • test capabilities of the regional geodatabase • test linear systems and supplies from multiple sources • identify gaps in data, infrastructure, policy, and operations • determine off-load risks and test how quickly water providers can react and provide water where needed 47 attendees from 21 water-provider agencies participated in the exercise.
August 2012	**Drill** with emergency water distribution systems using multiple water sources. The drill included a scenario and public outreach materials as well as mock water distribution to the public with the assistance of the Washington County Citizen Emergency Response Team.
May 2015	**Demonstration and drill** using EWDS, newly acquired mobile water treatment plant, and portable piping system. The demonstration also highlighted regional UASI-funded equipment. 137 attendees from 47 agencies participated.

The Consortium exercises and trainings are well attended, and participation is high. After-action reports have been completed for all tabletop exercises and drills.

Coordination and Outreach

One of the main objectives of the EPC is to improve coordination and communication among water providers and partners. The EPC meetings provide opportunities for members to share information on plans and programs they are working on and exchange resources. The following projects highlight some of the work the Consortium has carried out to foster better communication and coordination among water providers, partners, and the public.

Emergency Contact List

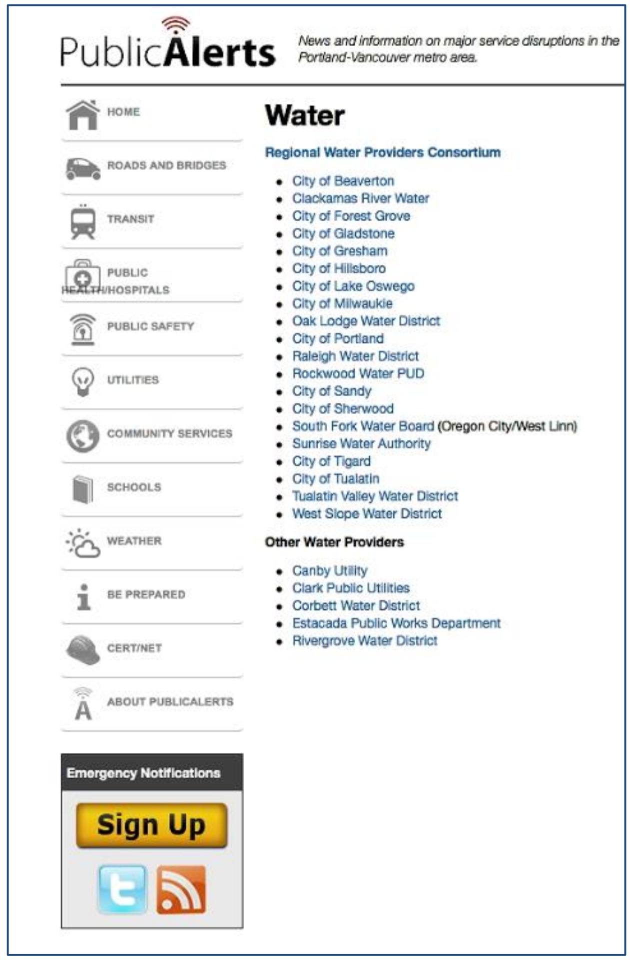
In 2004, the Consortium developed an emergency contact list so that water providers have easily accessible contact information for water provider colleagues. This list is updated annually and has been expanded to include mutual-aid agreement information, regional equipment, and county and state contact information.

Website

In 2014, the Consortium established a new website, www.regionalh2o.org, to more fully represent the work of the Consortium. The www.conserveh2o.org website continues to be the online source for the Consortium's conservation program information. The www.regionalh2o.org website is a forum for highlighting the Consortium's work in emergency preparedness. The website includes citizen preparedness information, details on member projects that focus on resiliency, and a secure members-only page to share plans and reports.

Drinking Water Advisory Tool

With the help of the EPC, the Consortium developed an online look-up tool to publicize drinking water advisory (DWA) information to the public via the Public Alerts website (www.publicalerts.org) and on individual water provider websites.



The purpose of the tool is to:

- improve public health and safety by improving public awareness of DWA events
- provide the public with a quick and easy way to determine from their computer or smartphone whether a DWA event affects them
- reduce the number of customer service calls to water providers during a DWA event

When a drinking water advisory is published on www.publicalerts.org by a Consortium member, the public can go to the website, enter the address of their current location or home, and determine if they are affected by the advisory. The tool will provide viewers with a map of the affected area, their location relative to the affected area, a summary of the drinking water advisory, and a link to the affected water provider's website for additional information. The DWA tool went live in June 2015.

Future Projects

The Consortium will continue to invest in projects that support its strategic goals and, specifically, the Oregon Resilience Plan. The following are some near-term projects the Consortium will be implementing.

Public Messaging

In FY 2015–16, the Consortium began work on a public information campaign on the subject of personal preparedness. Part of this campaign is to inform the public about how soon water systems may be restored after a large-scale earthquake and to promote the importance of having adequate emergency water supplies in their homes. The campaign includes displaying messaging on the sides of TriMet buses and adding content and instructional videos to the website.

The Consortium has developed information modules for Consortium members to use in their mailings and outreach material.

Regional Interconnections Geodatabase Update and Exercise

In FY 2016–17, the Consortium will update the Regional Interconnections Geodatabase with the help of a UASI grant. The update will incorporate infrastructure changes that have occurred since the original study; identify critical water supply and distribution points, seismic upgrades, and critical GIS layers (hazards, hospitals, etc.); identify gaps; and rank interconnections. The study will conclude with a tabletop exercise.

Seismic Risk Assessments

Because of increased awareness of the impact of a Cascadia earthquake on water system infrastructure, future work will be focused on reducing seismic vulnerabilities. The two largest water providers, Portland Water Bureau and Tualatin Valley Water District, are completing work on incorporating seismic vulnerability into their water system master plans, as are the Joint Water Commission, Gresham, Clackamas River Water, and Sunrise Water Authority. The Consortium's goal is to develop support tools to help smaller providers develop seismic risk assessments to reduce their vulnerability.

Interoperable Communications

Interoperable communications continue to be a challenge, and the Consortium is committed to projects that help identify solutions for improved radio communications. Clackamas River Water is undertaking a UASI grant-funded emergency communications pilot study for water suppliers and public works agencies in the Clackamas Basin. Based on the outcomes of the project and lessons learned, additional phases will be undertaken to establish interoperable communications for additional Consortium members and interdependent public works agencies in the UASI region.

Drought Planning

The summer of 2015 highlighted the need for water providers to create a regional communication and coordination plan concerning drought conditions. Drought is the current driver, but a plan will also help during other water supply shortage emergencies. Work on the plan will begin in FY 2016–17.

Oregon Resilience Plan

The Consortium will continue to fund projects that support the implementation of the Oregon Resilience Plan.

Chapter 5: Regional Interconnections

Overview 53
Vulnerabilities 53
Interconnections 54
Interconnections Map and Evaluation Project 55
New and Proposed Interconnections 58
Interagency Agreements 58
Looking Forward 58

Overview

The Portland metro region is fortunate to have a diversity of water supply options including the Bull Run Watershed, Clackamas River, Trask River, Tualatin River, Willamette River, and groundwater from three major aquifers. The groundwater supply includes aquifer storage and recover, which is the injection of potable water into an aquifer for later recovery and use. Each source is unique, and together they provide a high level of water supply resiliency in the region.

Vulnerabilities

The region's water systems are vulnerable to natural and human-caused hazards such as:

- wind and ice storms
- earthquake
- heavy rain and flooding
- landslides
- mudflows
- fire
- volcanic eruptions
- contamination, accidental or intentional
- power outages
- accidents
- breaks or system failures
- terrorism
- vandalism
- climate change
- drought

These hazards could affect one or all of the region's water sources. With the exception of a major earthquake, however, the likelihood of all water sources being affected simultaneously by the same event is small. Therefore, having multiple sources reduces the region's vulnerability to catastrophic events as long as infrastructure is in place to move water to the locations where it is needed.

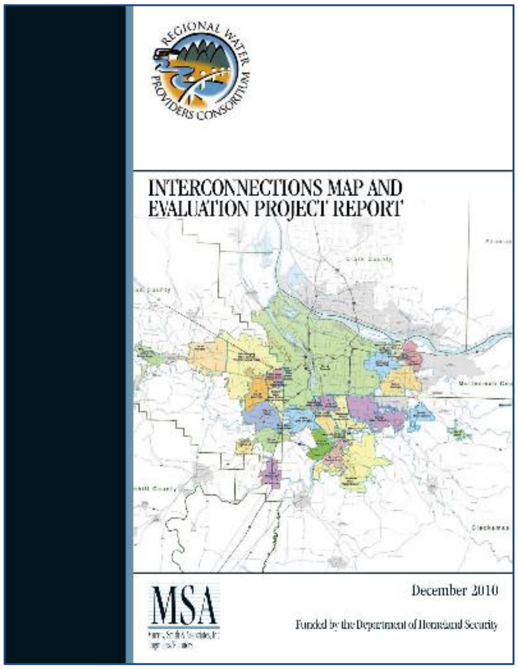
This chapter discusses the importance of both large and small interconnections to supply water around the region in the event of an emergency. The Emergency Preparedness chapter discusses other work water providers are carrying out to provide emergency water supplies and improve emergency planning, communication, and response.

Interconnections

The original 1996 Regional Water Supply Plan (RWSP) recognized regional transmission linkages as key to meeting long-term water supply needs, addressing system shortages during peak events, and providing emergency backup supplies. In 1999, the Consortium funded the development of long- and short-term strategic visions for regional transmission and storage and to identify the institutional arrangements to facilitate these visions.

One of the recommendations of the "July 2000 Regional Transmission and Storage Strategy" (RTSS) was to work toward building interconnections among water systems within the region to increase the reliability of supply to individual communities and the region as a whole. Among other things, the RTSS recommended that each community in the region have access to both a primary supply and an alternate emergency source of water.

Although the RTSS identified and discussed major regional interconnections, the report did not provide information on the smaller, yet important, interconnections that exist between each of the water providers. In 2008, the Consortium was awarded an Urban Area Security Initiative (UASI) grant to identify and map all of the provider interconnections.



Interconnections Map and Evaluation Project

The Interconnections Map and Evaluation Project (IMEP) consisted of three phases and resulted in the creation of an ArcGIS geodatabase of all existing water system facilities within the region, including existing water system interconnections and a pipe network overlay. The geodatabase was designed to help water providers:

- identify pathways for routing water in emergency situations
- identify system vulnerabilities
- develop emergency operational strategies

Phase One IMEP. Phase One of the IMEP focused on developing the geodatabase mapping layers and related attributes needed to allow for a more detailed analysis of system interconnections and emergency response. The data collected for the geodatabase included:

- supply, transmission, and distribution piping
- water storage facilities
- water pumping facilities
- sources of water supply
- population served
- current and 20-year projected water demands

Phase Two IMEP. Phase Two work included the development of a critical transmission facilities layer and identified local intertie opportunities and important regional intertie opportunities. GIS layers were developed for major source facilities to show the potential service area for a source based on existing interties.

Phase Three IMEP. Phase Three of the IMEP commenced in September 2011 and was funded by a second UASI grant. Phase Three included two tasks. The first task involved staff training and the verification, cleanup, and organization of data. The second task involved an evaluation of the effort required to develop a preliminary regional hydraulic model based on data contained in the geodatabase.

The geodatabase provides useful information but lacks quantitative analysis, such as intertie capacity. A regional hydraulic model would offer an appropriate level of confidence for a regional and subregional emergency supply analysis. The evaluation included the development of a pilot hydraulic model, which was used to identify data gaps and recommend next steps for a regional model. The Consortium did not pursue the development of a regional hydraulic model because of the cost and complexity of the project.

As part of the implementation of the IMEP, a Water System Data Use and Confidentiality Agreement was developed to allow sharing the geodatabase while maintaining confidentiality and water system security among Consortium members.

The IMEP demonstrates that the majority of regional providers have a high level of emergency supply redundancy from major sources with the existing interconnections. Limitations in pumping capacity exist, however.

The geodatabase has proved to be a useful tool that can be used to show the major sources of supply in the region, how water can be moved, and the total area that can be served by these sources through existing system interconnections. The project also identified additional interconnection opportunities. Without a hydraulic model, however, it is difficult to determine the amount of water available to each water system.

The Consortium members have a geodatabase tool that can be used to:

- provide the foundation for a stronger, more resilient regional water supply system
- identify, within the region and on a subregional basis, resource availability in the event of a water supply emergency
- provide a framework to inform local decision-making regarding priorities for infrastructure improvements
- support funding opportunities for future interconnection projects
- identify future regional and subregional water system interconnections to strengthen regional water system reliability and resiliency

Beginning in Fiscal Year 2016, the Consortium will update the IMEP. The update to the geodatabase will include:

- water system interconnection changes since 2011
- important risk-related map overlays
- critical facilities
- seismic upgrades of facilities

The update will also include the evaluation and ranking of interconnections based on specific criteria, identification of key locations for deployment of emergency water treatment and distribution equipment, and the development of a regional tabletop exercise to test the updated geodatabase.

In the future, the Consortium will continue to maintain the geodatabase, conduct exercises to test the ability of interconnections to supply water under different scenarios, and promote the testing and exercising of interconnections.

Although establishing a list and assessments of interconnections is helpful, it doesn't fully address how interconnections can be used to supply water in an emergency or during routine rehabilitation or replacement of existing system components. The RWSP needs to continue to understand the limitations of such interconnections for the region to plan effectively and make informed decisions. Several issues exist that that may limit the capacity and the availability of water supply through these interconnections. Some considerations include the following:

- A pressure differential between the systems is required to allow to water to flow from one system to another, which makes understanding the pressure differential at the boundaries of each water system essential.
- Pump capacity and the size of the interconnected pipe is a limiting factor that will need to be considered.
- The hydraulics of each system when using the different sources should be understood. System interconnections should be tested before using them in an emergency situation to confirm that expected flows do not have a negative effect on the remainder of the system. Testing in advance will allow the operators a chance to work under controlled conditions to ensure that reservoirs, pumps, and valves work appropriately for the changed flow conditions.
- Water quality is also a factor when using interconnections. In the region, providers use different types of disinfection methods, which, when mixed, could result in reduced water quality. Also, water in seldom-used interties is likely to require flushing prior to emergency use so that stagnant water is fully removed from the pipelines to ensure good water quality.

Studies have been conducted through hydraulic modeling and other more direct testing to ensure sufficient water flow at different interconnections. One example is the Tualatin Valley Water District (TVWD) project with the City of Tualatin to use a portable pump station to pump water from the large former Wolf Creek service area of the TVWD system to the Metzger area of TVWD and the City of Tualatin.

Additional studies and testing will be needed to determine flow capacity and the viability of providing emergency water through the various regional interconnections. The results of these studies may lead to projects to increase the size of key interconnections or other added appurtenances that will allow potential “reverse flow” conditions.

New and Proposed Interconnections

According to the IMEP, the majority of water providers are well connected to neighboring water systems, but few new regional interconnections have been built in the last ten years. One project worth highlighting is the Joint Water Commission’s (JWC) work to build an emergency intertie connection point on the South Transmission Line to facilitate a connection to the Willamette Water Supply System in the future. The JWC is also working on a 10-mgd intertie on the North Transmission Line to move water back from Tualatin Valley Water District into the transmission system in an emergency event.

As noted, the existing interconnections have limitations, and additional study, improvements, and testing are needed. The update of the IMEP may provide some useful recommendations for priority interconnection projects.

Interagency Agreements

Interagency and mutual-aid agreements (IGA) are an important part of the region’s resiliency because they define how water providers work together during normal and emergency situations. Water providers also have IGAs for sharing water that outline operational strategies and cost. With few exceptions, there are no prohibitions to sharing water between providers. Some providers, however, are prohibited from using water from the Willamette River without a citizen vote or state-declared emergency.

Looking Forward

Although the region has an excellent foundation for resiliency through interconnections and source diversity, more can be done to improve the state of interconnections. Below are some potential projects the Consortium and its members could undertake:

- **Regional hydraulic model:** The IMEP highlighted the need for a regional hydraulic model as a potential next step in meeting the objectives for the IMEP project. Although the IMEP provides valuable information, the geodatabase cannot be used to evaluate how much water can move through regional interconnections to serve water providers in the event of an emergency.

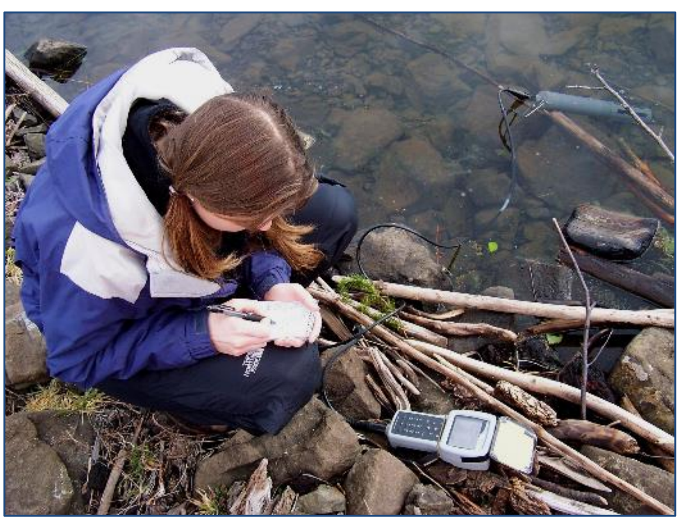
- **Water quality compatibility study:** The potential impact of water from different sources mixing as the result of employing interconnections should be well understood. Best management practices should be in place to ensure that water quality is maintained.
- **Testing and maintenance of interconnections**: Interconnections should be functioning and maintained on a regular basis.
- **Exercises and training**: The Consortium should continue to conduct tabletop exercises, drills, and training on the IMEP Geodatabase and to test interconnection scenarios.

Chapter 6: Source Water Protection

Overview 61
Summary of Source Water Protection Efforts for Surface Water Sources 62
Bull Run Watershed 62
Tualatin and Trask Rivers 63
Joint Water Commission 64
Forest Grove 65
Clackamas River 66
Willamette River 68
Summary of Source Water Protection Efforts for Groundwater Sources 68
Columbia South Shore Well Field 69
Powell Valley Well Field 69
Cascade Well Field 69
Milwaukie Well Field 70
Aquifer Storage and Recovery (ASR) 70
Water Quality Monitoring 70
Safe Water Drinking Act Compliance 71
Water Level Monitoring 71
Looking Forward 71

Overview

In 1998, the Consortium adopted a strategy for participating and supporting source water protection (SWP) efforts. With the understanding that a one-size-fits-all strategy is not appropriate for the region because of the variety of water sources, the Consortium has focused on promoting SWP efforts with the member agencies and elected officials and on legislative efforts. This strategy was incorporated into the 2004 Regional Water Supply Plan (RWSP) Update. This chapter highlights the SWP programs and plans in place for the major water sources and discusses notable program changes since the last RWSP update.



Source water protection plans and programs are unique to each water system. The final products are highly dependent on the size and type of watershed or recharge area, land uses, potential contaminant sources, and the water provider's goals. Following a cooperative effort between the Oregon Department of Environmental Quality (DEQ) and the Oregon Health Authority (OHA), water providers completed source water assessments for all public water systems in the state between 2000 and 2005. The assessments delineated the source area supplying drinking water, identified areas sensitive to contamination, and inventoried potential contamination sources. Some providers have conducted additional assessments or developed source water protection plans and programs.

Although development of source water protection plans is voluntary, a plan can lead to financial, public education, and water quality benefits. Protecting source water quality by implementing a SWP plan and program may help avoid treatment costs, aid in protecting public health, improve aesthetic water quality characteristics (such as taste and odor problems), create opportunities to leverage funds from multiple sources, and provide additional messaging to communicate with the public.

In addition to water providers, there are a number of other organizations that are involved in protecting water quality in the region for multiple purposes. This section focuses on the specific efforts of water providers.

Summary of Source Water Protection Efforts for Surface Water Sources

Bull Run Watershed

The Bull Run Watershed is the primary drinking water supply for the City of Portland and its 20 wholesale customers. The protected Bull Run watershed is located 26 miles east of downtown Portland in the Sandy River Basin. The Bull Run Watershed Management Unit (BRWMU) includes the 102-square-mile area that drains to the water supply intakes, as well as about 40 square miles of surrounding buffer land.

Approximately 95 percent of the BRWMU is federal land administered by the U.S. Forest Service; 4 percent is owned by the City of Portland; and 1 percent is federal land administered by the U.S. Bureau of Land Management. In 2007, the City and Forest Service signed a partnership agreement to update watershed management roles and to promote communication and collaboration.

Bull Run Lake

The Bull Run watershed is one of the most protected water supply watersheds in the nation, and the pollution control strategy relies heavily on prevention. The watershed has been closed to private development, agriculture, and recreation for more than 100 years. Commercial timber harvest is prohibited. Public entry is restricted; only escorted public tours are permitted. Trespassers are subject to federal law enforcement and substantial fines. Best management practices, contract specifications, and standard operating procedures are used to strictly control human sanitation, exclude domesticated animals, limit the risk of introduction and spread of invasive species, and otherwise restrict activities that may impair water quality. The City of Portland, Forest Service, and Oregon Department of Forestry coordinate closely throughout the fire season to control the risk of human-caused forest fires, monitor weather conditions that increase fire risk, and ensure prompt response to fire starts in or near the watershed.

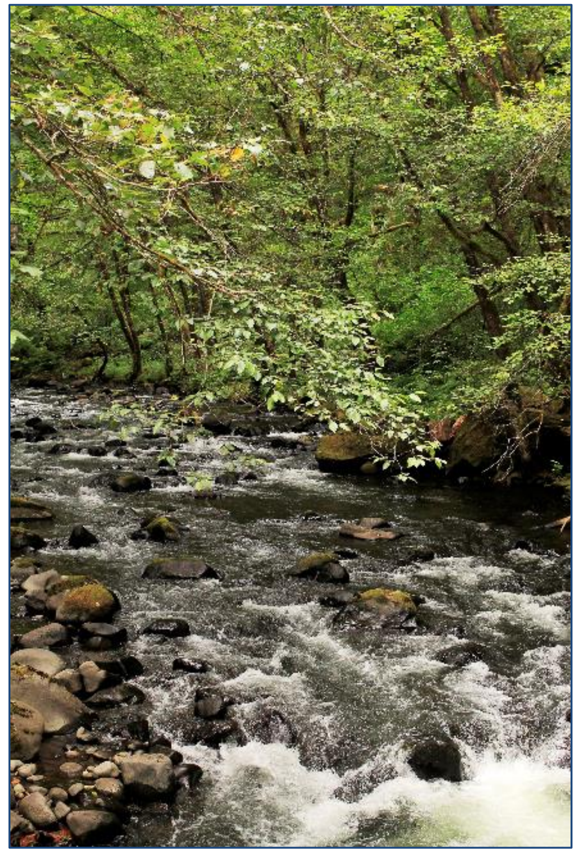
The City conducts an extensive water-quality monitoring program for the reservoirs and tributary streams in order to detect short- and long-term changes in source water quality. In 1992, the City was granted a waiver from federal requirements under the Surface Water Treatment Rule to filter the water supply, one of a handful of such waivers in the nation. In 2012, the City was also granted the nation's only variance from federal requirements under the Long Term 2 Enhanced Surface Water Treatment Rule (LT2) for treatment of *Cryptosporidium.* Maintaining these exceptions from federal rules requires extensive water quality monitoring, strict adherence to watershed protection control measures, reporting on watershed conditions and controls, and inspections by the state of Oregon.

