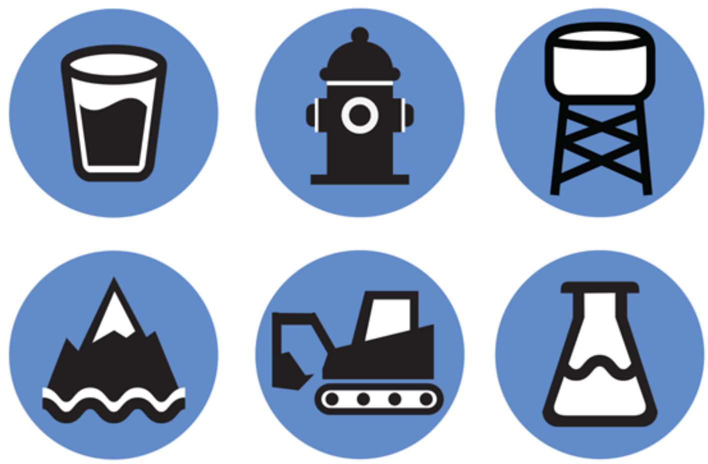
Seattle Public Utilities

2019 WATER SYSTEM PLAN



Our Water. Our Future.

REVISED FINAL | Volume 1

August 2019

Seattle Public Utilities

2019 Water System Plan

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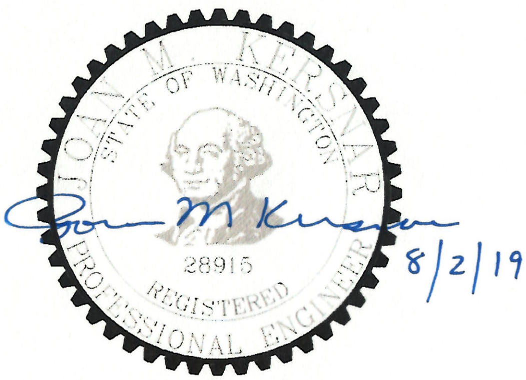
Certification

Seattle Public Utilities
2019 Water System Plan
August 2019

This 2019 Water System Plan for Seattle Public Utilities has been prepared under the direction of the following Registered Professional Engineers:



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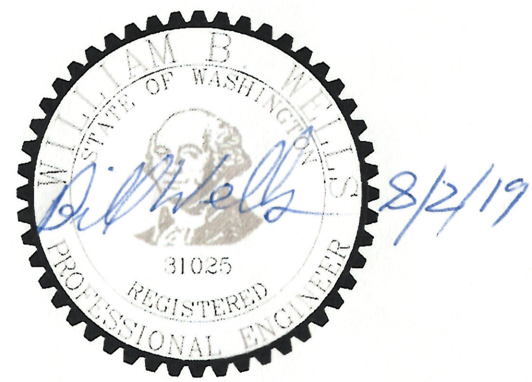

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Abbreviations

AC	Alternating Current
AMC	Asset Management Committee
AMP	Asset Management Plan
AMI	Advanced Metering Infrastructure
AMR	Automated Meter Reading
ASR	Aquifer Storage and Recovery
AVA	Air Valve Assembly
AWWA	American Water Works Association
BO	Blowoff
BPA	Bonneville Power Administration
CCF	hundred cubic feet
CCL	Contaminant Candidate List
CCR	Consumer Confidence Report
CFP	Capital Facilities Plan
cfs	Cubic feet per second
CI	cast iron
CIP	Capital Improvement Program
COEHHA	California Office of Environmental Health Hazard Assessment
CP	Cathodic Protection
CRPL	Cedar River Pipeline
CUE	Conjunctive Use Evaluation
CWSP	Coordinated Water System Plan
DBP	Disinfection By-Products
DI	ductile iron
DNS	Determination of Nonsignificance
DSL	Distribution System Leakage
EDC	Endocrine Disrupting Compounds
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ERU	Equivalent Residential Unit
ESA	Endangered Species Act
F	Fahrenheit
FCF	Flow Control Facilities
FERC	Federal Energy Regulatory Commission
FWP	Finished Water Pipeline
GIS	Geographic Information System
GMA	Growth Management Act
HAAs	Haloacetic acids
HCP	Habitat Conservation Plan
HISB	High Impact Shutdown Block