In addition to the protections for source water quality described above, the City is implementing a federally approved habitat conservation plan, approved in 2008, to maintain compliance with the federal Endangered Species Act (ESA). This plan involves 49 measures to protect and improve habitat for both aquatic and terrestrial species. The plan is implemented in partnership with public and private organizations working together on habitat conservation in the larger Sandy River Basin.

Tualatin and Trask Rivers

The Tualatin and Trask Rivers provide drinking water for many residents in Washington County and supply water for 10 public water systems including the following Consortium members: Hillsboro, Forest Grove, Tualatin Valley Water District, and Beaverton. The source water protection efforts for the Joint Water Commission and the City of Forest Grove are described below. Note that the City of Hillsboro owns and operates a water treatment plant (WTP) and distribution system in the upper Tualatin River watershed in addition to receiving water from the Joint Water Commission. The source area for this WTP is encompassed by the source area for the Joint Water Commission. There are also numerous public and private wells in the watershed using the groundwater resource.

Joint Water Commission. The Joint Water Commission (JWC) is a collective water supply agency consisting of the Cities of Hillsboro, Forest Grove, Beaverton, and the Tualatin Valley Water District. The JWC is responsible for treating, transmitting and storing potable water for approximately 400,000 customers in Washington County including the member agencies and wholesale customers. The Source Water Protection program is coordinated by the City of Hillsboro, the managing agency for JWC, with guidance from a Technical Advisory Committee (TAC) consisting of representatives from each member agency.


Tualatin River

The drinking water source area (DWSA) for the JWC is composed of two surface water systems. The first surface water system is a 220-square-mile portion of the upper Tualatin River Basin that drains to the WTP intake. The second surface water system is the 8.2-square-mile watershed of Barney Reservoir in the upper Trask River Basin. Water released from Barney Reservoir is diverted to the upper reaches of the Tualatin River. The land within the DWSA is owned by myriad private landowners and public agencies, and the JWC does not have regulatory authority over activities occurring within it. The western section is in the Oregon Coast Range characterized by steep terrain and forested land in timber production. The eastern section is dominated by flatter terrain and agricultural activities. The areas closest to the WTP intake include residential land and major transportation corridors.

In 2003, a Source Water Assessment (SWA) of JWC's DWSA was completed through a cooperative effort between Oregon DEQ, OHA, and the JWC. The analysis found that 200 of the 306 potential contamination sources were classified as high risk and located in sensitive areas.

In 2013, a more thorough and spatially explicit SWA was completed. Contamination risks and watershed sensitivities were combined in a GIS tool to guide determination of the highest priorities for the SWP program to address. Overall results were that 2 percent of the area that had a relatively high contaminant risk ranking was located in highly sensitive areas. About 71 percent of the drinking water source area did not have a risk present in a sensitive area. A water quality database was also developed that enables viewing water quality monitoring sites and data on maps.

In 2014, a Source Water Protection Plan was finalized based on the results of the 2013 SWA that outlines source water protection programs in nine categories. Tasks were identified for each program category in a five-year implementation plan (Fiscal Years 2014–19). This schedule is dependent on annual budget approvals and annual program approval from the SWP TAC. The program categories are:

- Agricultural Runoff
- Forestry
- Septic Systems
- Point Source Discharges
- Nonpoint Sources
- Water Quality and Turbidity Projects
- Public Outreach
- Research and Education
- Water Quality Monitoring

Forest Grove. While the City of Forest Grove is a member of the Joint Water Commission (JWC), it also independently owns and operates a water treatment plant. The City of Forest Grove owns 4,225 acres of the land in the upper Clear Creek Watershed of the Tualatin River Basin within the JWC's drinking water source area. The land is on the forested mid-to-lower slopes of the Oregon Coast Range about four miles northwest of Forest Grove. It includes almost 1,000 acres of 90- to 110-year-old forest.

In 1917, the City of Forest Grove began buying land to have a controllable source of water for its water treatment plant. Most of the land was purchased after World War II. The City obtains about 50 percent of its water from five diversion structures on the watershed (on Clear Creek, Roaring Creek, Deep Creek, Smith Creek, and Thomas Creek). These five structures combined provide a supply of about 2 to 4 mgd. Forest Grove serves approximately 22,500 people.

In July 2013, the City of Forest Grove updated its Watershed Stewardship Management Plan. The plan describes the current forest conditions and management accomplishments since 2001, establishes monitoring and evaluation protocols, and updates forest policy and management recommendations. It is intended to guide activities until 2022.

These lands are managed to protect and improve forest ecosystem health for the purpose of providing the City with high-quality drinking water. The plan strives to increase the natural diversity of the forest and enhance its wildlife habitat.

The City conducts tree harvesting as a sustainable resource management activity. The City's practices are consistent with the Forest Stewardship Council's certified forest management practices. An independent third-party assessment ensures that forest management meets stringent standards for environmental sensitivity, sustainability, and community and social concerns. The plan also protects one-third of the land from harvesting due to sensitive characteristics including riparian areas, steep slopes, inaccessible areas, representative ecosystems, and old forest. Herbicide use is minimized and strictly controlled. Public access in the watershed is restricted, and recreational activities are prohibited.

The recommended actions in the updated plan include:

- stream restoration, including slope stabilization
- sustainable tree harvest and stand condition monitoring
- wildlife surveys and habitat enhancement
- road maintenance, improvement, and condition monitoring
- control of invasive vegetation
- public education and involvement through public tours
- land acquisition
- fire management coordination with Oregon Department of Forestry

Clackamas River

The Clackamas River serves most residents in Clackamas County and supplies water for the following Consortium members: Clackamas River Water, City of Lake Oswego, Sunrise Water Authority, South Fork Water Board, Oak Lodge Water District, City of Tigard, and the City of Gladstone.

Clackamas River

The Clackamas River is a drinking water source for more than 300,000 people in Clackamas County. The watershed drains approximately 940 square miles. More than half of its length runs through forested areas over rugged terrain, and the lower reaches flow through agricultural and densely populated areas. Seventy-two percent of the watershed is publicly owned, 3 percent is tribally owned, and 25 percent is privately owned. There are five municipal surface water intakes on the Clackamas River represented by the Clackamas River Water Providers (CRWP): City of Estacada, Clackamas River Water, North Clackamas County Water Commission (Sunrise Water Authority, Oak Lodge Water District, and the City of Gladstone), South Fork Water Board (Oregon City and West Linn), and City of Lake Oswego.

The water providers in the Clackamas River Basin have been working together on various water resource issues for more than a decade. In July of 2005, an Intergovernmental Agreement for Joint Funding for Watershed Activities in the Clackamas Basin was signed between water providers and Clackamas County Water Environment Services to formalize collaborative work on watershed and water-quality-related projects.

In 2007, an intergovernmental agreement created the Clackamas River Water Providers (CRWP). CRWP funds and coordinates efforts relating to water source water protection and water conservation. The CRWP has no regulatory authority over activities other than its own within the Clackamas River watershed. There are multiple federal, state, and local authorities that do have existing and proposed rules, regulations, and programs that can protect water quality. The CRWP supports existing protective requirements and positively affects proposed protections for the Clackamas River.

In 2002 and 2003, DEQ and DHS, with the assistance of the Clackamas Basin Watershed Council and the water providers, completed four source water assessments on the Clackamas River. These assessments were for the U.S. Forest Service Timber Lake Job Corp; the City of Estacada; a joint assessment for South Fork Water Board, the North Clackamas County Water Commission, and Clackamas River Water; and the City of Lake Oswego. More than 1,200 potential contaminant sources were identified and ranked by risks (low, moderate, high).

In 2010, a Drinking Water Protection Plan was approved by CRWP. The overall drinking water protection strategy includes eight sub-programs that outline management measures, programs, and strategies to accomplish the goals of addressing various threats to water quality and ensuring the long-term viability of the Clackamas River as a drinking water source. The sub-programs include:

- Basin Analysis: Studies, GIS, Modeling, and Water Quality Monitoring
- Education and Research Assistance
- Point Source Evaluation and Mitigation
- Nonpoint Source Evaluation and Mitigation
- Disaster Preparedness and Response

- Public Outreach and Information Sharing
- Watershed Land Use Tracking and Management
- Land Acquisition

Every year the CRWP completes a report summarizing the year's source water protection activities.

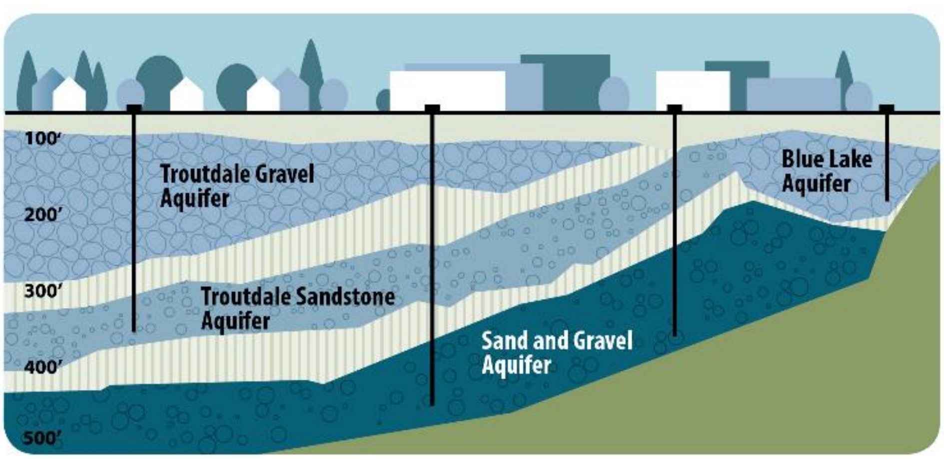
Willamette River

The Willamette River currently provides drinking water for the City of Sherwood and the City of Wilsonville. Tualatin Valley Water District and the City of Hillsboro are also partnering to develop the mid-Willamette River at Wilsonville as an additional water supply source.

In 2002 and 2003, Source Water Assessments were conducted by DEQ and OHA for all public water systems using the Willamette River or tributaries as a source at that time. Currently, no formal SWP plan is administered by Consortium members, but many other organizations conduct work in the watershed that benefits water quality. As the Tualatin Valley Water District and the City of Hillsboro develop this supply source, development of a source water protection plan is anticipated.

Summary of Source Water Protection Efforts for Groundwater Sources

Groundwater is the primary and/or secondary drinking water source for several communities in the greater Portland metropolitan area including the City of Milwaukie (primary), the City of Gresham (secondary), Rockwood Water People's Utility District (secondary), and the Portland Water Bureau and its wholesalers (secondary). The cities of Portland, Gresham, and Fairview have partnered to implement a groundwater protection program to protect the Columbia South Shore Well Field. Gresham and Rockwood jointly administer the Cascade Well Field Protection Program.



Columbia South Shore Well Field

The Portland Water Bureau operates a well field capable of producing close to 100 mgd of high-quality drinking water. The Columbia South Shore Well Field (CSSWF) is the second largest water source in the state of Oregon and the largest developed groundwater source, containing about half of the daily capacity of Portland's Bull Run source. The well field is located just south of the Columbia River, east of Portland International Airport, and west of Troutdale. Water is drawn from three aquifers using 26 wells spread over a 12-square-mile area.

The cities of Portland, Gresham, and Fairview protect the aquifers of the CSSWF through joint implementation of a groundwater protection program that meets the requirements of Oregon's Wellhead Protection Program (OAR 340-40-170). The goal of the groundwater protection program is to prevent future groundwater contamination and to discover and remediate preexisting contamination.

Businesses within the state-certified wellhead protection area boundary are subject to regulation if they transport, store, or use certain types and quantities of chemicals. Regulated businesses are required to implement spill prevention and containment measures, train employees on groundwater protection practices, and annually report their hazardous materials directly to the Portland Water Bureau.

Portland provides technical assistance to regulated businesses through a partnership with the Columbia Corridor Association. Portland routinely monitors groundwater quality at 80 locations and has an intergovernmental agreement with DEQ to expedite remediation within the CSSWF. Outreach and education for the general public are conducted through a partnership with the Columbia Slough Watershed Council and focus on how residents can help protect the city's drinking water.

Powell Valley Well Field

The City of Portland is in the process of updating the groundwater protection program for the Powell Valley Well Field (PVWF) located near Powell Butte. The Powell Valley Well Field was annexed to the City in 2005 and is not currently in use, but it is part of the City's long-term water supply strategy.

Cascade Well Field

The Cascade Well Field Protection Area (CWFPA) encompasses portions of the cities of Gresham, Fairview, Troutdale, and Wood Village. The City of Gresham, in partnership with the Rockwood Water People's Utility District, developed and administers the Cascade Well Field Protection Program. Both agencies provide financial support for the program.

The designated groundwater protection area is based on a groundwater model simulation of the 30-year time of travel to the Cascade production wells. For sites located in the designated CWFPA, the transport, storage, and use of mobile chemicals that are halogenated solvents, hazardous substances, hazardous waste, or petroleum products (including fuel) may be subject to requirements similar to those in place within the CSSWF. Regulated businesses are required to submit an annual site plan and hazardous materials inventory report; participate in site inspections; maintain adequate containment areas for hazardous materials; maintain spill kits, procedures, and signage; and provide spill response training program for employees. The program also provides recommended best management practices.

Milwaukie Well Field

The Troutdale Gravels Aquifer encompasses about 300 square miles and extends from northern Clark County in Washington to south of Milwaukie and from east of Troutdale to the Willamette River. Milwaukie has seven operating wells that range from 300 feet to nearly 500 feet deep. A source water assessment was completed in 2004 and updated in 2010.

At that time, the drinking water protection area was slightly expanded. The City of Milwaukie is currently extending its wastewater service area to reduce threats from septic systems. They work closely with DEQ and EPA to monitor and clean up past contaminated sites.

Aquifer Storage and Recovery (ASR)

ASR (Aquifer Storage and Recover) on the Westside of the Metro area has steadily increased since the start of the City of Beaverton's ASR program in 1999. Beaverton and the Tualatin Valley Water District share an Oregon Water Resources Department (OWRD) ASR limited license. Additionally, the cities of Tigard and Tualatin have ASR wells and other providers have wells in development. For additional information on ASR supplies, see Chapter 1.

Water Quality Monitoring

Water quality monitoring is required for ASR activities to demonstrate that the injected and recovered water quality meets potable standards, to assess potential chemical reactions between source water and native groundwater that could result in clogging of the injection wells or adversely affect native groundwater quality, and to comply with ASR limited license requirements. The complete list of parameters is extensive, and water quality testing is to be conducted by an Oregon-certified laboratory.

Safe Drinking Water Act Compliance

Analytical results must show that the water quality meets EPA/OHA drinking water standards for regulated parameters for source water, storage water, and recovered water. Quality assurance/quality control (QA/QC) must be performed on all analyzed data in general compliance with U.S. Environmental Protection Agency's (EPA) National Functional Guidelines, with no exceedances or QA/QC issues identified.

Water Level Monitoring

ASR limited-license testing is also required to evaluate potential water losses due to ASR activity in order to determine an appropriate recovery percentage for the ASR permit. Specifically, monitoring of the aquifer system is required to evaluate the dynamic response of the system to ASR operation. Beaverton has been monitoring its ASR wells and monitoring wells, as well as nearby private wells, for the past 16 years. In general, groundwater levels have been rising within the vicinity of the Beaverton ASR wells since ASR was initiated by the city in 1999. Within the network of monitoring wells, the records have shown no long-term decline in the static water level in the regional Columbia River basalt aquifer attributable to ASR activities, strongly suggesting that there is no appreciable net loss of stored water from the aquifer. This trend is important because most of the ASR wells on the west side are within the Cooper Mountain–Bull Mountain critical groundwater area designated by OWRD in 1974. From a regional perspective within the critical groundwater area, the groundwater level within the aquifer has increased and remains roughly 20 feet higher than it was before the start of ASR activities in 1999.

During this period of time, nearly 3.74 billion gallons of water have been stored and 4.10 billion gallons of water have been pumped (ASR storage plus native groundwater) from the local Columbia River Basalt aquifer.

Looking Forward

A tremendous amount of work has been done to protect water quality since the Consortium prepared its first source water protection strategy back in 1998. Most of the recommended strategies have been implemented. Looking forward, the Consortium will continue to be a champion for source water protection through legislative advocacy, partnerships, grants, studies, conservation, and education. Individual water providers and partner organizations will continue to evaluate, implement, and expand their individual plans to ensure the long-term quality of our region's water sources.

Specific measures the Consortium may undertake to promote source water protection include:

- continuing to promote water efficiency and raise awareness about the role water conservation can play in source water protection through the increased longevity of existing and potential drinking water sources
- continuing to participate in the Oregon Health Authority's Drinking Water Advisory Committee
- tracking changes in water quality and source water protection regulations by monitoring existing rules and regulations for changes and amendments that could impact drinking water quality
- supporting regulatory efforts that promote the protection of water quality
- participating in or pursuing legislation and administrative mechanisms to promote source water protection; participate in agency planning and rulemaking processes in support of source water protection
- supporting implementation of Oregon Integrated Water Resources Strategy measures that promote source water protection such as
    - effective management and oversight of stormwater in urbanized areas (National Pollution Discharge Elimination System permits)
    - monitoring for contaminants of emerging concern
    - supporting state revolving loan funds for source water protection programs
    - toxics reduction, including pesticide management plans
    - monitoring and preventing blue–green algae blooms
- participating in and tracking state and regional research efforts on climate change and its affect on water supply, fire risk, disease, and water quality related to temperature and stream flow.
- educating policy makers, including the Consortium Board, legislators, and state agency policy bodies about the importance of protecting drinking water sources and related issues

Chapter 7: Regulatory Changes

Overview ... 73
Regulatory Issues Affecting Water Sources ... 74
Federal ... 74
Long Term 2 Enhanced Surface Water Treatment Rule ... 74
Stage 2 Disinfection Byproducts Rule ... 75
Total Coliform Rule ... 75
Lead and Copper Rule ... 75
Contaminant Candidate List 4 ... 76
Unregulated Contaminant Monitoring Rule 4 ... 76
Endangered Species Act ... 76
Water Infrastructure Finance and Innovation Act ... 75
State ... 77
Fish Persistence (House Bill 3038) ... 77
Oregon Resilience Plan ... 78
Integrated Water Resources Strategy ... 78
Infrastructure Finance ... 79
Local and Regional ... 79
Metro Urban Growth Boundary ... 79
Potential Future Regulatory Issues Affecting Water Sources ... 79
Federal ... 79
Algal Toxins ... 79
Endocrine Disruptors ... 80
Pharmaceuticals ... 80
Cybersecurity ... 80
Waters of the United States (WOTUS) ... 80
State ... 80
Drought ... 80
Local and Regional ... 81
Climate Change ... 81

Overview

Several major regulatory changes have taken place at the federal, state, and local levels since 2004 that may directly affect the viability and management of municipal water sources. Changes at the federal level include new rules issued by the Environmental Protection Agency (EPA) for the Long Term 2 Enhanced Surface Water Treatment Rule (LT2), the Revised Total Coliform Rule (RTCR), and the Lead and Copper Rule (LCR). At the state level, the passage of House Bill 303 created a requirement that diversions of water for municipal purposes be conditioned to maintain the persistence of threatened or endangered fish. Locally, the Metro Council has reevaluated the urban growth boundary, which can affect development decisions in the region. Issues that may require regulatory action based on current knowledge are also discussed in this chapter.

Acronym GLOSSARY
EPA: Environmental Protection Service
LT2: Long Term 2 Enhanced Surface Water Treatment Rule
DB: Disinfection Byproducts
TCR/RTCR: Total Coliform Rule/ Revised Total Coliform Rule
LCR: Lead and Copper Rule
NPDWR: national primary drinking water regulations
CCL 4 Contaminant Candidate List 4
UCMR 4: Unregulated Contaminant Monitoring Rule 4
ESA: Endangered Species Act
NOAA: National Oceanic and Atmospheric Administration
USFWS: U.S. Fish and Wildlife Service
WIFIA: Water Infrastructure Finance and Innovation Act
TIAFIA: Transportation Infrastructure Finance and Innovation Act
OWRD: Oregon Water Resources Department
IWRS: Integrated Water Resources Strategy
UGB: urban growth boundary
UBR: urban growth report
EDSP: Endocrine Disruptor Screening Program
WOTUS: waters of the United States
CREAT: Climate Resilience Evaluation and Awareness Tool

Regulatory Issues Affecting Water Sources

Federal

Long Term 2 Enhanced Surface Water Treatment Rule. The Long Term 2 Enhanced Surface Water Treatment Rule (LT2), implemented in 2006, is targeted at reducing the human health risk associated with *Cryptosporidium* in surface water used as a drinking water supply. *Cryptosporidium* is a protozoan parasite that is relatively resistant to disinfectants such as chlorine, and it is associated with acute gastrointestinal illness and other disease-causing microorganisms in drinking water. LT2 addresses two main areas relating to water supply: treatment of unfiltered surface water and covering or treating finished drinking water found in open reservoirs.

Under LT2, managers of surface water systems are required to monitor their water sources to determine treatment requirements, and the water sources are subject to risk classification based on the results. Initial monitoring requires two years of monthly sampling for *Cryptosporidium*. Managers of small filtered-water systems can control costs by monitoring first for *E. coli* — a bacterium that is less expensive to monitor than *Cryptosporidium* — and monitor for *Cryptosporidium* only if their *E. coli* results exceed certain levels. A second round of monitoring is required six years after completing the first round to determine if source water conditions have changed over time.

In addition to meeting treatment requirements, systems that store treated drinking water in open reservoirs must have covered reservoirs or the reservoirs must be treated to inactivate 4-log virus, 3-log *Giardia lamblia*, and 2-log *Cryptosporidium*.

LT2 was issued simultaneously with the Stage 2 Disinfection Byproduct Rule to address concerns regarding risk tradeoffs between pathogens and disinfection byproducts (DBPs).

Stage 2 Disinfection Byproducts Rule. As a supplement to the LT2 rule, EPA also issued the Stage 2 Disinfection Byproducts Rule, which requires water systems managers to take steps to reduce the formation of disinfection byproducts resulting from treatment for microbial pathogens. DBPs form in drinking water when disinfectants used to control microbial pathogens such as chlorine combine with various organic and inorganic materials in the water to form potentially harmful compounds. The rule, finalized in 2005, is intended to reduce potential health risks including related cancer and reproductive and developmental health concerns as a result of the presence of DBPs.

Total Coliform Rule. Based on the 2003 review of drinking water regulations, EPA revised its Total Coliform Rule (TCR), which was published as the Revised TCR (RTCR) in 2013. The purpose of the TCR is to increase public health protection from pathogenic microbial contaminants. The coliform bacterium is not pathogenic, but it is an indicator of pathogens and is relatively easy to detect.

The revised rule eliminates the maximum contaminant load (MCL) requirement for total coliform and the public notice requirement based only on the presence of total coliform. The rule also contains new requirements intended to ensure that assessment and corrective action will take place when monitoring results indicate that a potential risk of contamination exists.

Lead and Copper Rule. The purpose of the Lead and Copper Rule (LCR) is to protect public water system consumers from exposure to lead and copper in drinking water. After conducting a review of its Lead and Copper Rule in 2004, EPA released a Drinking Water Lead Reduction Plan in March 2005, which outlined short-term and long-term goals for improving implementation of the Lead and Copper Rule.

EPA is implementing a rule that makes several revisions to the existing national primary drinking water regulations (NPDWRs) for lead and copper, although there is not a clear timeline for publication of the proposed or final rule. The revisions to the LCR modify requirements for lead and copper monitoring, treatment, lead service line replacement, and public education on the subject of lead in drinking water.

The conversation relating to modifications to the LCR intensified in 2015 after the exposure of high levels of lead in the water in Flint, Michigan. Congress is considering various approaches to legislation that may affect the final LCR rule.

Contaminant Candidate List 4. In accordance with the Safe Drinking Water Act, the Draft CCL 4 was released in 2015 and is expected to be finalized in early 2016. The CCL (contaminant candidate list) is a list of contaminants that are known to exist in public water systems and may require regulation in the future. CCL 4 includes 100 chemicals or chemical groups and 12 microbial contaminants that are known or anticipated to occur in public water systems.

Unregulated Contaminant Monitoring Rule 4. Every five years, in accordance with the Safe Drinking Water Act, EPA issues a new list of no more than 30 unregulated contaminants to be monitored by public water systems. EPA released the proposed Unregulated Contaminant Monitoring Rule 4 (UCMR 4) in December 2015. The list includes 30 chemical contaminants or contaminant groups. The EPA expects to publish the final UCMR 4 in late 2016 or early 2017, with monitoring possibly beginning in early 2018.

Endangered Species Act. The Endangered Species Act (ESA) outlines a program for the conservation of threatened or endangered plant and wildlife species and their habits. Species covered under the ESA are listed and delisted on an ongoing basis. Any government body authorizing an activity that specifically causes "take" (killing or harming a listed species) may be found to be in violation of the Section 9 *take* prohibitions. Every action conducted by a utility must be examined for its potential regarding *take* under the ESA, especially actions that may affect the habitat of or actual species with an assigned designation as threatened or endangered. Section 10 of the ESA allows for the approval of *incidental take* of threatened and endangered fish and wildlife species during the performance of otherwise lawful activities provided certain conditions are met.

Section 7 requires that each federal agency consult with NOAA Fisheries and/or U.S. Fish and Wildlife Service (USFWS) to ensure that any action authorized, funded, or carried out by a federal agency is not likely to jeopardize the continued existence of any threatened or endangered salmon species or would result in the destruction of adverse modification of critical habitat designated for the species. Section 7 generally applies to actions (or funded activities) such as U.S. Army Corps of Engineers Section 404 permits, EPA approval of state water quality standards, mortgage and facility development assistance from federal agencies, and licensing and regulation of hydroelectric facilities by the Federal Energy Regulatory Commission.

Water Infrastructure Finance and Innovation Act. The Water Infrastructure Finance and Innovation Act (WIFIA) was enacted in 2014 as part of the Water Resources and Reform Development Act. WIFIA is an infrastructure-financing program based on the successful Transportation Infrastructure Finance and Innovation Act (TIFIA) that provides low-interest federal loans for as much as 49 percent of the project costs for large drinking water, wastewater, stormwater, and water reuse projects. The law, as written, prohibited tax-exempt bonds from funding the remaining 51 percent of a project, thereby taking away the most cost-effective project-funding tool for communities that might seek WIFIA loans. In December 2015, Congress passed legislation that lifted the ban on the use of tax-exempt bonds with loans authorized under WIFIA.

Congress has not yet appropriated funds for the program, although the EPA fiscal year 2017 budget request included funds for WIFIA, with the first loan expected in fiscal year 2017. Additional funding for water infrastructure through WIFIA loans is possible as a result of potential legislation spurred by the lead crisis in Flint, Michigan.

State

Fish Persistence (House Bill 3038). Oregon water law requires a city to apply for a permit from the Oregon Water Resources Department (OWRD) before diverting water for municipal use. When a permit is issued, it gives the city a certain amount of time to put the volume of water authorized in the permit to municipal use. If the city is unable to divert all of the water it applied for within the time specified in the permit, it must apply for an extension of time for the undeveloped portion of the water, or it must obtain a water right certificate for the amount of water that was developed.

In 2005, the Oregon State Legislature passed House Bill 3038 (HB 3038), which applied what are known as fish persistence conditions to the first extension of municipal water rights permits. These conditions are intended to protect and maintain threatened and endangered fish in the river. Following passage of the 2005 legislation, OWRD implemented the statute on a prospective basis. WaterWatch filed a lawsuit against the city of Cottage Grove for water that the city had fully developed and put to full municipal use in 2008. In 2013, the Oregon Court of Appeals ruled that the application of the persistence conditions should have been applied to the last-approved extension, which for many municipalities was in the 1990s (approximately 10 years before the adoption of the requirement). Failed bills during both the 2015 and 2016 Legislative Sessions would have clarified that application of conditions would occur as of the date of the Court of Appeals decision, or December 11, 2013. Absent legislative action, any municipality filing for a water rights extension or that has developed water that was undeveloped pre-1998 must apply fish persistence conditions to the permit.

Oregon Resilience Plan. In 2013, the Oregon Legislature passed Senate Bill 33 (SB 33), which created a 17-member Task Force on Resilience Plan Implementation. The purpose of the task force was to facilitate development of a comprehensive plan to implement the Oregon Resilience Plan, the goal of which is to reduce risks and improve recovery after the next Cascadia earthquake. In December 2014, the task force narrowed more than 140 recommendations in the Oregon Resilience Plan down to the most critical for implementation. Recommendations relating to water supply include: 1) that water providers complete a seismic-risk assessment and mitigation plan as part of the existing requirement for periodic updates to water system master plans, 2) that wastewater agencies complete a seismic-risk assessment and mitigation plan as part of periodic updates to facility plans, and 3) that firefighting agencies, water providers, and emergency management agencies establish joint standards for use in planning the firefighting response to a large seismic event. For more information on resiliency planning, see Chapter 4: Emergency Preparedness.

Integrated Water Resources Strategy. In 2009, House Bill 3369 (HB 3369) directed OWRD to lead a statewide effort to complete an integrated water resources plan for Oregon that identified the current state of Oregon's water supply and steps to be taken to ensure that sustainable supplies of water are available to meet future in-stream and out-of-stream needs. The IWRS was completed in August 2012 and provides recommended actions to help understand current water resources, to help understand and meet in-stream and out-of-stream needs and demands, and to understand coming pressures that will affect needs and supplies. The IWRS work plan identifies specific legislative strategies related to data collection; development of water management tools; and funding of state agencies and local communities to finance place-based planning, infrastructure, restoration efforts, and partnerships. The IWRS will be updated in 2016, which could result in additional legislative initiatives.

Infrastructure Finance. In 2015, the Oregon State Legislature approved almost $50 million for a combination of water development funds. These funds included $750,000 for place-based planning grants administered by OWRD, a recommended action from the 2012 Integrated Water Resources Strategy (IWRS).

Local and Regional

Metro Urban Growth Boundary. Metro, local jurisdictions, and many other partners work together to guide development in the region. Oregon law requires that every six years the Metro Council evaluate the capacity of the region's urban growth boundary (UGB) to accommodate a 20-year forecast of housing needs and employment growth. The Consortium participates in the Metro Technical Advisory Committee to provide input on growth decisions because they affect the availability and accessibility of water supply and service in the region. The Regional Water Supply Plan, as referenced in Chapter 4 of Metro's Regional Framework Plan, outlines how water needs will be met in the region through 2050.

Potential Future Regulatory Issues Affecting Water Sources

The production of safe water is the primary goal for all water providers. As science and technology evolve and local water conditions change, issues that are unknown or not a priority today may be issues tomorrow. This section includes information regarding emerging contaminants of concern and regulatory issues that are known at the time of the publication of this report that may require regulatory actions.

Federal

Algal Toxins. In March 2015, EPA announced new health advisory values for the algal toxins microcystin and cylindrospermopsin. The recommendations include separate values for young children under the age of five and for school-age children six years and older through adults based on a 10-day exposure period. The EPA is continuing to evaluate recommended actions and some specific issues that are still in question, such as the validity of the age split for the separate advisory levels.

Endocrine Disruptors. EPA collects data under its Endocrine Disruptor Screening Program (EDSP) along with other hazard information to determine whether a pesticide, chemical, or other substance that could be found in sources of drinking water, may pose a risk to human health or the environment as a result of disruption of the endocrine system. Based on assessments of that data, EPA may choose to list a chemical in the next UCMR.

Pharmaceuticals. In August 2015, the EPA proposed the Management Standards for Hazardous Waste Pharmaceuticals Rule. This rule proposes a sector-specific set of regulations for the management of hazardous waste pharmaceuticals by health care facilities (including pharmacies) and reverse distributors. The proposed rule will make drinking and surface water safer and healthier by reducing the amounts of pharmaceuticals that enter waterways.

Cybersecurity. Cybersecurity is a major concern for water utilities. The water sector's greatest cybersecurity need is information about emerging or imminent threats and actions that can be taken to mitigate the threat of cyberattacks. The National Institute of Standards and Technology has developed a framework to help utilities assess and address risks.

Waters of the United States (WOTUS). In 2015, the EPA and Army Corps of Engineers released a new rule to clarify the definition of "waters of the United States" (WOTUS). Under the Clean Water Act, discharge of pollutants into WOTUS is regulated to protect water quality. The new rule, which continues to include traditionally navigable waters and the territorial sea, clarifies the scope of waters defined as WOTUS, and defines what constitutes water of "significant nexus" relative to WOTUS. The rule also modifies the definitions of tributary and adjacent waters to include waters with a bed, bank, and ordinary high-water mark.

Several states filed lawsuits that have put the rule on hold during litigation. This issue continues to play out in both U.S. Congress and the courts.

State

Drought. In 2015, the Governor of Oregon declared drought emergencies in 25 of Oregon's 36 counties. Historic warm temperatures and low snowpack contributed to a challenging water year for many areas of the state. Although the counties in the Metro area experienced drought conditions, including warmer-than-average temperatures and low stream flow, many municipalities in the region did not experience supply issues.

Future forecasts and climate change trends indicate that the conditions of 2015 may occur more frequently in the future. Drought will continue to be a focus of the current governor and could generate future policies and regulations that will affect water providers.

Local and Regional

Climate Change. Although climate change may affect policy at federal, state, and local levels, most of the current climate policy work is taking place at the local and regional levels because of the nuanced nature of each water supply and system. Collecting and understanding climate information is fundamental to addressing climate change and determining how the latest climate science could affect water supply sources. Several water utilities and water utility groups have partnered to develop and share climate information, science, and decision-support tools.

In 2015, the EPA released the Climate Resilience Evaluation and Awareness Tool (CREAT) to assist water utilities in assessing the risk of the potential effects of climate change. The tool provides lists of drinking water and wastewater utility assets (such as water resources, treatment plants, and pump stations) that climate change could impact, possible climate change-related threats (such as flooding, drought, and water quality), and adaptive measures that utilities can implement to reduce potential impacts. Following a risk assessment for water utilities, CREAT provides a series of risk reduction and cost reports to allow water utilities to evaluate various adaptation options as part of long-term planning.

Chapter 8: Future Challenges and Opportunities

Overview 83
Change in Demand 84
Full Cost Recovery and Financing Capital Improvements 85
Renewal and Replacement of Aging Infrastructure 86
Source Water Protection 87
Water Quality 87
Resilience to Natural and Manmade Disasters 89
Climate Variability 90
Water Rights 90
Meeting Future Supply Needs and Uncertainty in Demand 91
Conservation/Demand Management 92
Regional Planning, Coordination, and Cooperation 93
Regulatory Changes 93
Customer Understanding of Water Systems 94
Workforce Planning 95

Overview

Providing safe and reliable drinking water is the core mission of municipal water providers. In the mid-1800s, cities began to construct municipal water systems to bring water into resident's homes and to drive industry. Over the next 150 years, our knowledge of water quality and treatment has grown exponentially, and the industry has evolved accordingly.

Today's water providers use state-of-the-art science and technology to supply exceptional drinking water. Water providers, however, continue to face challenges in improving and maintaining our drinking water and the infrastructure that supports it.

This chapter details the most pressing challenges that face our region's water providers and describes the potential impact of these issues and how Consortium members can address them. The list of challenges is distilled from a much longer list that was compiled from Consortium surveys, workshops, and the American Water Works Association State of the Water Industry Report.

The most notable challenge is the change in water demand that has resulted in decreased revenues for water utilities. Since 2004, water providers in the region have experienced an average of 1.7% to 3.6% yearly decreases in demand by the residential customer class despite increases in the populations of their service areas. This decrease in demand and revenue comes at a time when much of the water system infrastructure is in need of replacement, repair, and seismic upgrades.

Change in Demand

Since 2004, most water providers in the Portland metro region have experienced general declines in water demand in the residential customer class despite population growth. Factors that generally contribute to declining per capita water demand include water conservation, land use changes, and most significantly, the price of water in the residential sector and loss of demand due mainly to the slow economy in the nonresidential sector. (See the Water Demand Trend Analysis chapter for a more detailed analysis of per capita and total demand changes in the region.)

IMPACT	HOW TO ADDRESS
Decline in water use has the effect of decreasing operating revenue, and it affects the ability to recover costs to maintain a water system. Reduction in demand can put upward pressure on rates as a means of maintaining revenue. Rate increases may be necessary for utilities to maintain or increase levels of service, including infrastructure operations, maintenance, and replacement. Declining demand may result in deferring new construction. In some cases, where build-out and growth are near their limits, this decline may eliminate the need to develop new water supplies or to build additional capacity, which can help offset the need for rate increases.	• Communicate with stakeholders about the funding dilemma and the impact of reduced rates, highlighting capital projects that already have been deferred as a result of demand reductions • Conduct a rate structure analysis to determine alternative approaches to achieve sustainable revenue generation to meet utility requirements • Actively promote leak detection and repair on the part of customers • Update master plan and rate analysis more frequently, including regularly reassessing supply and demand projections and developing multi-scenario analyses • Carry out effective planning and demand modeling

Full Cost Recovery and Financing Capital Improvements

Full cost recovery includes all water system costs and costs that must be incurred to provide services at sustainable levels. Costs include 1) operating, maintenance, and administration expenditures, 2) land, financial, and capital investments to repair, rehabilitate, replace, expand, and upgrade facilities, and 3) in some cases, expenses related to decommissioning and disposing of infrastructure. Cost recovery refers to the generation of sufficient revenue to cover the cost of water services. It includes fees and charges for services that allocate costs to users in an equitable manner.

The decline in water use can negatively affect the generation of operating revenue and a provider's ability to recover costs to maintain the water system and to fund critical infrastructure improvements.

IMPACT	HOW TO ADDRESS
Rates and system development charges may need to increase to fund ongoing and infrastructure operations and maintenance and replacement. Rising rates cause issues of affordability and equity.	• Evaluate potential funding options, such as Water Infrastructure Finan-cing and Innovation Act (WIFIA), State Revolving Fund programs (SRFs), and Public–Private Partner-hips (PPPs) to identify strategies for cost-efficient financing of construction and main-tenance of needed improvements • Support legislation and work with lawmakers to appropriate funds for infrastructure improvements • Communicate with stakeholders • Focus on utility efficiency and effect-tiveness in order to minimize costs of operation and mitigate rate increases • Develop alternative funding structures or adjust rates and System Development Charges to provide full cost recovery • Implement asset management programs • Evaluate affordability programs for vulnerable customers (such as income- and need-based bill discount programs)

Renewal and Replacement of Aging Infrastructure

Drinking water infrastructure in many parts of the region is nearing the end of its useful or design life and will require a full condition assessment, renewal, or replacement in the near future.

IMPACT	HOW TO ADDRESS
Lack of depreciation funding in rate structures results in periodic rate spikes that can be politically unacceptable. Deferring repair and replacement reduces the level of service and increases the risk of contamination, localized leaks, breaks, and potentially catastrophic failure and service disruptions. Some failures could result in damage to other infrastructure.	• Carry out public outreach, education, and communication with stake-holders (elected officials, customers) about infrastructure needs • Develop alternative funding structures (rate and System Development Charge adjustments) that provide full cost recovery • Advocate at state and federal level for funding to support infrastruc-ture renewal and replacement • Evaluate alternative funding sources such as Water Infrastructure Finan-cing and Innovation Act (WIFIA) and State Drinking Water Revolving Funds • Implement asset management program to establish priorities and determine the most cost-effective way to maintain, repair, or replace assets at a specific level of service • Explore public–private partnerships • Continue to fund and implement leak detection and repair programs (required under OAR 690-086-0010) • In addition to asset management, develop condition assessment program in order to determine where to spend limited funds. Include criticality in the planning and priority of investments

Source Water Protection

Surface and groundwater sources are vulnerable to contamination from point and nonpoint source pollution, changes in water quality, land use, water flows, climate change, and natural and manmade disasters. The source water protection efforts for the major water sources are described in Chapter 6.

IMPACT	HOW TO ADDRESS
Degradation and potential loss of any drinking water source in the region has the potential to increase treatment costs, monitoring needs and cause other issues such as not meeting Safe Drinking Water Act requirements. Treating degraded water or developing replacement supply is arduous and expensive and could take years to accomplish.	• Develop and implement comprehensive source water protection plans that include water quality monitoring as well as projects and programs that address the potential risks of the source area • Advocate for needed legislative and statutory laws and regulations (at state and local levels) • Customer and stakeholder outreach • Partner with stakeholders to further limited funding • Apply for grants to execute projects that may otherwise lack funding

Water Quality

Ensuring water quality and protecting public health are fundamental to the mission of water providers.

All utilities must be successful in these endeavors, and customers must feel assured that their utility manages the quality of its product to meet or exceed all drinking water standards and regulatory requirements.

(Water Quality continued)

IMPACT	HOW TO ADDRESS
Meeting water quality regulations can cost money; therefore, rates and bills may increase. Customers demand the highest quality, safest water.	• Meet or exceed all water quality standards and regulations to protect public health • Undertake various actions listed elsewhere in this document (such as increase rates as needed, conduct customer education and outreach) • Proactively respond to "hot topics" of water quality concerns • Implement recommended EPA best management practices and guidelines • Stay abreast and be involved in water quality rule-making. When rule-making is complete, prepare to be in compliance before the date the rule goes into effect • Maintain and support water system flushing, cross connection control and other programs to protect water quality • Implement source water protection program

Resilience to Natural and Manmade Disasters

Our understanding of the potential impact of a Cascadia Subduction Zone earthquake on water systems has increased significantly over the last 10 years. Other natural disasters such as wildfires, volcanic ash, severe storms, and contamination can also affect water providers' ability to provide water.

IMPACT	HOW TO ADDRESS
There are many potential disasters that could affect the region's water supply. For example, the Oregon Resilience Plan (ORP) highlights the potential impact of a Cascadia Subduction Zone earthquake on water systems and identified current recovery times ranging from 6 to 12 months and beyond. Other disasters include drought, catastrophic fire, storm events, contamination, pipe damage, and others. These types of events could necessitate mandatory water conservation, curtailment of services, issuance of drinking water advisories, and personal preparedness advisories.	• Implement recommendations from the Oregon Resilience Plan • Apply for grants through Department of Homeland Security Urban Area Security Initiative • Support relevant legislation • Participate in Regional Disaster Preparedness Organizations • Develop multiple regional water sources • Undertake Infrastructure improvements, including water system provider interconnections, in order to move water to communities in need • Prepare seismic assessments and include seismic-related infrastructure projects in multiyear capital improvement plans • Use resilient materials (including pipe) • Undertake emergency preparedness training and exercises • Include resilience-related criteria in regular system Master Plan development and updates • Encourage citizens to prepare for emergencies

Climate Variability

Climate variability (such as drought or the effects of climate change) can lead to water shortages, water quality changes and increased flooding.

IMPACT	HOW TO ADDRESS
Reduced stream flow, light snowpack, and certain changes in stream flow patterns increase water temperatures, which can result in less water availability due to competing beneficial uses (in-stream flows), reduced water storage, extreme weather events.	• Undertake joint climate studies with stakeholders in the region (such as other utilities, universities, and researchers) • Coordinate curtailment plans among all utilities in the region • Address climate variability in planning efforts such as demand forecasting, Facility Plans, Water Management and Conservation Plans, and individual utility conservation programs • Obtain Willamette Basin Storage reauthorization

Water Rights

Oregon water law is based on the prior appropriations doctrine (first in time, first in right). Most surface water in the state is fully allocated to in-stream and out-of-stream uses such as agriculture, municipal, industrial uses, or for persistence of fish and wildlife and recreation. Over the years, legislation has attempted to balance the needs of competing uses, which often affects municipal water providers' ability to plan for future water needs.

The Growing Communities Doctrine recognizes that municipal water providers must plan for future growth and therefore need more time to perfect water rights.

IMPACT	HOW TO ADDRESS
There are many competing uses for water in Oregon, and conflicts among the various users are inevitable. The certainty of the region's water supply is dictated by the water rights of individual utilities. The extent to which	• Support legislation that protects the water rights of municipal water providers, recognizing the competing values and demands of all stakeholders. • Use the Oregon Integrated Water

(Water Rights continued)

IMPACT	HOW TO ADDRESS
water rights are at risk implies the similar risk to the region's water supplies and supply reliability.	Resources Strategy as a vehicle to discuss the allocation and use of water (in the Willamette Basin) for municipal purposes • Investigate the potential for partnerships that result in the pooling and allocation of undeveloped water rights among municipal permit holders • Obtain Willamette Basin Storage Reauthorization

Meeting Future Supply Needs and Uncertainty in Demand

Water suppliers must plan for changes in supply and demand over long periods of time. Climate change; economic uncertainty; seismic risk; and federal, state, and local policies increase demand forecast uncertainty.

IMPACT	HOW TO ADDRESS
Uncertainty in demand makes long-term planning very challenging. The potential impact of not meeting future supply needs includes: • water shortages leading to service disruptions, • rationing and curtailment, • higher customer bills, and • constrained economic development opportunities.	Collectively, all of the actions listed for the other 13 challenges described in this chapter address this overarching challenge. Others include: • Develop, maintain, and improve regional partnerships and relationships with state, regional, county, and local stakeholders • Prepare annual population and household estimates for regional water providers • Balance growth with conservation • Demonstrate flexibility in the face of regulatory and political changes • Establish regional emergency water system interconnections • Continue to update water demand projections regularly

Conservation/Demand Management

Conservation has played a key role in demand reduction and meeting future water needs. Plumbing and building code changes, the economy (financial crisis), land use changes (smaller lot sizes), multifamily housing, rate increases, other economic demands on utility services, and education have all contributed to a reduction in demand.

IMPACT	HOW TO ADDRESS
Conservation may lead to reduction in demand and the expectation by ratepayers that by conserving water they will lower their water bills. Water saved through conservation is a source of water supply and can defer or eliminate the need to develop new water supplies or build additional capacity.	• Continue to implement local and regional water conservation programs as discussed in Chapter 3. • Pool resources to achieve economies of scale • Update water demand forecasts

Regional Planning, Coordination, and Cooperation

Regional coordination ensures effective use of limited resources for projects that benefit everyone and helps facilitate coordinated response on issues of mutual interest.

IMPACT	HOW TO ADDRESS
Effective regional planning and coordination will help ensure the development of required water supplies to meet the growth needs of the region and the efficient use of limited resources. Regional coordination and planning can help provide stability during changing political climate. Regional planning is a challenge when not all interests participate.	• Continue ongoing and new efforts that have been led and developed by the Regional Water Providers Consortium • Continue Consortium's participation on Metro's Technical Advisory Committee • Invite other water providers to join the Consortium • Continue to represent municipal water providers in national, state, and local efforts (such as Oregon's Integrated Water Resources Strategy and Drinking Water Advisory Committee)

Regulatory Changes

Chapter 7 describes the major regulatory changes over the past 10 years. Future regulatory changes are anticipated that relate to climate change, drought, cybersecurity, Waters of the United States (WOTUS) ruling by the Supreme Court, emerging contaminants of concern and toxins in drinking water.

IMPACT	HOW TO ADDRESS
Regulatory changes can result in changes to treatment requirements and system operations and can add costs to a utility.	• Be involved in regulation development and advocate for sound and reasonable regulations • Continue to research and evaluate emerging contaminants of concern

Customer Understanding of Water Systems

Utilities face many challenges, all of which cost money to address. Customers need to aware of these challenges and support the rate increases (and ensuing higher bills) required to address them.

IMPACT	HOW TO ADDRESS
The cost of service is rising faster than household income, which can result in resistance to rate increases. Postponing rate increases may mean that water system maintenance will be deferred. Deferred maintenance may result in failures and service disruptions.	• Undertake public outreach, education, and communication with stakeholders about all aspects of water supply, water delivery, water protection, and related matters. In short, educate the public about the challenges detailed in this document. • Use the entire toolbox of education and communication strategies (for example, printed material, bill stuffers, websites, focus groups, open houses, school programs, facility tours) • Provide transparency in decision-making • Support and implement financial assistance programs for customers who need it • Use the Consortium for regional messaging • Implement education for young customers and continue educational efforts

Workforce Planning

Utilities, like all business enterprises, must plan for labor turnover due to retirement, relocations, and other factors.

IMPACT	HOW TO ADDRESS
Ineffective workforce planning may result in utilities losing critical knowledge about its water system, operations, processes, etc.	• Implement succession planning as well as knowledge management programs

Conclusion

The Regional Water Supply Plan was adopted originally in 1996, and it was first updated in 2004. This 2016 RWSP Update was prepared by Consortium members and provides an integrated framework for the region's water supply planning and development efforts, water demands, conservation program efforts, regional emergency response planning and interconnections, source water protection programs, regulatory changes, and future challenges for the local drinking water agencies.

The Regional Water Providers Consortium continues to serve as a collaborative and coordinating forum for public education, regional water planning, and emergency response coordination. Through this valuable forum, the Consortium members are able to respond proactively to the multiple challenges facing the drinking water industry. By working collaboratively, the Consortium and its members achieve economies of scale implementing regional programs that save customers money.

This summary report is an illustrative example of all of the work that goes into delivering water to the customer's tap by the municipal water providers and the planning that goes into ensuring that high-quality water can be delivered for future generations.

Appendix A: Analysis of Trend in Water Demand in the Retail Service Areas of the Regional Water Providers Consortium Members

Introduction

Regional Water Providers Consortium (RWPC) studied the trend in demand for water in the region represented by its members since the last update of the Regional Water Supply Plan (RWSP) in 2004. Consortium members also wanted to know what factors have impacted the trend and whether some of the impact can be attributed to conservation related issues. Two levels of analysis are considered to shed light on this matter. The Level One analysis looks at the overall trend in water demand of a larger group of Consortium members and tries to determine the nature of trend and quantify its intensity. Consumption and production data over the 2004–2013 period from the Consortium members are used to explore the nature and intensity of trend in demand for water. The Level Two analysis attempts to determine and quantify the impact of various factors, such as weather, economy, price of water, and conservation related issues on trend. For this analysis, daily production data from a smaller set of Consortium members along with weather, demographic, and economic related data are used. The data for this analysis spans a longer period of time in order to better quantify the impact of weather on demand and its trend. A regression demand model is developed to estimate the relationship between water demand and the various factors mentioned above.

Study Findings

Level One Analysis Findings

1. For the majority of the participating Consortium members that had data available, per capita consumption and production metrics have statistically significant negative trend. This indicates that trend in per capita demand in the region is negative in general.
2. In majority of the cases, trend in per capita consumption and production metrics is steeper than trend in total consumption and production metrics. This indicates that the decline in per capita demand is outpacing the growth in demand due to population increase.
3. Intensity of trend in per capita residential and nonresidential consumption is the same for most members with some exceptions such as Hillsboro with steeper residential trend and Tigard, Sandy, and Wilsonville with steeper nonresidential trend. This might indicate that, for the most part, factors

that impact per capita demand affect residential and nonresidential the same.

4. Negative trend in demand of the participating Consortium members could be due to changes in factors that are related to conservation issues, economy, weather, price of water, and land use. Some of these factors will be the focal point of the Level Two analysis.

Level Two Analysis Findings

1. The inflation- adjusted revenue per million gallons, used as a proxy for price of water, has increasing trend for all five Level Two Analysis participants over the 2004–2013 period.
2. Price has statically significant reverse effect on trend intensity for all water demand metrics by all but one participant. The exception case, Tualatin, has low upward trend in price proxy relative to the other participants.
3. Weather and short-term economic cycles, represented by detrended Portland MSA unemployment rate, have no statistically significant effect on the trend intensity of the per capita water demand metrics.
4. The impact of price on trend intensity could be partly attributed to conservation and factors related to water efficiency, land use, price of sewer, and other factors that affect water demand in the long-term that are not represented in the demand models.

Level One Analysis

The goal of this analysis is to determine the nature and the intensity of trend in the demand for water in the retail service areas of Consortium members. Water demand is represented by various consumption and production metrics. Consortium members were asked to provide water consumption and production data for their retail service area for the 2004–2013 period. The consumption data consist of annual billed consumption by residential and nonresidential retail customers. The production data consist of annual, winter, summer, and peak day, which include retail consumption plus unaccounted-for-unbilled water. Winter is defined as the 90- or 91-day period covering months of December, January, and February, depending on non-leap or leap year. Summer spans the months of June through September, a 122-day period. The peak day is the day that maximum production occurs.

Eleven of the Consortium members provided the complete set of consumption data, and fourteen provided the complete set of production data. The retail service area populations, estimated for the Consortium members by the Portland State University Population Research Center (PRC), along with the demand data, are used to develop various consumption and production metrics for the purpose of trend analysis.

The Data and the Metrics

Fifteen Consortium members participated in this study. The majority of the participating members provided consumption data in hundred cubic feet (CCF) and production data in million gallons (MG) units. The data that were provided in other types of units of measurements are also converted to the respective units to keep the data uniform. Annual consumption by residential, nonresidential, and all customer classes is used as annual consumption metrics to observe and detect trend. Average day consumption per capita by residential, nonresidential, and all customer classes combined, measured in gallons per capita per day (GPCPD), are also computed and used as consumption metrics for trend detection. In this study, the residential class consists of both single and multifamily residential customers. Household population estimated by PRC is used to compute the residential per capita consumption. The nonresidential consists of all other classes, such as commercial, industrial, and industrial, and any other class that is not considered residential. Total service area population estimated by PRC is used to compute nonresidential and all classes per capita consumption.

Average day production metrics are computed by dividing the period specified production measure by the appropriate number of days in the period. Average day production per capita metrics are also computed based on the total retail service area population. A seasonal daily per capita use metric is calculated by subtracting winter average day per capita from summer average day per capita production. Both average day and average day per capita production metrics are used for trend detection.

The Approach and the Methodology

The consumption and production metrics are used to explore the direction and intensity of trend in the demand for water in the retail service areas of the participating Consortium members. By observing the consumption metrics, we can detect the general direction of trend in the total demand. We can also observe and measure the intensity of trend in demand by residential and nonresidential customer classes. Examining the production metrics, on the other hand, shows whether trend in winter demand, that is considered as base, summer demand, or both drive the trend in overall demand. Trend in the per capita consumption and per capita production metrics, show how socioeconomic and conservation-related factors impact the trend, which is beyond the impact of population growth.

Regression models are used to fit trend lines to the natural log of the various consumption and production metrics considered in this study. The regression model (1) is defined as

$$\ln(Y_t) = a + bt + u_t \quad (1)$$

where Y_t are the values of any consumption or production metrics at time *t*,

t is the trend variable, which takes the values of the years data are available, i.e., 2004–2013,

a is the intercept,

b is the trend coefficient that measures the average annual percentage change over the years considered, and

u_t are the regression errors with standard least square properties.[9]

The coefficient of t allows us to detect whether a statistically significant trend exists and also measures the average annual percentage rate of decline or growth in the metrics considered.[10]

The Results

The participating Consortium members are of different service area and population sizes and therefore demand. Table 1 shows the 2013 retail average day production, ordered by the service area population, along with the consumption shares of residential and nonresidential customer classes, to give a sense of the range in sizes and customer composition of the water providers. The PWB with 63.7 MGD average day production and 575,365 retail population is the largest, and Raleigh Water District with 0.5 MGD average day production and 4,142 retail population is the smallest of the participating members. The customer class composition ranges from 78% share of residential consumption for Tigard and 41% for Hillsboro. The consumption and production metrics, as defined in the above, are calculated for each of the participating Consortium members. Table 2 shows the means and standard deviations for the average day per capita consumption and production metrics for the participating members in alphabetical order over the 2004–2013 period.[11] The standard deviation of each metric indicates the degree of variability of the metric over time for each provider. The table also includes the minimum and maximum of the means to give a sense of the range in average day per capita metrics among the providers. For instance, PWB has the lowest mean and Tualatin has the highest mean residential average day per capita consumption. Tualatin also has the highest level of means of all

---

[9] Standard LS assumptions state that the errors are independently and identically distributed according to normal distribution with $N(0,\sigma^2)$.

[10] The details of the regression trend model are explained in Supplement A.

[11] The complete set of average day per capita consumption and production metrics for the participating providers is shown in Table A1 in the Supplement A..

production metrics among the participating members. The difference in the mean of average day per capita consumption by all customer classes among the participating members could be due to number of factors, such as relative residential density, relative size of the commercial, industrial, and industrial class, and conservation-related issues, to name a few. The difference in the mean average day per capita production metric among the members could be also due to relative sizes of the customer classes, difference in socioeconomic factors, land use, conservation attitude, and relative size of unaccounted for water.

Table 1. Average day production, population, and the share of total consumption by customer classes of the retail service area of the participating Consortium members.

Provider	Average Day Production (MGD)	Population	Share of Total Consumption	
			Residential	Nonresidential
PWB	63.7	575,365	58%	42%
TVWD	18.6	211,361	71%	29%
Hillsboro	15.1	82,766	41%	59%
Gresham	6.6	71,654	70%	30%
Beaverton	6.9	68,515	71%	29%
Rockwood	6.4	61,514	68%	32%
Tigard	5.4	60,236	78%	22%
Sunrise	4.6	46,228	N/A	N/A
Oak Lodge	2.9	27,417	N/A	N/A
Tualatin	4.1	26,510	53%	47%
Forest Grove	3.1	22,518	59%	41%
Wilsonville	3.2	21,550	52%	48%
Sandy	0.9	10,337	75%	25%
West Slope[(a)]	1.1	10,245	N/A	N/A
Raleigh	0.5	4,142	N/A	N/A

(a) Consumption data are used since production data are not available.

Provider	Stat	Average Day Per Capita Consumption (GPCPD)		Average Day Per Capita Production (GPCPD)				
		Residential	All Classes	Winter	Summer	Seasonal	Peak Day	Total
Beaverton	Mean	73.1	101.8	87.2	157.0	69.9	210.4	113.0
	Std	5.7	8.6	7.1	20.2	14.1	26.4	11.8
Forest Grove	Mean	68.5	109.9	111.6	194.2	82.6	350.1	144.3
	Std	4.7	6.1	5.9	13.7	14.2	49.3	9.6
Gresham	Mean	65.7	93.2	85.5	135.6	50.1	176.2	103.2
	Std	3.2	4.9	5.8	10.7	6.6	22.7	7.6
Hillsboro	Mean	72.0	171.9	122.3	211.1	88.8	314.4	157.9
	Std	6.3	11.0	13.8	13.6	10.2	26.1	13.7
Oak Lodge	Mean	N/A	N/A	97.4	154.3	56.9	222.5	116.0
	Std	N/A	N/A	6.8	16.9	12.2	35.9	10.9
PWB	Mean	58.8	98.0	100.2	137.8	37.5	194.9	113.8
	Std	4.8	7.7	7.3	8.3	6.3	24.3	6.4
Raleigh	Mean	N/A	127.9	95.5	200.6	105.1	N/A	135.9
	Std	N/A	10.4	7.4	17.9	13.2	N/A	11.4
Rockwood	Mean	67.4	97.0	103.6	136.8	31.8	185.3	117.0
	Std	5.5	8.1	9.1	13.0	7.9	21.9	9.7
Sandy	Mean	64.9	86.0	100.2	145.9	45.7	222.2	115.8
	Std	3.7	7.9	12.4	18.3	9.2	25.7	16.2
Sunrise	Mean	N/A	103.9	73.7	174.2	100.4	268.2	111.5
	Std	N/A	7.4	4.3	18.0	15.2	35.0	9.9
Tigard	Mean	77.8	99.8	73.5	145.0	71.5	205.7	100.0
	Std	6.5	10.4	6.9	16.5	11.6	28.2	10.6
Tualatin	Mean	80.7	150.7	137.2	285.1	148.0	379.2	192.6
	Std	5.7	11.0	16.9	43.2	42.1	53.6	23.5
TVWD	Mean	74.8	105.3	77.8	150.3	72.5	217.4	105.1
	Std	6.6	9.2	6.9	24.7	18.6	37.4	14.2
West Slope	Mean	N/A	117.3	N/A	N/A	N/A	N/A	N/A
	Std	N/A	14.9	N/A	N/A	N/A	N/A	N/A
Wilsonville	Mean	75.2	136.7	111.0	239.4	128.4	360.8	160.9
	Std	7.9	19.2	8.8	22.6	16.5	43.7	14.5
All Means	Min	58.8	86.0	73.5	135.6	31.8	176.2	100.0
	Max	80.7	171.9	137.2	285.1	148.0	379.2	192.6

Table 2. Average day per capita consumption and production metrics descriptive statistics, 2004–2013.

Exploring the Nature and Intensity of Trend

Figures 1 and 2 show the annual and average day per capita consumption by the retail residential customer class of the participating Consortium members respectively. Trend lines are fitted to the graphs to visually assist assessment of the direction of trend. Figure 1 shows that for 9 of the 11 providers that had residential data available the annual consumption has visible downward trend. Figure 2 on the other hand shows visible downward trend in the average day per capita consumption for 10 of the same 11 providers. This is an indication that for the majority of providers, 10 out of 11, reduction in per capita residential consumption out paces the increase in demand as a result of population growth.[12]

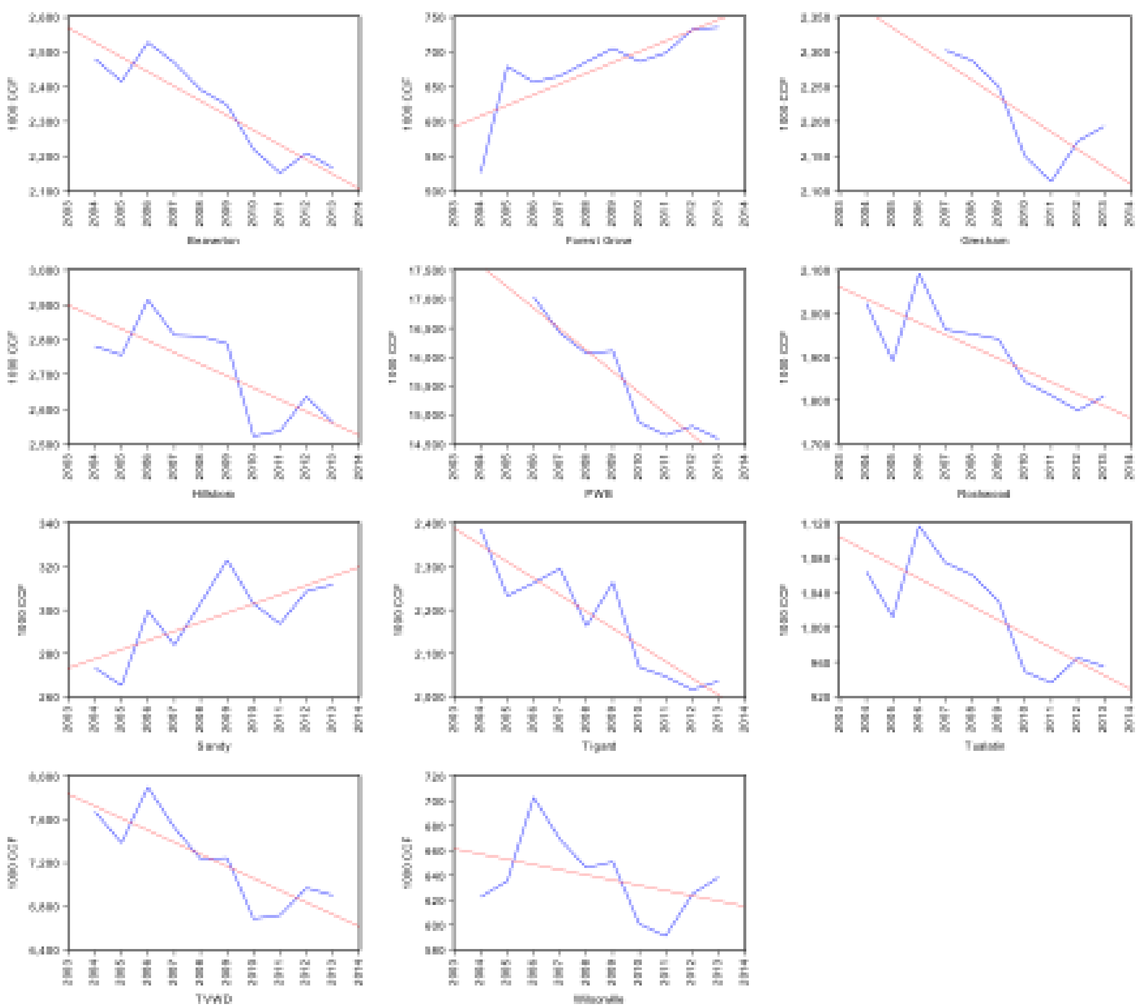


Figure 1. Annual water consumption by the residential class of the participating Consortium members, 2004–2013.

[12] Forest Grove shows positive trend in both annual and average day per capita residential consumption.

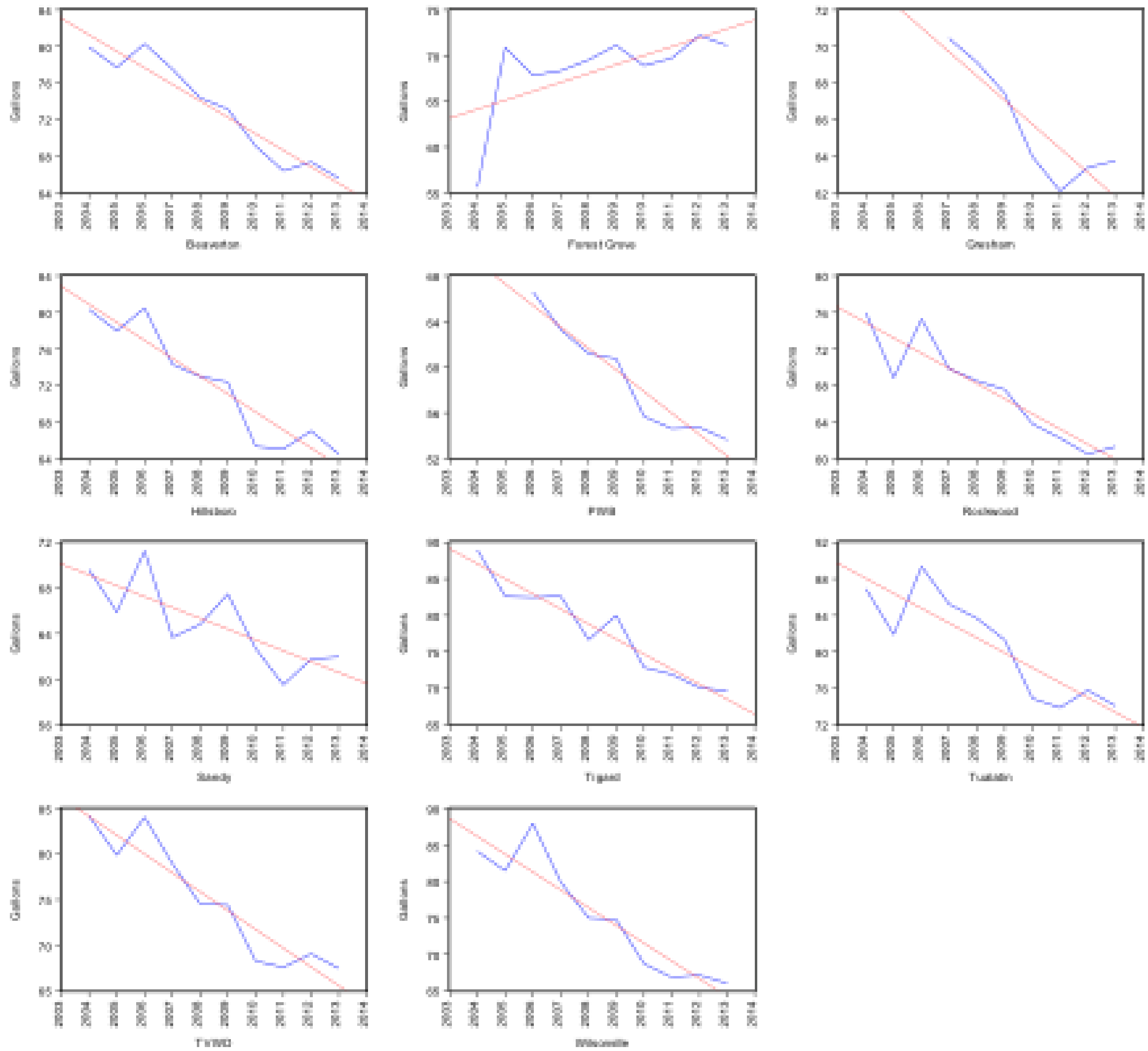


Figure 2. Average day per capita consumption by the residential class of the participating Consortium members, 2004–2013.

In order to measure the intensity and the statistical significance of trend in the various consumption and production metrics, regression model (1) is used. Tables 3 and 4 show the results of the regression trend lines fitted to the natural log of the consumption and production metrics respectively. The cells marked by N/A indicate lack of data availability for trend analysis. The highlighted cells in both tables indicate that the coefficients of the trend lines are not statistically significant at 90% level.

Table 3 shows that for the majority of the participating members, trend in consumption metrics is negative and statistically significant. It also shows that for the majority of the participating providers, the negative trend line in per capita consumption metrics is steeper than the trend line for total consumption metrics.

Forest Grove is the only provider that shows statistically significant positive trend in total and per capita residential consumption and total consumption by all customer classes. Sandy also shows statistically significant positive trend in total residential consumption, but negative trend in per capita residential and per capita consumption by all customer classes. This indicates that consumption increase due to population growth outpaces the decline in per capita consumption. Trend in nonresidential total and per capita consumption is statistically significant and negative for seven of the eleven members who had data available. For all of the statistically significant cases, nonresidential per capita consumption trend line is steeper than that of the total. This indicates that for those members, decline in per capita consumption outpaces the increase as a result of population growth. Table 3 also shows that, in most cases, the intensity of trend in residential and nonresidential per capita consumption is very close. The exceptions are Hillsboro with steeper trend in per capita residential consumption and Tigard, Sandy, and Wilsonville with steeper trend in nonresidential per capita.

The two large water providers, PWB and TVWD, show similar trend characteristics in residential and consumption by all class's metrics. Trend in all consumption metrics for the PWB is negative and statically significant. For TVWD, however, trend in total and per capita nonresidential consumption metrics are not statistically significant. The comparison will be revisited in the Level Two analysis.

Provider	Stat	Residential		Nonresidential		All Classes	
		Total	Per Capita	Total	Per Capita	Total	Per Capita
Beaverton	Coef	-1.8%	-2.5%	-2.2%	-2.9%	-1.9%	-2.6%
	Prob	0.000	0.000	0.008	0.001	0.001	0.000
Forest Grove	Coef	2.4%	1.5%	0.9%	0.0%	1.8%	0.8%
	Prob	0.009	0.058	0.260	0.984	0.023	0.213
Gresham	Coef	-1.1%	-2.0%	-0.7%	-1.6%	-1.0%	-1.9%
	Prob	0.055	0.009	0.523	0.192	0.165	0.031
Hillsboro	Coef	-1.3%	-2.7%	0.8%	-0.7%	-0.1%	-1.5%
	Prob	0.012	0.000	0.223	0.372	0.882	0.016
Oak Lodge	Coef	N/A	N/A	N/A	N/A	N/A	N/A
	Prob	N/A	N/A	N/A	N/A	N/A	N/A
PWB	Coef	-2.3%	-3.1%	-2.0%	-2.9%	-2.2%	-3.0%
	Prob	0.000	0.000	0.000	0.000	0.000	0.000
Raleigh	Coef	N/A	N/A	N/A	N/A	-2.2%	-2.3%
	Prob	N/A	N/A	N/A	N/A	0.002	0.001
Rockwood	Coef	-1.4%	-2.4%	-1.8%	-2.8%	-1.5%	-2.6%
	Prob	0.004	0.000	0.001	0.000	0.001	0.000
Sandy	Coef	1.5%	-1.4%	-3.2%	-6.0%	0.3%	-2.6%
	Prob	0.018	0.008	0.009	0.000	0.610	0.001
Sunrise	Coef	N/A	N/A	N/A	N/A	1.0%	-1.8%
	Prob	N/A	N/A	N/A	N/A	0.263	0.013
Tigard	Coef	-1.7%	-2.6%	-4.1%	-5.0%	-2.3%	-3.2%
	Prob	0.000	0.000	0.038	0.016	0.001	0.000
Tualatin	Coef	-1.6%	-2.0%	-1.5%	-1.9%	-1.5%	-2.0%
	Prob	0.009	0.001	0.070	0.019	0.021	0.003
TVWD	Coef	-1.5%	-2.7%	-0.4%	-1.7%	-1.4%	-2.6%
	Prob	0.003	0.000	0.764	0.273	0.007	0.000
West Slope	Coef	N/A	N/A	N/A	N/A	-3.6%	-3.8%
	Prob	N/A	N/A	N/A	N/A	0.000	0.000
Wilsonville	Coef	-0.7%	-3.2%	-1.8%	-4.8%	-1.2%	-4.2%
	Prob	0.261	0.000	0.081	0.000	0.121	0.000

N/A idicates no data available for analysis.
The highlighted cells indicate less than 90% statistical significance for the trend coefficeint.

Table 3. Average annual percentage change in consumption metrics as measured by the regression trend line, 2004–2013.

Provider	Stat	Winter		Summer		Seasonal	Peak Day		Annual	
		Total	Per Capita	Total	Per Capita	Per Capita	Total	Per Capita	Total	Per Capita
Beaverton	Coef	-1.9%	-2.6%	-2.8%	-3.4%	-4.5%	-3.1%	-3.8%	-2.5%	-3.2%
	Prob	0.000	0.000	0.008	0.002	0.015	0.000	0.000	0.001	0.000
Forest Grove	Coef	0.3%	-0.7%	-0.8%	-1.7%	-2.9%	-1.4%	-2.3%	-0.2%	-1.2%
	Prob	0.628	0.277	0.213	0.015	0.115	0.350	0.127	0.716	0.100
Gresham	Coef	-0.9%	-2.1%	-1.2%	-2.4%	-2.9%	-2.9%	-4.1%	-1.0%	-2.3%
	Prob	0.016	0.000	0.031	0.000	0.038	0.001	0.000	0.016	0.000
Hillsboro	Coef	4.2%	2.6%	3.1%	1.6%	0.4%	1.8%	0.3%	3.9%	2.4%
	Prob	0.001	0.000	0.000	0.002	0.811	0.075	0.000	0.000	0.000
Oak Lodge	Coef	-2.1%	-2.2%	-2.7%	-2.8%	-3.8%	-4.5%	-4.6%	-2.5%	-2.7%
	Prob	0.000	0.000	0.008	0.006	0.107	0.002	0.001	0.001	0.001
PWB	Coef	-0.7%	-1.6%	-0.4%	-1.4%	-0.2%	-1.6%	-2.5%	-0.4%	-1.3%
	Prob	0.246	0.021	0.411	0.026	0.923	0.207	0.059	0.368	0.017
Raleigh	Coef	-2.0%	-2.2%	-2.4%	-2.5%	-2.8%	N/A	N/A	-2.3%	-2.4%
	Prob	0.002	0.002	0.004	0.002	0.039	N/A	N/A	0.001	0.001
Rockwood	Coef	-1.9%	-2.8%	-2.5%	-3.3%	-8.2%	-1.6%	-2.5%	-2.3%	-3.2%
	Prob	0.189	0.082	0.023	0.005	0.066	0.386	0.193	0.003	0.000
Sandy	Coef	-1.1%	-3.9%	-0.7%	-3.5%	-2.7%	0.7%	-2.2%	-1.4%	-4.2%
	Prob	0.069	0.000	0.450	0.001	0.222	0.630	0.103	0.120	0.000
Sunrise	Coef	1.0%	-1.8%	-0.1%	-2.8%	-3.6%	-1.1%	-3.8%	0.1%	-2.6%
	Prob	0.063	0.000	0.912	0.002	0.016	0.300	0.001	0.882	0.000
Tigard	Coef	-1.8%	-2.7%	-2.6%	-3.5%	-4.2%	-3.4%	-4.2%	-2.4%	-3.2%
	Prob	0.003	0.000	0.001	0.000	0.007	0.001	0.000	0.001	0.000
Tualatin	Coef	1.6%	1.1%	-2.4%	-2.9%	-7.4%	-2.9%	-3.3%	-1.4%	-1.9%
	Prob	0.281	0.426	0.162	0.097	0.040	0.060	0.031	0.313	0.181
TVWD	Coef	-1.6%	-2.8%	-3.9%	-5.1%	-7.6%	-4.0%	-5.2%	-3.0%	-4.2%
	Prob	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
West Slope	Coef	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Prob	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wilsonville	Coef	0.6%	-2.4%	0.5%	-2.5%	-2.5%	3.2%	0.1%	0.4%	-2.6%
	Prob	0.194	0.000	0.538	0.007	0.075	0.056	0.927	0.538	0.001

N/A idicates no data available for analysis.
The highlighted cells indicate less than 90% statistical significance for the trend coefficeint.

Table 4. Average annual percentage change in production metrics as measured by the regression trend line, 2004–2013.

Table 4 shows that, in majority of the cases, there is statistically significant trend in total and per capita production metrics. Other than for Hillsboro, trend in per capita summer production for all fourteen members for whom data were available, is negative and statistically significant. The negative trend in per capita summer production ranges between –5.1% for TVWD and –1.4% for PWB. The difference in the intensity of trend among the providers could be as a result of changes in residential densification, increase in multifamily dwellings, and changes in conservation-related factors. Overall, the negative trend in summer production could be due to the mild summers that the region has experienced during the decade that the study focuses on. Table 4 also shows that, in general, for the majority of participating members, the per capita winter, summer, seasonal, peak day, and annual production metrics have statistically significant negative trend. Trend in total production metrics are negative for the most part as well. There are couple of exceptions such as Hillsboro that shows statistically significant positive trend in all total production metrics and all per capita production metrics, except for seasonal and peak day. Sunrise only shows statistically significant positive trend in total winter production. Trend in the rest of the production metrics for Sunrise are either negative or not statistically significant. The Hillsboro case could be as a result of unusually high and negative unaccounted-for water over the 2004–2010 period, which is related to data quality issues of the master meters.[13] Forest Grove shows positive trend in the consumption metrics in Table 3, but shows statistically significant negative trend in per capita summer and annual production in Table 4. Further examining the Forest Grove data shows that its unaccounted-for water was high in the earlier years, but steadily declining over the period of the study. This could be the reason behind the positive trend in the consumption and negative trend in production metrics.

[13]Negative unaccounted-for water indicates that the amount of water consumed by all customers is greater than the amount of water produced. This situation is definitely unrealistic and is an indication of a data-quality issue.

Level Two Analysis

The Level Two analysis includes a more-detailed study of the demand and the factors that affect demand. It also tries to determine which factors contribute to the trend in demand during the 2004–2013 period. Five of the participating Consortium members agreed to provide daily retail production data for the Level Two analysis. Retail service area populations are used to compute daily per capita water production. Using per capita figures controls for the effect population growth on demand. Econometric demand models are developed to explain the variations in daily per capita demand due to factors such as weather, seasonality, economy, and price of water. The econometric models allow us to estimate the impact of the above factors on per capita demand in each service area. The estimated impacts are used to adjust the per capita demand and determine its trend under normalized, weather, economy, and price conditions. Next, trend in unadjusted demand is compared to the trends under the various normalized conditions. A statistical test is conducted to determine if there is a statistically significant change in trend intensity as a result of demand normalizations over the 2004–2013 period. As in Level One analysis, trend and its potential changes are examined for the annual, winter, summer, and seasonal per capita demand.

The Data and the Metrics

Daily production data from Gresham, PWB, Tigard, Tualatin, and TVWD are used for this analysis. In addition to daily retail production, the participants provided data on annual revenue per million gallons as well. The revenue data are used as a proxy for price of water in the econometric models. It should be noted that the goal of this study is not to estimate price elasticities of demand for water. The participating water providers have different rate structures, which might not be the same for all customer classes. The retail production, used in this analysis, includes water consumed by all customer classes and the unaccounted-for water. Estimating price elasticity for different customer classes under different rate structures is beyond the scope of the study. However, using revenue per million gallons as a proxy for price in the econometric models would enable us to see the extent of the relationship between the trend in overall price of water and trend in demand. The other issue to consider is the circuitous cause-and-effect relationship between price and demand that exists for water utilities. Facing falling demand as a result of factors other than price, a water utility tends to recover costs by increasing rates while staying revenue neutral. In turn, the increase in rates could also put downward pressure on demand, which could lead to another round of rate increases. Furthermore, usually the effect of non-price factors on demand such as conservation programs, plumbing code changes, changes in conservation attitude, and changes in land use, are of long-term nature and continuous. As a result, the trend in demand reflects the trend in price of water as well as trend in non-price factors and trend in price of related services such as sewer. This means that the estimated effect of price variable in the demand model includes the effect of other factors also. Figure 3 shows the inflation-adjusted revenue per million gallons for all Level Two participating members during the 2004–2013 period. The figure shows upward trend in the price proxy with different intensities for the five participants.

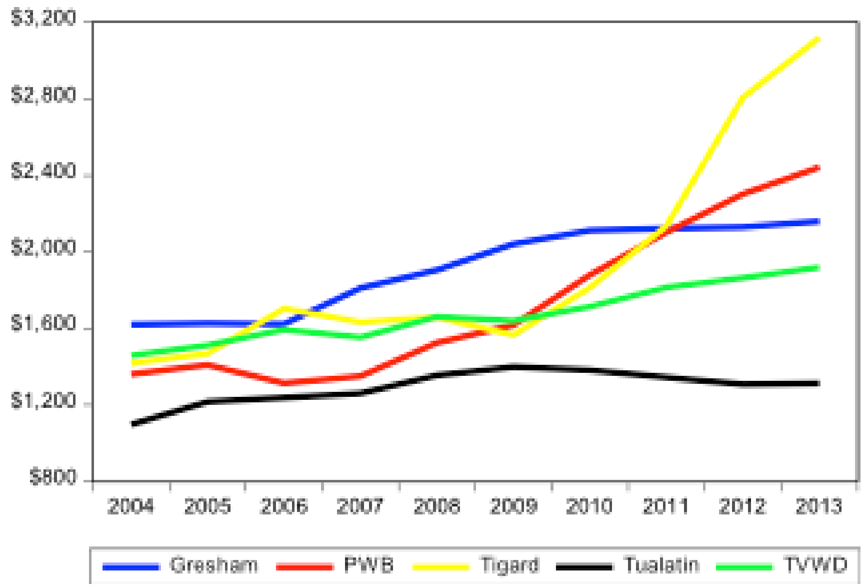


Figure 3. Inflation adjusted revenue per million gallons used as a proxy for price, 2004–2013.

Maximum daily temperature and total daily precipitation data for the 1940–2013 period, measured at the Portland Airport weather station, are used to represent weather in the demand model. Annual rate of unemployment for the Portland Metropolitan Statistical Area (MSA), provided by the Bureau of Labor Statistics, is used to reflect the state of the economy during the study period. The trend in unemployment rate is removed to only reflect the short-term cyclical changes in the economy and their impact on demand.

Daily retail production data provided by the five RWSP participants are used to model daily demand. Each participant's daily production data are converted to per capita figures, using the retail service area populations. The production data span different lengths of periods: Gresham (2001–2014), PWB (1993–2014), Tigard (1997–2014), Tualatin (1999–2014), and TVWD (1990–2014). Instead of matching the time and lengths of the production data series, the full set of data for each participant is used in the regression models to allow for better estimation of the coefficients of the demand model.

The Approach and the Methodology

The per capita retail production, revenue per million gallon, weather, and unemployment rate data are used in five regression models, representing the demand patterns of the participants. The detail of the demand models and the regression results are presented in Supplement B. The demand models explain the short- and long-term variations in demand as a result of weather, price, and the economy. The models also include trend variables to detect trend in demand that are due to factors not represented in the demand model. The models are estimated with different lags of the unemployment rate variable to see if the water demand has a delayed response to economic cycles. Lags of 6, 12, 18, 24, and 30 months are examined. The models that show the greatest impact and highest degree of statistical significance for the coefficient of the economic cycles are chosen. Estimates of the impacts of weather, price, and the economic cycles are used to adjust the daily per capita annual, winter, summer, and seasonal demand. The trend in the adjusted demand metrics is estimated for the 2004–2013 period, by the same technique used in the Level One analysis. The intensity of trend in unadjusted and adjusted daily per capita demand metrics is compared to see if there has been a statistically significant change in trend due to the effect of the factors considered.[14]

The Results

Results of the demand models, shown in Supplement B, indicate high degree of fit of the models as measured by the R-squared. As expected, the coefficient of the economic cycles variable in all models is negative. The coefficient estimates the reduction in per capita demand as a result of one percent point increase in unemployment rate in the Portland MSA. The models show statistically significant effect of economic cycles on per capita water demand with 24 and 18 months lags for Gresham and Tualatin, respectively, and with no lags for Portland and TVWD. The economic cycles coefficient estimated in the Tigard model turns out negative but not statistically significant for all the lags examined. Table 5 shows the estimated economic cycles coefficients along with the residential-nonresidential shares of total consumption for the five water providers. The table shows that the short-term economic cycles have no statistically significant effect on per capita demand in the Tigard service area with the highest share of residential consumption and highest impact on per capita demand in the Tualatin service area with the lowest share of residential consumption. The results for the other three service areas are mixed. The estimated impact of economic cycles is the second highest for the TVWD service area, which has the second highest residential consumption share of 71%. On the other hand, Gresham and PWB service areas,

[14] Wald test is used to test the statistical significance of change in trend intensity.

which have diverse residential consumption shares of 70% and 58% respectively, show similar levels of impact of economic cycles on per capita demand. The indication might be that in addition to shares of residential-nonresidential demand, the composition of the commercial, industrial, and industrial sector, the nature of the industries and how well established they are, could also determine the impact of short-term economic cycles on per capita demand.

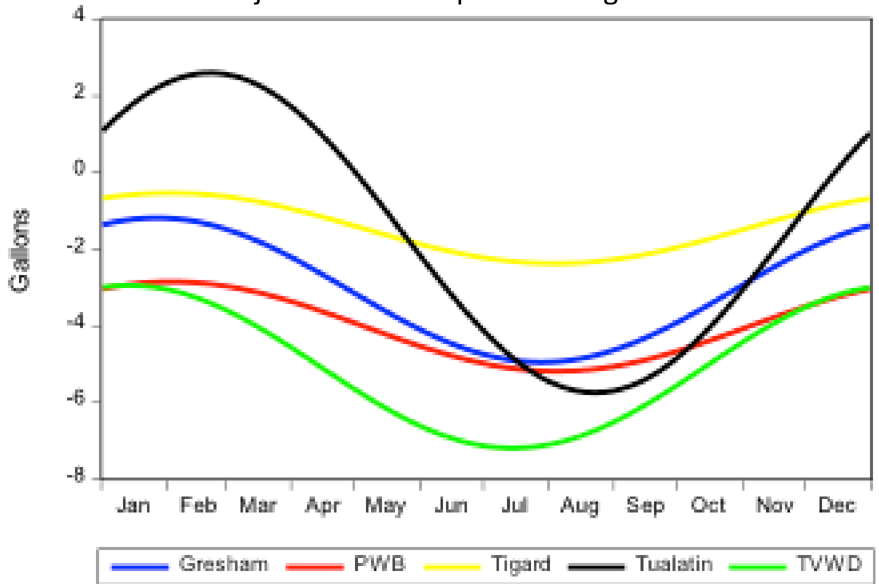
Table 5. Share of the total consumption by customer classes and coefficient of economic cycles of the participants.

Service Area	Share of Total Consumption		Economic Cycles Coefficient [a]
	Residential	Nonresidential	
Gresham	70%	30%	-0.69
PWB	58%	42%	-0.60
Tigard	78%	22%	-0.03
Tualatin	53%	47%	-3.15
TVWD	71%	29%	-2.43

(a) The coefficent of Economic cycle estimates the change in per capita per day demand in gallons as a result of 1% point change in detrended unemployment rate in the Portland MSA.

The price proxy variable is designed to have flexible coefficients to allow for variation in response to price throughout the year. Figure 4 shows the effect of $100 increase in inflation-adjusted revenue per million gallons on per capita demand over the course of one year for all Level Two participants. For all except Tualatin, the effect is negative throughout the year. For all also, the price effect is more pronounced in summer than other parts of the year. The off-peak positive impact of price in the Tualatin service area could be related to the high share of non-residential demand and its demand behavior.

Figure 4. Estimated effect of $100 change in the inflation-adjusted revenue per million gallons.



The weather variables show the effect of daily weather on per capita demand relative to a historical norm established by 1940–2013 weather patterns. The estimated weather effect is used to adjust per capita demand and examine trend under weather-normalized conditions.

The trend in adjusted per capita demand estimates under price and weather-normalized conditions and absence of economic cycles are compared with the trend in unadjusted demand. The price-normalized per capita demand reflects demand under the average of the price over the 2004–2013 period. This would remove the impact of trend in price, but leaves the impact of price intact.

Using the procedure explained in Supplement A, trend lines are fitted to the natural log of the unadjusted and adjusted production metrics. The coefficient of the trend lines measures the intensity of trend under unadjusted and adjusted conditions. The difference in the intensity of trend in per capita production metrics show how much of the trend can be attributed to the factors examined.

Figures 5–9 show the extent of change in trend in average day per capita production metrics adjusted for all factors considered in the demand models visually.

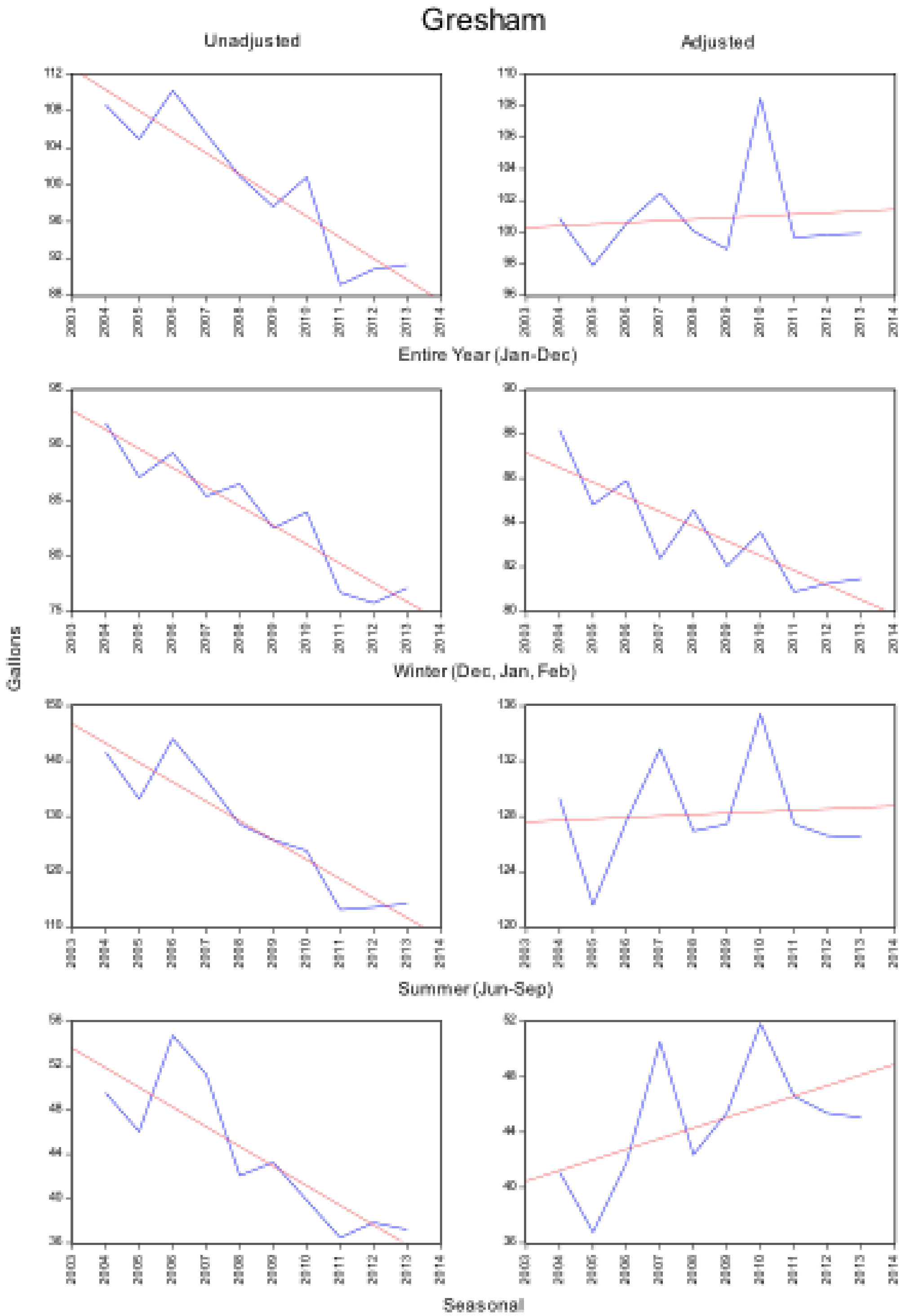


Figure 5. Gresham's adjusted vs. unadjusted annual average day per capita production metrics, 2004–2013.

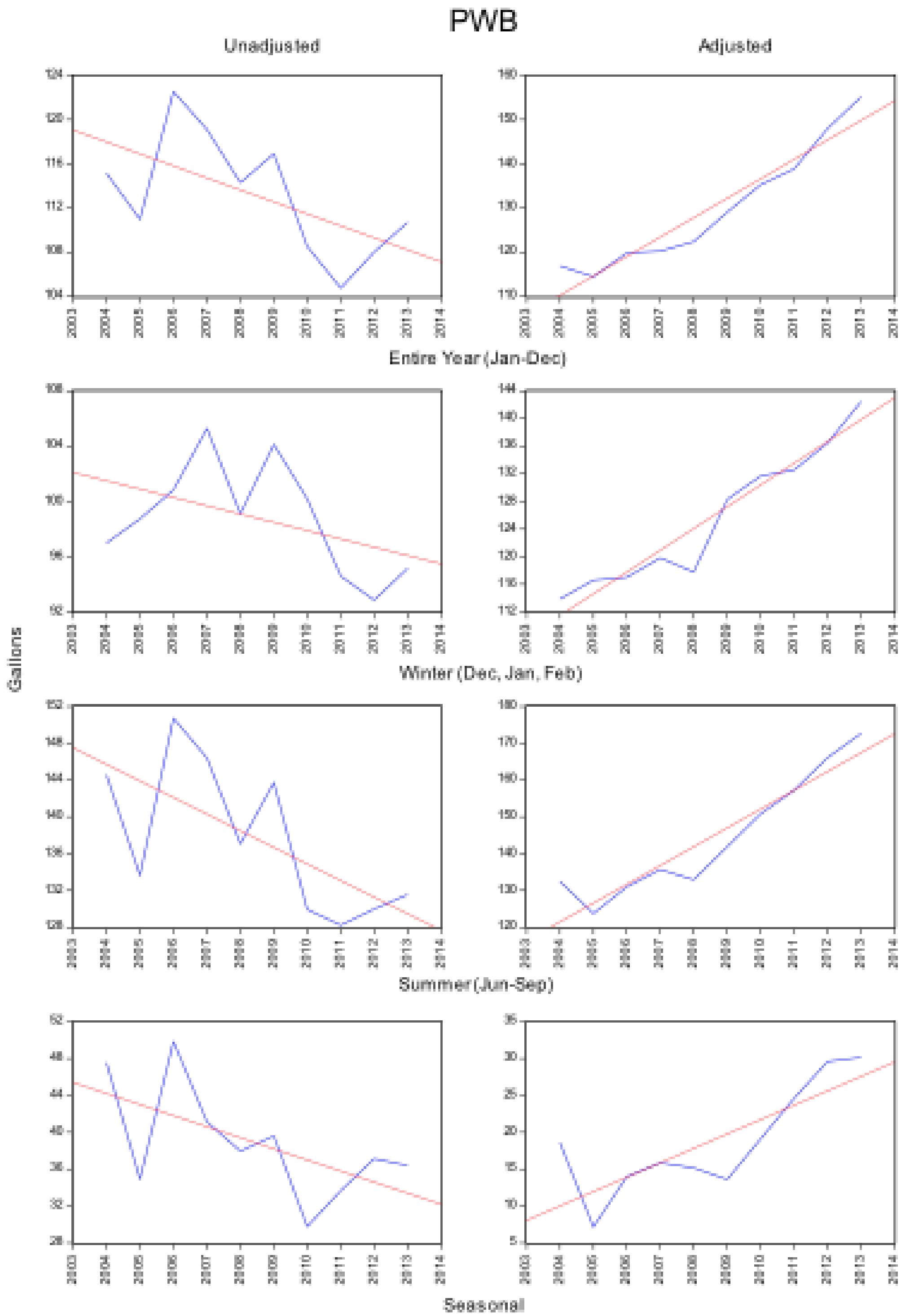


Figure 6. PWB's adjusted vs. unadjusted annual average day per capita production metrics, 2004–2013.

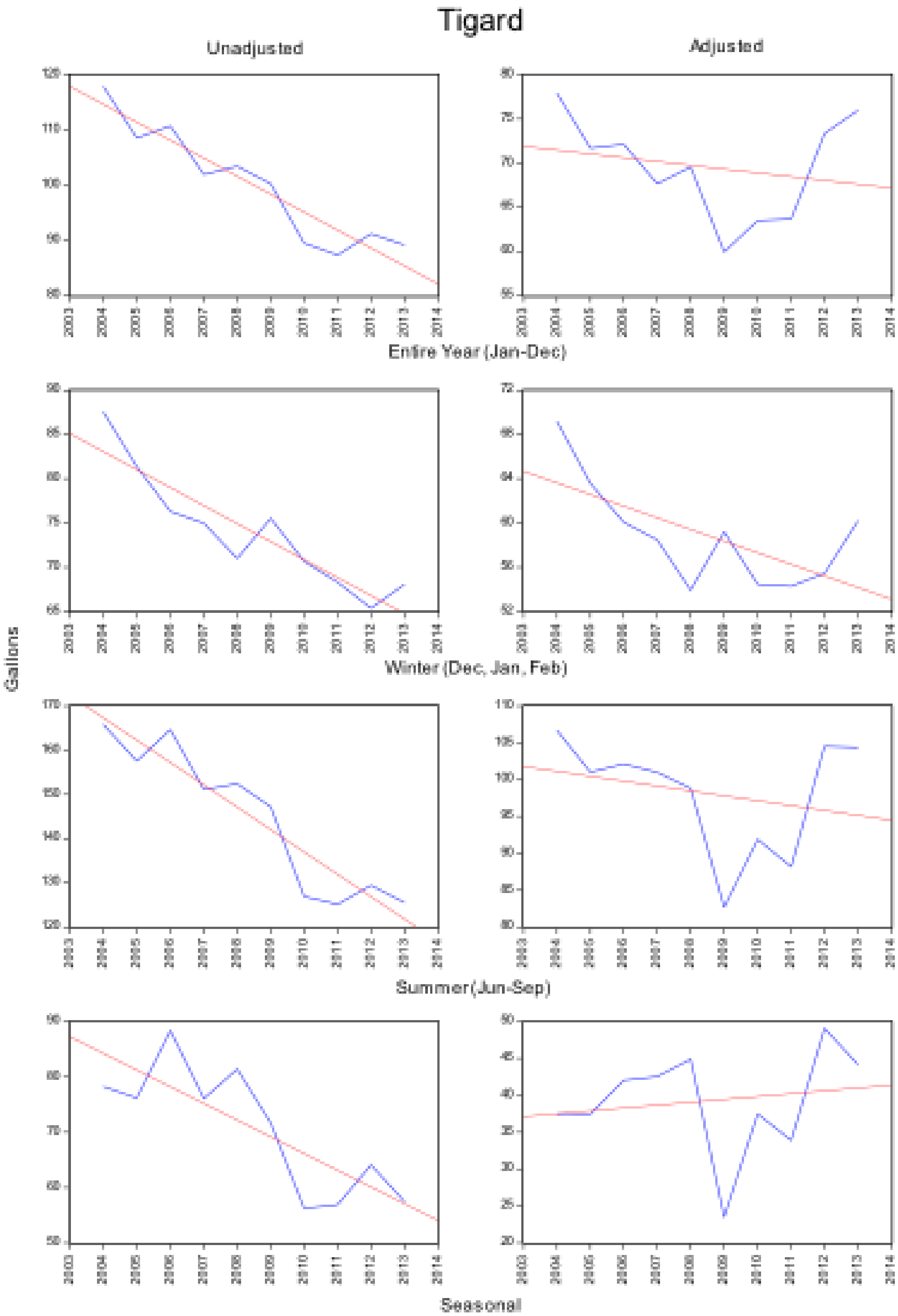


Figure 7. Tigard's adjusted vs. unadjusted annual average day per capita production metrics, 2004–2013.

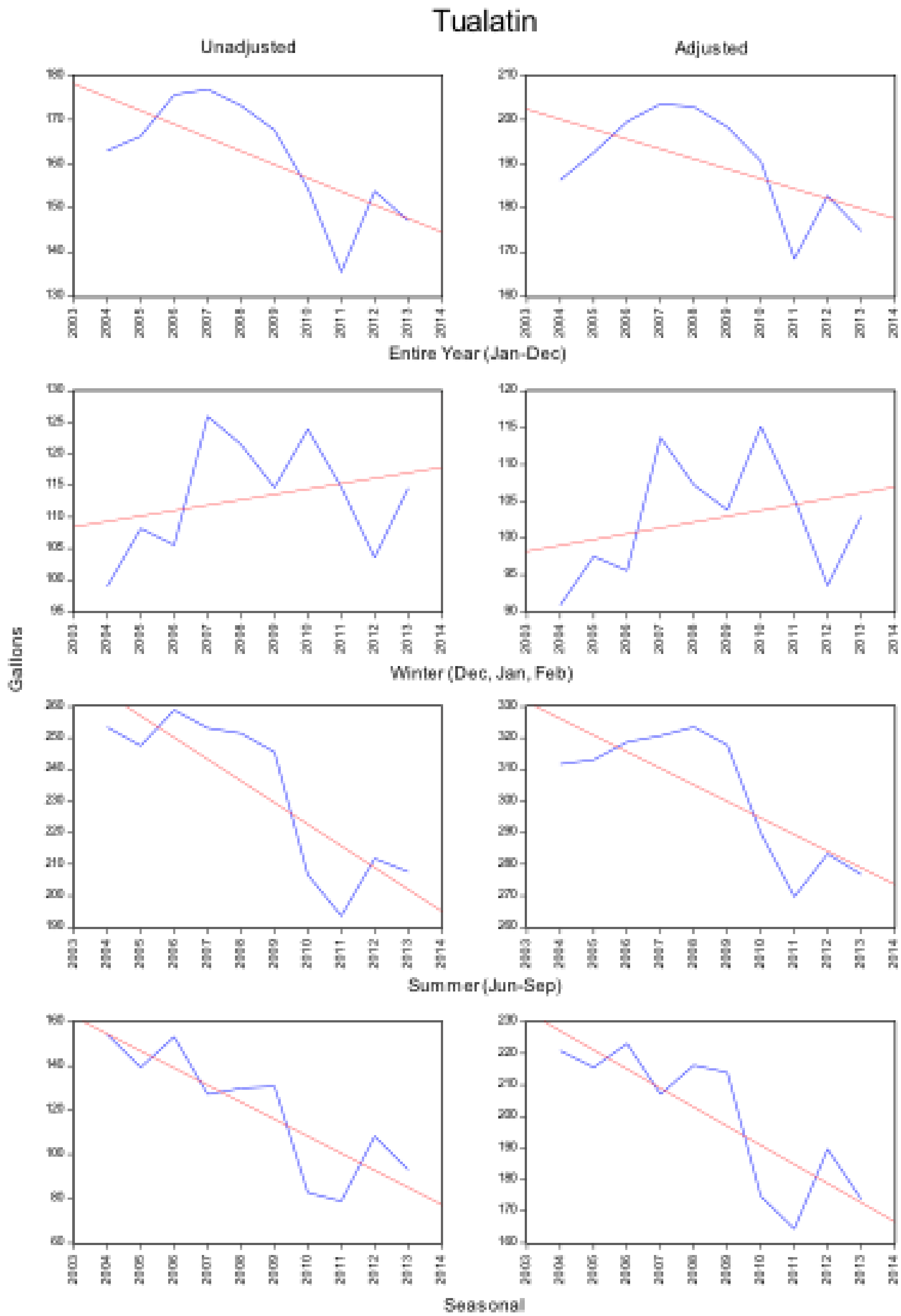


Figure 8. Tualatin's adjusted vs. unadjusted annual average day per capita production metrics, 2004–2013.

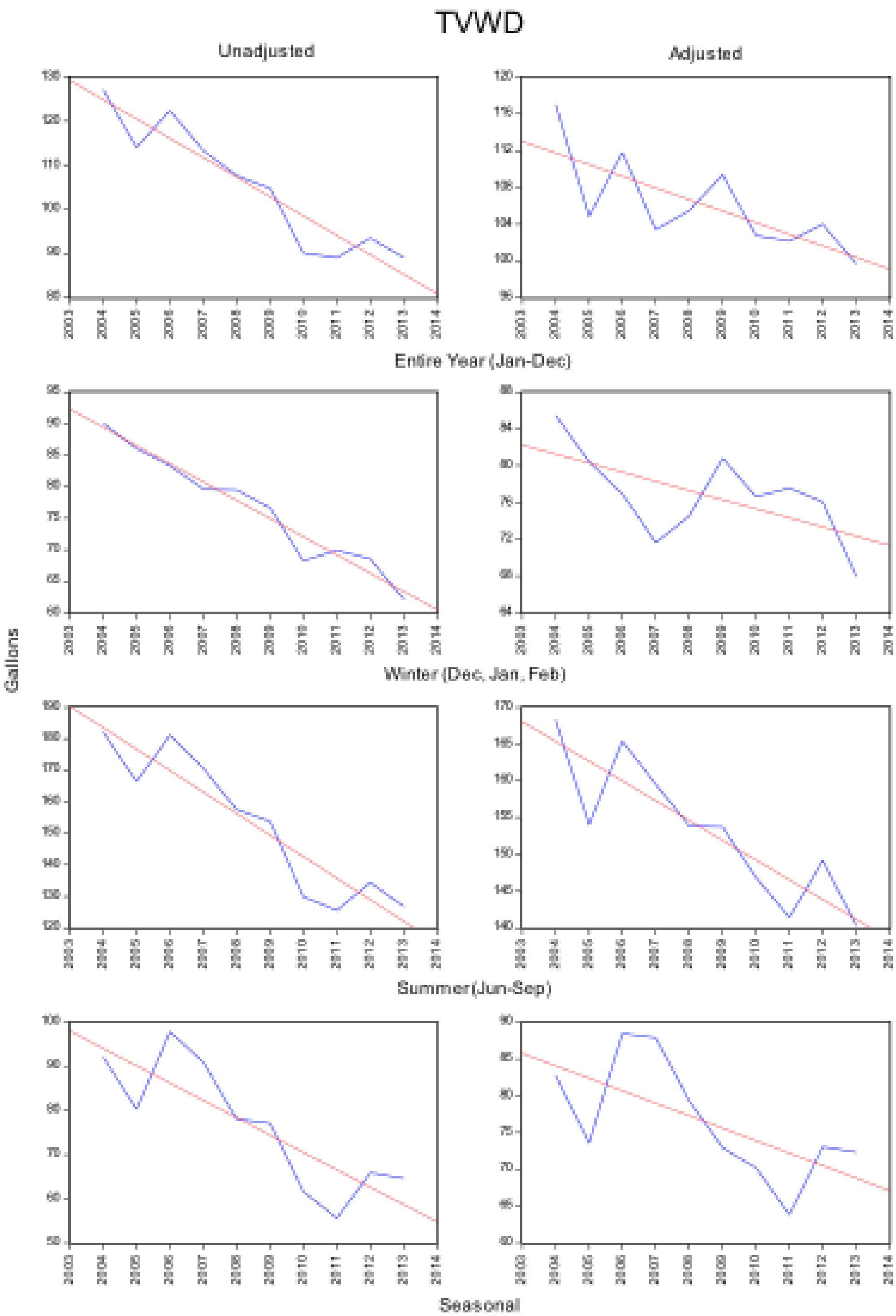


Figure 9. TVWD's adjusted vs. unadjusted annual average day per capita production metrics, 2004–2013.

Table 6 shows the trend intensity in the unadjusted and adjusted per capita production metrics for the Level Two participants over the 2004–2013 period. The table also shows the statistical significance of the coefficient of trend. Trend in all unadjusted per capita production metrics for all participants is negative and statistically significant. The only exception is Tualatin, which shows no statistically significant trend in the unadjusted winter metrics. Results of the test on the statistical significance of the difference in the trend intensity of the unadjusted and adjusted metrics are also reported. For example, the results for Gresham indicate an average annual decline of 2.3% in the unadjusted annual average day per capita production. The results also show that there are no statistically significant changes in the intensity of trend when the metric is adjusted for the impact of weather or economic cycles. However, adjusting for the impact of the price proxy brings a statistically significant reverse change in trend and reduces the rate of decline to only 0.1%. In fact, in Gresham's case the adjustment makes the trend intensity statistically not significant (this is indicated by the Prob. being 0.834). That is, if the price were to stay constant, there would not be a downward trend in Gresham's annual per capita demand. Further observation of the Gresham case reveals that the changes in trend intensity of the winter, summer, and seasonal metrics are also statistically significant when the metrics are adjusted for the impact of price. This change is more pronounced for the seasonal metric. The trend in the adjusted seasonal metric becomes positive, but not statistically significant (Prob. 0.194). Adjustment for price shows almost similar results for Tigard. For TVWD price-normalized demand metrics still show negative trends, but with lower intensities. In case of the PWB, the change in trends in the price-normalized metrics not only is statistically significant, but also the trend in the metrics turns positive.

Table 6 shows that for all Level Two participants, adjusting per capita production metrics for weather and economic cycles does not change the trend intensity in a statistically significant manner. Moreover, with the exception of Tualatin, the reverse change in the intensity of trend in all production metrics is statistically significant when adjusted for the impact of price proxy and all impacts combined. Lack of significant change in trend in case of Tualatin is mostly due to low upward trend in the price proxy, as shown in Figure 3. It is important to keep in mind that as discussed earlier, the impact of price can be partly attributed to non-price factors that put downward pressure on demand such as conservation- and water-efficiency related issues, land use, price of sewer, and other factors that are not represented in the demand model.

Demand Metrics and Status		Gresham Rate of Change	Gresham Prob.	Gresham Difference Relative to Unadjusted [a]	PWB Rate of Change	PWB Prob.	PWB Difference Relative to Unadjusted [a]	Tigard Rate of Change	Tigard Prob.	Tigard Difference Relative to Unadjusted [a]	Tualatin Rate of Change	Tualatin Prob.	Tualatin Difference Relative to Unadjusted [a]	TVWD Rate of Change	TVWD Prob.	TVWD Difference Relative to Unadjusted [a]
Annual	Unadjusted	-2.3%	0.000		-1.0%	0.066		-3.2%	0.000		-1.9%	0.028		-4.1%	0.000	
	Adjusted for weather	-2.2%	0.000	Not Sig	-0.8%	0.055	Not Sig	-2.8%	0.000	Not Sig	-1.8%	0.029	Not Sig	-3.9%	0.000	Not Sig
	Adjusted for economy	-2.2%	0.000	Not Sig	-0.9%	0.079	Not Sig	-3.2%	0.000	Not Sig	-1.7%	0.004	Not Sig	-3.7%	0.000	Not Sig
	Adjusted for Price	-0.1%	0.834	Sig	3.7%	0.000	Sig	-0.9%	0.330	Sig	-1.7%	0.050	Not Sig	-1.8%	0.022	Sig
	Adjusted for all	0.1%	0.769	Sig	3.9%	0.000	Sig	-0.6%	0.535	Sig	-1.7%	0.002	Not Sig	-1.2%	0.015	Sig
Winter	Unadjusted	-2.1%	0.000		-0.6%	0.181		-0.6%	0.181		0.8%	0.410		-3.7%	0.000	
	Adjusted for weather	-2.1%	0.000	Not Sig	-0.7%	0.140	Not Sig	-0.7%	0.140	Not Sig	0.8%	0.407	Not Sig	-3.7%	0.000	Not Sig
	Adjusted for economy	-2.0%	0.000	Not Sig	-0.5%	0.255	Not Sig	-0.5%	0.255	Not Sig	1.0%	0.152	Not Sig	-3.2%	0.001	Not Sig
	Adjusted for Price	-0.8%	0.021	Sig	3.2%	0.000	Sig	-1.4%	0.036	Sig	0.5%	0.575	Not Sig	-1.8%	0.001	Sig
	Adjusted for all	-0.8%	0.002	Sig	3.3%	0.000	Sig	-1.4%	0.040	Sig	0.7%	0.283	Not Sig	-1.3%	0.062	Sig
Summer	Unadjusted	-2.7%	0.000		-1.3%	0.031		-3.5%	0.000		-3.0%	0.003		-4.4%	0.000	
	Adjusted for weather	-2.6%	0.000	Not Sig	-1.1%	0.026	Not Sig	-3.0%	0.000	Not Sig	-2.8%	0.001	Not Sig	-4.2%	0.000	Not Sig
	Adjusted for economy	-2.7%	0.000	Not Sig	-1.2%	0.038	Not Sig	-3.5%	0.000	Not Sig	-2.8%	0.000	Not Sig	-4.2%	0.000	Not Sig
	Adjusted for Price	-0.1%	0.754	Sig	3.4%	0.000	Sig	-1.0%	0.271	Sig	-2.6%	0.009	Not Sig	-2.2%	0.011	Sig
	Adjusted for all	0.1%	0.810	Sig	3.7%	0.000	Sig	-0.5%	0.480	Sig	-2.2%	0.001	Not Sig	-1.7%	0.001	Sig
Seasonal	Unadjusted	-4.0%	0.001		-2.9%	0.081		-4.3%	0.005		-6.4%	0.004		-5.1%	0.003	
	Adjusted for weather	-3.4%	0.002	Not Sig	-2.1%	0.090	Not Sig	-3.3%	0.005	Not Sig	-6.1%	0.002	Not Sig	-4.6%	0.001	Not Sig
	Adjusted for economy	-4.0%	0.001	Not Sig	-2.9%	0.085	Not Sig	-4.3%	0.005	Not Sig	-6.4%	0.002	Not Sig	-5.1%	0.004	Not Sig
	Adjusted for Price	1.3%	0.194	Sig	4.0%	0.032	Sig	-0.5%	0.741	Sig	-5.4%	0.008	Not Sig	-2.7%	0.054	Sig
	Adjusted for all	1.8%	0.105	Sig	4.8%	0.007	Sig	0.5%	0.706	Sig	-5.0%	0.003	Not Sig	-2.2%	0.043	Sig

Highlighted cells indicate trend intensities that are not statistically significant at 90% confidence level.

(a) Wald test was used to test the significance of change in the intensity of trend.

Table 6. Changes in trend intensity as a result of adjusting per capita demand metrics for weather, economy, and price effects, 2004–2013.

Supplement A

The Regression Trend Model

The regression trend model used for estimating average rate of positive or negative growth is based on the compound interest formula defined as:

$$Y_t = Y_0(1+r)^t$$

where Y_t is the principal plus interest at time t, Y_0 is the initial investment, r is the periodic interest rate, and t is time. Taking the natural log of both sides of the equation we have

$$\ln(Y_t) = \ln(Y_0) + t\ln(1+r)$$

Letting

$$a = \ln(Y_0)$$
$$b = \ln(1+r),$$

substituting for a and b, and adding the error term we get the regression model

$$\ln(Y_t) = a + bt + u_t$$

The estimate of the coefficient of time, b, can be used to calculate the compound rate of growth, r, as follows.

$$e^b = e^{\ln(1+r)} = 1 + r$$
$$r = e^b - 1$$

Estimate of r measures the average rate of growth or decline in the metric examined.

Average Day Per Capita Consumption and Production Metrics

Table A1. Average day per capita consumption and production metrics, 2004–2013.

Provider	Year	Average Day Per Capita Consumption (GPCPD)		Average Day Per Capita Production (GPCPD)				
		Residential	All Classes	Winter	Summer	Seasonal	Peak Day	Total
Beaverton	2004	79.9	110.8	94.7	171.2	76.5	256.5	128.6
	2005	77.7	107.8	94.9	167.0	72.1	231.1	121.4
	2006	80.3	113.3	96.1	199.0	102.9	238.4	131.4
	2007	77.5	108.6	92.6	166.2	73.6	211.8	119.2
	2008	74.4	104.5	87.6	156.3	68.6	206.2	112.2
	2009	73.1	102.6	85.5	159.8	74.3	220.5	112.6
	2010	69.1	94.6	83.2	140.0	56.8	194.2	103.4
	2011	66.4	91.1	80.8	136.1	55.3	178.2	99.7
	2012	67.3	93.8	78.2	139.6	61.4	190.0	101.9
	2013	65.6	90.4	77.8	135.2	57.4	177.2	100.0
Forest Grove	2004	55.6	93.6	108.5	210.7	102.2	352.2	163.1
	2005	70.9	110.9	121.1	190.3	69.3	328.8	142.9
	2006	67.8	113.6	105.5	209.1	103.6	434.0	134.3
	2007	68.3	114.2	122.5	204.9	82.5	340.3	149.2
	2008	69.5	113.1	112.7	213.2	100.5	424.6	155.7
	2009	71.1	111.3	113.8	182.6	68.8	389.5	148.9
	2010	68.9	107.0	106.7	184.0	77.3	314.0	137.4
	2011	69.7	109.9	109.0	181.5	72.5	303.9	134.4
	2012	72.2	114.2	107.6	186.8	79.2	303.6	139.2
	2013	71.1	111.4	108.4	178.5	70.2	310.0	138.1
Gresham	2004			93.3	149.3	56.0	200.2	112.8
	2005			92.0	143.5	51.5	200.3	108.0
	2006			93.7	140.2	46.5	201.4	112.4
	2007	70.4	101.2	84.4	141.2	56.7	193.6	108.5
	2008	69.1	97.8	86.0	141.3	55.3	174.5	104.3
	2009	67.4	94.6	85.8	144.1	58.3	184.0	105.7
	2010	64.0	89.8	80.2	130.3	50.1	160.5	97.4
	2011	62.1	87.3	81.4	123.4	41.9	152.8	94.0
	2012	63.4	90.0	80.1	125.9	45.8	151.8	96.5
	2013	63.7	91.7	77.9	116.8	38.9	143.2	92.4

Provider	Year	Average Day Per Capita Consumption (GPCPD)		Average Day Per Capita Production (GPCPD)				
		Residential	All Classes	Winter	Summer	Seasonal	Peak Day	Total
Hillsboro	2004	80.3	188.6	105.5	199.5	94.1	343.9	145.1
	2005	78.0	184.6	111.1	206.0	94.8	332.3	147.6
	2006	80.5	188.3	136.4	202.8	66.4	290.7	154.6
	2007	74.3	164.5	111.1	199.2	88.0	269.6	149.4
	2008	73.0	165.1	113.2	208.4	95.2	327.1	150.4
	2009	72.4	168.8	115.1	211.5	96.4	290.1	150.3
	2010	65.3	164.3	117.8	196.0	78.3	290.9	151.8
	2011	65.0	158.1	132.4	221.7	89.3	335.8	167.7
	2012	67.0	168.9	133.7	234.5	100.8	331.0	179.6
	2013	64.5	168.0	146.8	231.1	84.3	332.7	182.8
Oak Lodge	2004			107.5	177.6	70.2	262.2	134.8
	2005			102.9	153.5	50.5	233.1	116.9
	2006			101.5	172.5	71.0	259.4	127.7
	2007			102.2	175.7	73.5	256.6	127.2
	2008			100.5	151.5	51.0	231.8	115.2
	2009			96.4	161.0	64.5	252.3	116.2
	2010			95.0	138.3	43.3	186.7	107.8
	2011			93.6	132.4	38.8	180.7	102.8
	2012			85.8	136.2	50.4	181.9	104.4
	2013			88.3	144.1	55.8	180.9	106.9
PWB	2004			117.7	146.1	28.4	214.5	124.5
	2005			98.3	133.7	35.4	177.3	110.9
	2006	66.6	110.6	100.6	150.7	50.2	230.0	122.6
	2007	63.3	105.1	104.8	146.3	41.5	219.7	116.4
	2008	61.2	101.8	95.2	137.1	41.9	184.8	114.4
	2009	60.8	100.8	103.7	143.8	40.1	204.1	116.9
	2010	55.7	93.4	99.9	130.0	30.1	214.9	108.6
	2011	54.6	91.2	94.4	128.2	33.7	170.5	104.7
	2012	54.7	91.6	92.7	130.0	37.4	167.5	108.0
	2013	53.6	89.4	94.9	131.6	36.7	165.6	110.7

(**Table A1** continued)

Provider	Year	Average Day Per Capita Consumption (GPCPD)		Average Day Per Capita Production (GPCPD)				
		Residential	All Classes	Winter	Summer	Seasonal	Peak Day	Total
Raleigh	2004		139.4	108.3	221.5	113.2		150.1
	2005		132.9	93.7	212.0	118.3		145.4
	2006		143.5	103.7	222.1	118.5		148.1
	2007		134.1	98.9	215.0	116.2		145.8
	2008		129.7	101.4	202.9	101.4		136.1
	2009		131.8	93.9	207.6	113.7		138.4
	2010		116.1	94.0	173.2	79.2		121.2
	2011		115.0	88.9	180.2	91.4		121.0
	2012		120.6	85.7	188.4	102.8		127.3
	2013		115.6	86.9	183.5	96.6		125.5
Rockwood	2004	75.9	109.4					
	2005	68.9	101.1					
	2006	75.3	107.9		146.6		187.2	125.8
	2007	69.8	102.0	116.1	151.4	35.3	191.8	127.8
	2008	68.5	98.9	104.1	138.9	34.9	191.2	124.2
	2009	67.6	95.6	115.9	153.3	37.3	219.2	125.0
	2010	63.8	91.5	92.8	136.0	43.2	201.2	114.7
	2011	62.2	88.9	100.7	123.8	23.1	165.1	107.8
	2012	60.5	87.7	98.7	124.6	25.9	147.5	107.1
	2013	61.3	87.3	97.1	119.8	22.8	179.3	104.0
Sandy	2004	69.6	95.3	113.1	155.4	42.3	230.0	126.8
	2005	65.9	91.3	113.7	158.4	44.8	211.7	130.6
	2006	71.2	100.6	114.6	178.3	63.7	254.7	140.1
	2007	63.7	84.8	112.5	158.4	45.9		130.0
	2008	64.8	85.9	100.2	151.3	51.1	236.9	116.9
	2009	67.5	87.7	94.6	148.6	53.9	250.4	114.0
	2010	62.7	82.5	94.8	129.1	34.3	223.0	106.9
	2011	59.5	75.7	89.9	127.5	37.5	209.5	100.8
	2012	61.8	78.0	85.1	134.0	48.9	214.2	103.7
	2013	62.0	78.7	83.2	118.0	34.8	169.3	88.0

(**Table A1** continued)

Provider	Year	Average Day Per Capita Consumption (GPCPD)		Average Day Per Capita Production (GPCPD)				
		Residential	All Classes	Winter	Summer	Seasonal	Peak Day	Total
Sunrise	2004		111.1	80.6	189.6	109.0	314.4	124.0
	2005		102.0	78.2	177.5	99.3	277.1	115.3
	2006		112.7	75.3	202.4	127.1	311.2	125.6
	2007		112.0	73.4	188.5	115.0	283.9	117.7
	2008		106.8	76.0	179.9	103.9	273.6	114.1
	2009		110.2	74.5	184.8	110.3	290.4	115.6
	2010		96.1	73.4	157.6	84.3	258.0	102.4
	2011		94.4	71.1	152.6	81.5	216.3	99.4
	2012		96.7	68.1	154.6	86.5	239.9	101.0
	2013		96.7	66.6	154.2	87.6	217.2	100.4
Tigard	2004	88.9	118.0	87.4	166.0	78.5	239.6	117.9
	2005	82.6	106.4	81.1	157.6	76.5	240.2	108.6
	2006	82.4	110.7	75.9	164.7	88.8	225.2	110.7
	2007	82.6	103.1	74.6	154.4	79.8	216.6	103.1
	2008	76.6	103.3	69.8	152.4	82.6	213.5	103.2
	2009	80.0	100.3	75.6	147.1	71.5	217.8	100.1
	2010	72.8	89.5	70.6	126.8	56.2	194.7	89.4
	2011	71.9	87.4	68.4	125.1	56.8	162.3	87.3
	2012	70.1	90.3	64.4	129.3	64.9	177.7	90.1
	2013	69.7	89.4	67.6	126.5	58.9	169.7	89.5
Tualatin	2004	86.9	160.3	121.3	276.4	155.1	385.3	186.1
	2005	81.9	153.4	124.6	275.6	151.0	380.6	181.3
	2006	89.3	165.2	122.5	307.6	185.1	411.8	200.6
	2007	85.2	164.1	136.9	326.6	189.7	432.3	214.0
	2008	83.7	159.6	161.1	331.1	170.0	429.9	225.0
	2009	81.3	146.1	148.1	337.5	189.5	426.9	224.0
	2010	74.9	139.5	158.1	286.7	128.6	391.5	192.3
	2011	73.9	138.2	123.2	277.1	153.9	355.3	180.7
	2012	75.8	139.8	155.4	218.6	63.2	295.6	167.7
	2013	74.1	141.2	120.7	214.3	93.5	282.5	153.9

(**Table A1** continued)

Provider	Year	Average Day Per Capita Consumption (GPCPD)		Average Day Per Capita Production (GPCPD)				
		Residential	All Classes	Winter	Summer	Seasonal	Peak Day	Total
TVWD	2004	84.1	118.1	89.8	183.1	93.4	279.4	127.6
	2005	79.9	111.6	85.6	167.5	81.9	243.7	114.6
	2006	84.0	118.2	82.8	181.2	98.4	258.4	122.4
	2007	78.9	110.7	79.2	170.7	91.5	229.3	113.4
	2008	74.5	106.0	79.1	157.5	78.4	220.5	107.7
	2009	74.4	104.4	76.5	145.1	68.6	223.9	102.0
	2010	68.3	95.6	75.3	128.5	53.2	192.9	93.0
	2011	67.6	95.3	72.3	125.2	53.0	162.1	90.3
	2012	69.1	97.7	68.3	125.7	57.4	183.6	91.8
	2013	67.5	95.2	69.6	119.0	49.4	180.4	88.0
West Slope	2004		143.3					
	2005		126.1					
	2006		124.7					
	2007		132.5					
	2008		120.7					
	2009		116.2					
	2010		107.2					
	2011		97.0					
	2012		101.2					
	2013		104.0					
Wilsonville	2004	84.1	160.3	127.2	258.1	131.0	392.3	180.9
	2005	81.4	151.9	117.2	248.1	130.9	363.0	167.2
	2006	87.9	166.2	112.9	271.4	158.5	363.0	178.6
	2007	79.9	149.1	120.0	261.3	141.3	356.0	173.1
	2008	75.0	138.5	112.4	248.8	136.3	350.1	165.5
	2009	74.8	130.6	111.3	242.3	131.0	332.8	159.6
	2010	68.7	118.6	105.1	210.2	105.1	302.4	144.5
	2011	66.8	115.7	102.2	206.0	103.8	301.6	139.5
	2012	67.2	117.9	102.4	232.0	129.7	438.7	151.6
	2013	66.0	118.6	99.8	216.2	116.5	408.4	148.0

(**Table A1** continued)

Supplement B

The demand model

Various studies (Hannan 1963, Jorgenson 1964, Jorgenson 1967, Harvey and Shephard 1993 Wong et al., 2010) show that time series data can be decomposed into trend, seasonal, and irregular components. Chesnutt and McSpadden (1995) show that part of the daily water demand variations can also be decomposed into variables that describe weather effect.

A structural time series model is adopted to represent the demand for water by all customer classes in each service area. The general specification of the demand model is represented by (B.1).

$$PCD = f(S, W, I, UER, P, LT) \qquad \text{(B.1)}$$

where PCD is the per capita daily demand by all customers in the service area, S and W represent seasonal weather variables, I represents indicator or dummy variables depicting weekends, holidays, and some data anomalies, UER is the unemployment rate in the Portland metropolitan statistical area (MSA), P represents price variable, and LT represents long-term trend variables. These variables are explained in more detail in the sections below.

Seasonal variables

There is a distinct bell-shaped seasonal pattern in daily per capita demand for water in both service areas as shown in Figure 1. Demand during the winter months is very flat; it starts increasing mid-spring, peaks in June-September period, and declines mid-fall. Granger and Watson (1984) suggest the use of a series of 11 dummy variables to represent 11 months of the year to depict seasonal variations. In this approach the 12th month dummy is dropped to avoid singularity.

Hannan (1963), Jorgenson (1964 and 1967), Harvey and Shephard, (1993), and Dziegielewski and Opitz (2002) also recommend use of Fourier series terms as a continuous function of time to express these seasonal patterns. We consider the latter approach in this study. For daily demand data these variables can be constructed as

$$SS_{it} = \sin\frac{2\pi it}{DIY} \text{ and } SC_{it} = \cos\frac{2\pi it}{DIY} \qquad \text{(B.2)}$$

where i is the number of cycles within each year, t is the day of the year, and DIY is the number of days in the year, i.e., 365 days for regular and 366 for leap years. For instance, SS_1 and SC_1 (t subscript is dropped to avoid clutter) complete one full Sine and Cosine cycle and SS_2 and SC_2 complete two full cycles within a year. Figure B.1 shows SS_1 and SC_1 cycles during a one-year period.

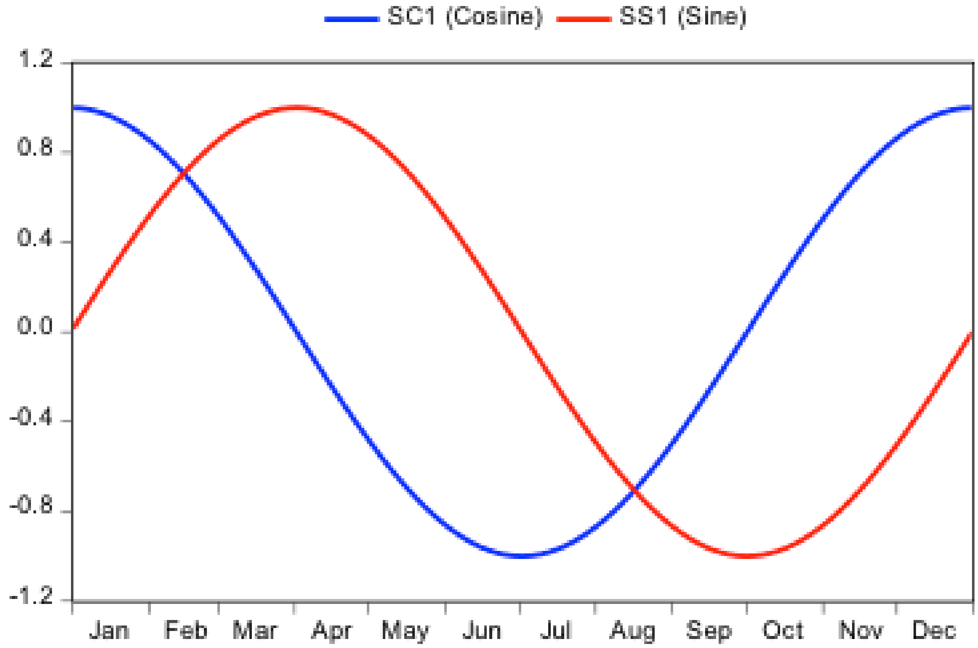


Figure B1. Harmonic variables used for representing seasonal variation in daily demand.

Weather variables

The weather is obviously governed by a seasonal pattern, which is reflected in demand as well. Using air temperature and precipitation directly as explanatory variables would entangle the seasonal demand pattern with the daily effect of weather on demand. To resolve such a problem, seasonal variations are removed from both daily air temperature and precipitation by auxiliary regression models. Maximum daily temperature and daily precipitation are used as the dependent variables and the harmonic cycles are used as explanatory variables in the auxiliary regression models. Furthermore, the air temperature model includes contemporaneous and one-day lagged precipitation as explanatory variables to remove the effect of precipitation on maximum daily temperature similar to the approach used in previous studies (Praskievicz and Chang 2009, Wong et al. 2010, Chang et al. 2014). The predictions of the auxiliary regression models depict the historical daily conditional means of air temperature and precipitation, and the residuals show daily deviations from their respective conditional means.

Equations represented in B.3 show how the seasonally adjusted contemporaneous daily precipitation values are generated.

$$P_t = \hat{\alpha} + \sum_{i=1}^{6} \hat{\beta}_i SS_i + \sum_{j=1}^{6} \hat{\gamma}_j SC_j + \varepsilon_t$$

$$Pdl(0)_t = P_t - \ \hat{\alpha} + \sum_{i=1}^{6} \hat{\beta}_i SS_i + \sum_{j=1}^{6} \hat{\gamma}_j SC_j \qquad \text{(B.3)}$$

Similarly, the seasonally and precipitation adjusted contemporaneous maximum daily temperatures are generated according to

$$T_t = \hat{\alpha} + \sum_{i=1}^{6} \hat{\beta}_i SS_i + \sum_{j=1}^{6} \hat{\gamma}_j SC_j + \hat{\delta} P_0 + \hat{\lambda} P_{-1} + \varepsilon_t \qquad \text{(B.4)}$$

$$Tdl(0)_t = T_t - \ \hat{\alpha} + \sum_{i=1}^{6} \hat{\beta}_i SS_i + \sum_{j=1}^{6} \hat{\gamma}_j SC_j + \hat{\delta} P_0 + \hat{\lambda} P_{-1}$$

In both (B.3) and (B.4), P_t and T_t are daily precipitation and maximum daily air temperature, $Pdl(0)_t$ and $Tdl(0)_t$ represent their contemporaneous deviations from the conditional means, respectively.

Various lags of mean adjusted daily precipitation and maximum temperature are used as explanatory variables in the demand models. These variables are also multiplied by low frequency harmonics and used as interaction variables to allow the model to correctly reflect the effect of weather on demand for water by having flexible coefficients for weather variables throughout the year. In addition, the number of consecutive days without precipitation adjusted for historical conditional mean is included to reflect the impact of dry spells on demand. This variable is also multiplied by low frequency harmonics and used as interaction variables to allow for flexible coefficients.

Indicator variables

There are variations in daily demand that are not associated with seasonal, weather, economic, or demographic factors. For instance, depending on the customer composition of the service area, demand might drop or rise on weekends and holidays. Typically, one would see a drop in weekend demand when water consumption by nonresidential customer class comprises a considerable part of the overall demand. This is due to the fact that most public and private work places, schools, and institutions are closed on weekends and holidays and therefore do not use as much water as they do during week days (Wong et al. 2010). These variations are represented by indicator or dummy variables in the demand models. Weekend dummy variable takes the value of one (1) for Saturday and Sunday and zero (0) for the rest of the week. Weekend variables are also interacted with the low frequency harmonics to allow seasonal flexibility for the coefficients. Holidays are represented by a series of dummy variables that take the value of one (1) on the days of observance and zero (0) otherwise. Short-term data anomalies with known period that occur as a result of meter malfunction are also handled by a set of daily or monthly dummy variables.

Economic and trend variables

Per capita demand for water is affected by a variety of economic factors. For instance increase in water and sewer rates has a negative impact on demand. Economic growth and slowdown affect water demand as well. As shown in Tables 5–9 above, per capita demand for all five water providers has a downward trend over the 2004–2013 period. The trends are a result of factors such as increases in water and sewer rates, 1992 plumbing fixture code changes for new homes, new appliances with higher water efficiency standards, change in the conservation attitude of customers, impact of conservation programs, changes in land-use and densification of residential dwellings, and trends in the overall economy. Economic changes are reflected in the model by the rate of unemployment in the Portland MSA. The unemployment rate data series is detrended to only reflect the short-term economic cycles and their effect on demand. The participating water providers have different rate structures and some even have different rates for different customer classes. The scope of this study does not include rate analysis and estimation of price elasticity for each water provider and their customer classes. However, we can see if overall changes in price of water are partly responsible for the trend in per capita demand. Revenue per million gallons of water sold to the retail customers was used as a proxy for price. The revenue included volumetric and base charges collected from the retail customers. The revenue figures were adjusted for inflation to represent changes in real price of water.

The intention of the study is to capture, as much as possible, the impact of weather, short-term economic cycles, and overall changes in price on per capita demand and its trend rather than structural analysis of the impact of all factors discussed. Consequently, long-term trend variables are used to depict the downward trend in demand caused by all other factors that are not represented in the model, such as sewer rate, land use, conservation-related factors, and other factors that affect long-term trend. A series of continuous low frequency harmonics are used in the demand models to depict long-term trend in the per capita demand. These variables are generated in a fashion similar to the seasonal variables; however, their phase of oscillation occurs over the period of the available demand data, which are different for each of the five service areas.

The variables are generated as

$$LTS_{it} = \sin \frac{2\pi it}{DID} \quad \text{and } LTC_{it} = \cos \frac{2\pi it}{DID} \tag{B.5}$$

where DID is total number of days in the periods of demand data, i is the number harmonic cycles, and t is the day number of the data point.

Functional form

A linear functional form is used to explain the variations in daily per capita demand in terms of the explanatory variables discussed above. Equation (B.6) shows the compact representation of the functional form.

$$PCD = b_0 + b_1 S + b_2 W + b_3 I + b_4 UER + b_5 P + b_6 LT + u \tag{B.6}$$

where PCD is the per capita demand in gallons per day. S and W are seasonal and weather variables as explained in the above. UER is the detrended unemployment rate in the Portland MSA, P is the deflated revenue per million gallons as a proxy for price, and variables I and LT are the indicator and long-term trend variables, respectively. b_i are the unknown coefficients to be estimated and u is the error term with Gaussian properties.

Regression results

Daily per capita production data along with data on the independent variables discussed above were used in five regression models. The production data provided by the participants were of various lengths. Instead of matching the lengths of the production data, the full set of data sets was used to get the best estimate of the coefficients.

The initial run of the regression models showed autocorrelation in the error terms. AR order of 2 was used to correct for autocorrelation. The results of the regression models for the five water providers are shown in Tables B1–B5. All five models have high degree of fit to the data as indicated by the R-squared.

Dependent Variable: Gresham Daily Per Capita Retail Production (Gallons), 2001-2014											
Variables	Coeff	Std Error	Prob	Variables	Coeff	Std Error	Prob	Variables	Coeff	Std Error	Prob
C1	-56.873	3.380	0.000	P_DL0*S2	-2.223	0.902	0.014	P_DL6*C1	3.542	0.871	0.000
C2	7.549	0.511	0.000	P_DL1	-4.718	0.806	0.000	P_DL6*S1	1.813	0.927	0.051
C3	1.290	0.502	0.010	P_DL1*C1	7.892	1.204	0.000	P_DL6*S2	-1.820	0.913	0.046
C4	-1.030	0.505	0.041	P_DL1*C2	-2.262	0.936	0.016	T_DL0	0.341	0.023	0.000
S1	-28.272	3.332	0.000	P_DL1*S1	3.236	0.948	0.001	T_DL0*C1	-0.526	0.034	0.000
S2	13.355	0.540	0.000	P_DL1*S2	-3.473	1.114	0.002	T_DL0*C2	0.150	0.028	0.000
S3	-5.129	0.505	0.000	P_DL2	-3.817	0.730	0.000	T_DL0*S1	-0.087	0.030	0.003
S5	-0.985	0.466	0.034	P_DL2*C1	6.075	1.076	0.000	T_DL0*S2	0.162	0.029	0.000
D_JUL4	2.754	1.127	0.015	P_DL2*S1	3.003	0.870	0.001	T_DL1*C1	-0.103	0.028	0.000
D_LBD	14.359	2.342	0.000	P_DL2*S2	-3.269	1.091	0.003	T_DL2*C1	-0.099	0.028	0.000
D_MEMD	9.924	1.298	0.000	P_DL3	-3.309	0.771	0.000	T_DL3*C1	-0.060	0.028	0.033
D_NYD	2.608	2.490	0.295	P_DL3*C1	4.483	1.102	0.000	T_DL3*S1	0.077	0.025	0.002
D_TG	3.364	3.048	0.270	P_DL3*S1	2.904	1.001	0.004	T_DL4*C1	-0.056	0.028	0.046
D_VETD	4.171	3.481	0.231	P_DL3*S2	-2.380	1.100	0.031	UER_DT_L24	-0.689	0.302	0.023
D_XMAS	-2.791	1.690	0.099	P_DL4	-2.607	0.752	0.001	R_AR_GRSHM	-0.031	0.002	0.000
D_WKND	4.337	0.211	0.000	P_DL4*C1	3.603	1.086	0.001	R_AR_GRSHM*C1	0.017	0.002	0.000
NPD_R	0.483	0.063	0.000	P_DL4*S1	2.196	0.962	0.023	R_AR_GRSHM*S1	0.008	0.002	0.000
NPD_R*C1	-0.196	0.088	0.026	P_DL4*S2	-2.055	1.069	0.055	C1_0114	16.881	4.454	0.000
NPD_R*S2	-0.225	0.076	0.003	P_DL5	-2.575	0.733	0.000	C2_0114	2.966	1.193	0.013
P_DL0	-3.145	0.663	0.000	P_DL5*C1	3.510	0.985	0.000	S2_0114	42.309	10.280	0.000
P_DL0*C1	5.189	1.031	0.000	P_DL5*S1	2.167	1.046	0.038	C	129.933	7.199	0.000
P_DL0*C2	-2.435	0.957	0.011	P_DL5*S2	-2.541	1.036	0.014	AR(1)	0.441	0.007	0.000
P_DL0*S1	2.181	0.892	0.015	P_DL6	-2.530	0.645	0.000	AR(2)	0.245	0.008	0.000
R-squared			0.941	Mean dependent var			102.16				
Adjusted R-squared			0.940	S.D. dependent var			28.78				
S.E. of regression			7.049	Akaike info criterion			6.76				
Sum squared resid			241366.90	Schwarz criterion			6.85				
Log likelihood			-16579.14	Hannan-Quinn criter.			6.79				
F-statistic			1119.12	Durbin-Watson stat			2.10				
Prob(F-statistic)			0.00								

Table B1. The results of the egression model for Gresham, 2001–2014.

Dependent Varaible: PWB Daily Per Capita Retail Production (Gallons), 1993-2014											
Variables	Coeff	Std Error	Prob	Variables	Coeff	Std Error	Prob	Variables	Coeff	Std Error	Prob
C1	-40.151	1.595	0.000	P_DL0	-2.030	0.629	0.001	T_DL1*S1	-0.093	0.036	0.010
C2	7.298	0.558	0.000	P_DL0*S1	2.507	0.932	0.007	T_DL1*S2	0.115	0.033	0.001
C3	1.258	0.537	0.019	P_DL0*S2	-3.097	0.921	0.001	T_DL2	0.080	0.026	0.002
C4	-1.523	0.507	0.003	P_DL1	-3.913	0.745	0.000	T_DL2*C1	-0.168	0.038	0.000
S1	-23.068	1.600	0.000	P_DL1*C1	6.204	1.015	0.000	T_DL3*C1	-0.079	0.032	0.015
S2	13.239	0.557	0.000	P_DL1*C2	-1.675	0.924	0.070	T_DL3*S1	-0.100	0.032	0.002
S3	-4.935	0.533	0.000	P_DL1*S1	2.851	1.038	0.006	T_DL4*C1	-0.083	0.033	0.013
S4	1.104	0.526	0.036	P_DL1*S2	-1.987	0.975	0.042	T_DL4*C2	-0.058	0.030	0.054
S5	-1.217	0.498	0.015	P_DL2	-3.168	0.850	0.000	T_DL6*C1	-0.067	0.029	0.019
D_JUL4	-10.475	1.900	0.000	P_DL2*C1	5.195	1.177	0.000	T_DL6*S1	-0.060	0.031	0.053
D_LBD	-3.647	2.177	0.094	P_DL2*C2	-2.165	0.921	0.019	UER_DT	-0.604	0.293	0.039
D_MEMD	-5.002	1.341	0.000	P_DL2*S1	3.895	0.974	0.000	R_AR_PWB	-0.040	0.001	0.000
D_NYD	-6.431	3.159	0.042	P_DL2*S2	-3.104	0.989	0.002	R_AR_PWB*C1	0.010	0.001	0.000
D_TG	-5.112	2.013	0.011	P_DL4	-2.824	0.606	0.000	R_AR_PWB*S1	0.006	0.001	0.000
D_VETD	-0.887	3.278	0.787	P_DL4*C1	3.667	0.910	0.000	C1_9314	7.350	2.547	0.004
D_XMAS	-7.781	3.358	0.021	T_DL0	0.368	0.025	0.000	S1_9314	5.080	0.773	0.000
D_WKND	-6.127	0.261	0.000	T_DL0*C1	-0.543	0.037	0.000	S2_9314	-32.214	5.666	0.000
D_WKND*C1	2.144	0.362	0.000	T_DL0*C2	0.140	0.030	0.000	C	211.344	4.618	0.000
D_WKND*C2	-0.672	0.350	0.055	T_DL0*S1	-0.125	0.034	0.000	AR(1)	0.328	0.006	0.000
D_WKND*S1	1.273	0.371	0.001	T_DL0*S2	0.111	0.034	0.001	AR(2)	0.314	0.006	0.000
D_WKND*S2	-0.834	0.367	0.023	T_DL1	0.151	0.027	0.000				
NPD_R	0.409	0.067	0.000	T_DL1*C1	-0.258	0.038	0.000				
NPD_R*C1	-0.362	0.095	0.000	T_DL1*C2	0.068	0.031	0.031				
R-squared			0.910	Mean dependent var			130.23				
Adjusted R-squared			0.909	S.D. dependent var			35.54				
S.E. of regression			10.699	Akaike info criterion			7.59				
Sum squared resid			904921.70	Schwarz criterion			7.67				
Log likelihood			-30249.68	Hannan-Quinn criter.			7.62				
F-statistic			902.17	Durbin-Watson stat			2.11				
Prob(F-statistic)			0.00								

Table B2. The results of regression model for PWB, 1993–2014.

Dependent Varaible: Tigard Daily Per Capita Retail Production (Gallons), 1997-2014											
Variables	Coeff	Std Error	Prob	Variables	Coeff	Std Error	Prob	Variables	Coeff	Std Error	Prob
C1	-56.633	2.357	0.000	P_DL0*C1	5.833	0.903	0.000	P_DL6	-1.327	0.634	0.036
C2	12.629	0.783	0.000	P_DL0*C2	-3.099	1.017	0.002	P_DL6*C1	2.538	0.851	0.003
C3	2.264	0.768	0.003	P_DL0*S1	2.467	0.986	0.012	T_DL0	0.387	0.026	0.000
C4	-1.654	0.735	0.025	P_DL0*S2	-3.458	0.853	0.000	T_DL0*C1	-0.470	0.037	0.000
C5	1.191	0.634	0.060	P_DL1	-9.647	0.656	0.000	T_DL0*C2	0.141	0.026	0.000
S1	-30.366	2.276	0.000	P_DL1*C1	13.795	0.924	0.000	T_DL0*S1	-0.117	0.031	0.000
S2	20.766	0.777	0.000	P_DL1*C2	-5.491	0.970	0.000	T_DL0*S2	0.127	0.029	0.000
S3	-7.553	0.676	0.000	P_DL1*S1	8.268	0.969	0.000	T_DL1	0.260	0.026	0.000
S5	-1.276	0.603	0.034	P_DL1*S2	-7.060	0.903	0.000	T_DL1*C1	-0.398	0.038	0.000
D_JUL4	-1.585	1.238	0.201	P_DL2	-8.941	0.732	0.000	T_DL1*C2	0.093	0.027	0.001
D_LBD	5.123	1.208	0.000	P_DL2*C1	13.488	1.067	0.000	T_DL2	0.092	0.025	0.000
D_MEMD	8.144	0.971	0.000	P_DL2*C2	-4.577	1.032	0.000	T_DL2*C1	-0.155	0.033	0.000
D_NYD	-0.344	2.844	0.904	P_DL2*S1	7.503	1.016	0.000	T_DL4	0.064	0.024	0.009
D_TG	0.675	2.724	0.804	P_DL2*S2	-5.821	0.950	0.000	T_DL4*C1	-0.101	0.032	0.002
D_VETD	0.836	3.748	0.824	P_DL3	-6.259	0.702	0.000	UER_DT	-0.031	0.405	0.939
D_XMAS	-1.156	2.673	0.665	P_DL3*C1	9.695	0.995	0.000	R_AR_TGRD	-0.015	0.001	0.000
D_WKND	-0.559	0.218	0.010	P_DL3*C2	-2.543	0.989	0.010	R_AR_TGRD*C1	0.008	0.001	0.000
D_WKND*C1	1.409	0.311	0.000	P_DL3*S1	4.520	0.998	0.000	R_AR_TGRD*S1	0.005	0.001	0.000
D_WKND*C2	-0.702	0.278	0.012	P_DL3*S2	-2.781	0.874	0.002	C1_9714	4.082	0.746	0.000
D_WKND*S1	1.140	0.305	0.000	P_DL4	-4.237	0.763	0.000	C2_9714	4.711	0.826	0.000
D_WKND*S2	-1.211	0.287	0.000	P_DL4*C1	5.858	1.082	0.000	S1_9714	8.185	0.943	0.000
NPD_R	0.331	0.070	0.000	P_DL4*S1	3.057	0.970	0.002	C	133.565	2.356	0.000
NPD_R*C1	-0.481	0.118	0.000	P_DL4*S2	-2.012	0.902	0.026	AR(1)	0.584	0.007	0.000
NPD_R*C2	-0.226	0.065	0.001	P_DL5	-2.080	0.676	0.002	AR(2)	0.195	0.008	0.000
NPD_R*S2	-0.153	0.063	0.016	P_DL5*C1	2.141	0.952	0.025				
P_DL0	-4.502	0.656	0.000	P_DL5*S1	1.666	0.922	0.071				

R-squared	0.970	Mean dependent var	108.10
Adjusted R-squared	0.970	S.D. dependent var	44.63
S.E. of regression	7.732	Akaike info criterion	6.94
Sum squared resid	388427.70	Schwarz criterion	7.02
Log likelihood	-22736.14	Hannan-Quinn criter.	6.97
F-statistic	2795.82	Durbin-Watson stat	2.06
Prob(F-statistic)	0.00		

Table B3. The results of regression model for Tigard, 1997–2014.

Dependent Varaible: Tualatin Daily Per Capita Retail Production (Gallons), 1999-2014											
Variables	Coeff	Std Error	Prob	Variables	Coeff	Std Error	Prob	Variables	Coeff	Std Error	Prob
C1	-98.905	7.853	0.000	P_DL0*S1	6.171	1.931	0.001	T_DL0*C2	0.182	0.055	0.001
C2	16.534	1.667	0.000	P_DL0*S2	-5.204	1.938	0.007	T_DL1	0.267	0.045	0.000
S1	-75.846	10.147	0.000	P_DL1	-10.727	1.303	0.000	T_DL1*C1	-0.280	0.058	0.000
S2	30.335	1.880	0.000	P_DL1*C1	15.485	1.825	0.000	T_DL2*C1	-0.239	0.053	0.000
S3	-8.873	1.689	0.000	P_DL1*C2	-8.521	1.626	0.000	T_DL3	0.119	0.042	0.005
D_JUL4	-2.705	2.643	0.306	P_DL1*S1	8.147	1.829	0.000	T_DL3*C1	-0.173	0.056	0.002
D_LBD	-2.834	4.258	0.506	P_DL1*S2	-5.080	1.846	0.006	T_DL3*S2	-0.129	0.048	0.007
D_MEMD	0.041	2.963	0.989	P_DL2	-7.053	1.374	0.000	T_DL4*C1	-0.207	0.047	0.000
D_NYD	-7.751	3.778	0.040	P_DL2*C1	10.449	1.887	0.000	T_DL6	0.118	0.036	0.001
D_TG	-7.825	3.656	0.032	P_DL2*C2	-5.566	1.672	0.001	D_SHRWD	22.680	1.190	0.000
D_VETD	1.697	4.352	0.697	P_DL2*S1	4.965	1.951	0.011	UER_DT_L18	-3.150	0.665	0.000
D_XMAS	-14.588	2.666	0.000	P_DL2*S2	-4.655	1.977	0.019	R_AR_TULTN	-0.016	0.006	0.012
D_WKND	-7.003	0.420	0.000	P_DL3	-2.926	1.466	0.046	R_AR_TULTN*C1	0.026	0.007	0.000
NPD_R	0.549	0.093	0.000	P_DL3*C1	5.332	1.874	0.004	R_AR_TULTN*S1	0.033	0.009	0.000
NPD_R*C2	-0.307	0.122	0.012	P_DL3*S1	4.996	2.008	0.013	C1_9914	-11.772	1.974	0.000
P_DL0	-7.120	1.321	0.000	P_DL3*S2	-4.015	1.979	0.043	C	182.156	7.438	0.000
P_DL0*C1	8.692	1.680	0.000	T_DL0	0.386	0.043	0.000	AR(1)	0.557	0.005	0.000
P_DL0*C2	-2.971	1.704	0.081	T_DL0*C1	-0.584	0.063	0.000	AR(2)	0.276	0.006	0.000

R-squared	0.957	Mean dependent var	170.79
Adjusted R-squared	0.956	S.D. dependent var	69.21
S.E. of regression	14.438	Akaike info criterion	8.19
Sum squared resid	1177801.0	Schwarz criterion	8.25
Log likelihood	-23307.22	Hannan-Quinn criter.	8.21
F-statistic	2322.42	Durbin-Watson stat	2.05
Prob(F-statistic)	0.00		

Table B4. The results of regression model for Tualatin, 1999–2014.

Dependent Varaible: TVWD Daily Per Capita Retail Production (Gallons), 1990-2014											
Variables	Coeff	Std Error	Prob	Variables	Coeff	Std Error	Prob	Variables	Coeff	Std Error	Prob
C1	-75.381	5.306	0.000	P_DL2*C1	9.180	1.201	0.000	T_DL1	0.322	0.027	0.000
C2	13.391	0.798	0.000	P_DL2*C2	-2.289	1.014	0.024	T_DL1*C1	-0.440	0.038	0.000
C3	1.468	0.803	0.068	P_DL2*S1	4.461	1.113	0.000	T_DL1*C2	0.128	0.031	0.000
C5	1.407	0.731	0.054	P_DL2*S2	-2.594	1.045	0.013	T_DL2	0.137	0.028	0.000
S1	-29.120	5.891	0.000	P_DL3	-6.930	0.886	0.000	T_DL2*C1	-0.284	0.038	0.000
S2	18.774	0.844	0.000	P_DL3*C1	10.605	1.246	0.000	T_DL2*C2	0.057	0.030	0.057
S3	-6.818	0.788	0.000	P_DL3*C2	-2.710	1.089	0.013	T_DL2*S1	-0.133	0.033	0.000
S5	-1.605	0.708	0.024	P_DL3*S1	7.177	1.204	0.000	T_DL3	0.116	0.028	0.000
D_JUL4	-4.003	1.961	0.041	P_DL3*S2	-5.358	1.112	0.000	T_DL3*C1	-0.156	0.037	0.000
D_LBD	0.433	1.549	0.780	P_DL4	-5.502	0.917	0.000	T_DL4	0.070	0.026	0.008
D_MEMD	1.024	2.129	0.631	P_DL4*C1	7.185	1.265	0.000	T_DL4*C1	-0.063	0.035	0.073
D_NYD	-4.474	2.648	0.091	P_DL4*C2	-2.296	1.059	0.030	T_DL5*S2	-0.084	0.030	0.005
D_TG	-1.944	2.652	0.464	P_DL4*S1	3.094	1.224	0.012	T_DL6	0.051	0.022	0.020
D_VETD	0.726	4.095	0.859	P_DL4*S2	-2.797	1.160	0.016	UER_DT	-2.432	0.520	0.000
D_XMAS	-0.492	2.513	0.845	P_DL5	-3.499	0.805	0.000	R_AR_TVWD	-0.051	0.017	0.003
NPD_R	0.540	0.065	0.000	P_DL5*C1	6.046	1.047	0.000	R_AR_TVWD*C1	0.021	0.004	0.000
NPD_R*C1	-0.267	0.094	0.004	P_DL5*S1	4.246	1.194	0.000	R_AR_TVWD*S1	0.005	0.004	0.272
NPD_R*S2	-0.207	0.073	0.005	P_DL5*S2	-2.341	1.033	0.024	C1_9014	123.589	14.008	0.000
P_DL0*C1	3.044	0.912	0.001	P_DL6	-1.933	0.796	0.015	C2_9014	-77.583	11.052	0.000
P_DL1	-6.698	0.708	0.000	P_DL6*C1	2.119	1.053	0.044	S1_9014	50.970	21.948	0.020
P_DL1*C1	9.384	1.104	0.000	P_DL6*S2	-1.610	0.966	0.096	C	149.528	37.841	0.000
P_DL1*C2	-3.199	0.969	0.001	T_DL0	0.304	0.027	0.000	AR(1)	0.427	0.006	0.000
P_DL1*S1	7.207	0.916	0.000	T_DL0*C1	-0.465	0.036	0.000	AR(2)	0.342	0.006	0.000
P_DL1*S2	-6.184	0.921	0.000	T_DL0*S1	-0.126	0.037	0.001				
P_DL2	-5.872	0.806	0.000	T_DL0*S2	0.074	0.036	0.041				
R-squared			0.943	Mean dependent var			122.74				
Adjusted R-squared			0.943	S.D. dependent var			49.57				
S.E. of regression			11.883	Akaike info criterion			7.80				
Sum squared resid			1278987.0	Schwarz criterion			7.85				
Log likelihood			-35520.10	Hannan-Quinn criter.			7.82				
F-statistic			2052.54	Durbin-Watson stat			2.08				
Prob(F-statistic)			0.00								

Table B5. The results of regression model for TVWD, 1990–2014.

The explanatory variables are defined as:

S(i) and C(i) are seasonal variable of different sine and cosine frequencies,

D_WKND is the dummy variable for weekends,

D_NYD, D_MEMD, D_JUL4, D_LBD, D_VETD, D_TG, and D_XMAS are dummy variables for New Year, Memorial, Independence, Labor, Veterans, Thanksgiving, and Christmas days respectively,

NPD is the number of consecutive days without rain,

P_DL(i) are daily precipitation variables with different lags,

T_DL(i) are maximum daily temperature variables with different lags,

UNE_DT is detrended unemployment rate in the Portland MSA,

R_AR_(Provider name) are the real average revenue per million gallons,

C(i)_jj12 and S(i)_jj12 are the long-term cyclical trend sine and cosine wave variables depicting impact of the sewer rates, conservation related issues, land use, and other factors effecting trend. The phase of oscillations spans the length of the data used for the water provider.

C is the constant term, and

AR(i) are the error correction terms for autocorrelation.

The PWB retail model also includes dummy variables for data anomalies that are not shown in Table B2. The weekend, weather, and price proxy variables are interacted with the low frequency harmonics to allow the variable have flexible coefficient throughout the year.

To estimate the effect of various factors on demand, one can multiply the estimated coefficients by the appropriate values of the variables at each point in time. For instance, the daily impact of weather can be estimated by the sum of estimated weather variable coefficients multiplied by the daily values of the variables. By the same token impact of economic cycles and price can be estimated. The estimated impacts can be used to adjust demand for weather, economic cycles, and price normalization.

References

Chang, H. Praskievicz, S., and Parandvash, H. 2014. "Sensitivity of urban water consumption to weather climate variability at multiple temporal scales: The case of Portland." *International Journal of Geospatial and Environmental Research* 1, 1, Article 7.

Chesnutt, T.W., and C.N. McSpadden. 1995. "Determinant of Phoenix water demand." A&T Technical Services, Inc., Santa Monica, CA.

Dziegielewski, Benedykt, and E. Opitz. Water Demand Analysis, In: L. W. Mays, ed., 2002. *Urban Water Supply Handbook*, 5.3–5.55.

Hannan, E. J. 1963. "The Estimation of Seasonal Variation in Economic Time Series." *Journal of the American Statistical Association* 58:301, 31–44.

Harvey, A. C., and N. Shephard. Structural Time Series Models, In: G. S. Maddala, C. R. Rao, and H. D. Vinod, eds.,1993. *Handbook of Statistics* 11, 261–302.

Jorgenson, D. W. "Minimum Variance, Linear, Unbiased Seasonal Adjustment of Economic Time Series," *Journal of the American Statistical Association* 59, 681–724, 1964.

Jorgenson, D. W. "Seasonal Adjustment of Data for Econometric Analysis." *Journal of the American Statistical Association* 62, 137–140, 1967.

Praskievicz, S., Chang, H. 2009. "Identifying the relationships between urban water consumption and weather variables in Seoul, Korea." *Physical Geography* 30(4): 324–337.

Wong, J.S., Zhang, Q. and Chen, Y.D. (2010). "Statistical modeling of daily urban water consumption in Hong Kong: Trend, changing patterns, and forecast." *Water Resour. Res.* 46, W03506.