HPC	Heterotrophic plate count
I-63 SO	Initiative 63 Settlement Ordinance (Seattle Ordinance 120532)
IDSE	Initial Distribution System Evaluation
IFA	Instream Flow Agreement
IWA	International Water Association
LAF	Limited Alternative to Filtration
LEED	Leadership in Energy and Environmental Design
LF	Linear feet
LIMS	Laboratory Information Management System
LRAA	Locational Running Annual Average
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
LT2SWTR	Long Term 2 Surface Water Treatment Rule
MAC	Mycobacterium Avium Complex
MCL	Maximum Contaminant Level
MDL	Minimum Detection Limit
mgd	million gallons per day
MLPP	Morse Lake Pump Plant
MIT	Muckleshoot Indian Tribe
MTBE	methyl tertiary butyl ether
MWL	Municipal Water Law
NO-DES	Neutral Output Discharge Elimination System
NZMS	New Zealand mud snail
O&M	Operation and Maintenance
OFM	Washington State Office of Financial Management
OS	Operational Storage
PHSKC	Public Health Seattle - King County
PPCP	Pharmaceuticals and Personal Care Products
PRV	Pressure regulating valve
psi	pounds per square inch
PSRC	Puget Sound Regional Council
PUMA	Piloting Utility Modeling Applications
RCM	Reliability Centered Maintenance
RCP	Representative Concentration Pathway
RWSP	Regional Wastewater Services Plan
SCADA	Supervisory Control and Data Acquisition
SCL	Seattle City Light
SDCI	Seattle Department of Construction and Inspection
SDOT	Seattle Department of Transportation
SFD	Seattle Fire Department
SPU	Seattle Public Utilities
SWTR	Surface Water Treatment Rule
TCR	Total Coliform Rule
TESS	Tolt Eastside Supply

TESSL	Tolt Eastside Supply Line
TPL	Tolt Pipeline
TTHMs	Trihalomethanes
UAS	Unapproved Auxiliary Supplies
UCMR	Unregulated Contaminant Monitoring Rule
UDF	Unidirectional Flushing
ug/L	Micrograms per liter
UV	Ultraviolet
UW-CIG	University of Washington Climate Impacts Group
VOC	Volatile Organic Compounds
W.D.	Water District
WAC	Washington Administrative Code
WDOH	Washington State Department of Health
WSDOT	Washington Department of Transportation
WSP	Water System Plan
WTF	Water Treatment Facility
WUE	Water Use Efficiency

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2019 Water System Plan

SUMMARY

Seattle Public Utilities (SPU) manages and operates the water system serving Seattle retail customers and wholesale customers in nearby cities and water districts as shown on the map at the end of this summary. This *2019 Water System Plan* describes how SPU meets current and future water demands, ensures high quality drinking water, and invests in and maintains its water system at the lowest life-cycle cost. While the plan focuses on the next 10 years, longer term outlooks to 2040 and beyond are also discussed.

SPU prepared the plan under regulations adopted by the Washington State Department of Health for public drinking water suppliers. The plan is also consistent with the state's Water Use Efficiency Rule, requirements of the Growth Management Act, and local and regional land use plans.

Key findings and implementation actions are highlighted below, with more detail provided in the chapters that correspond to the headings.

Water Resources

The SPU water supply system consists of surface water reservoirs on the Cedar River and South Fork Tolt River and two wellfields providing groundwater. The system is operated primarily for water supply and protection of instream flows, but also used for hydroelectric power generation and flood management.

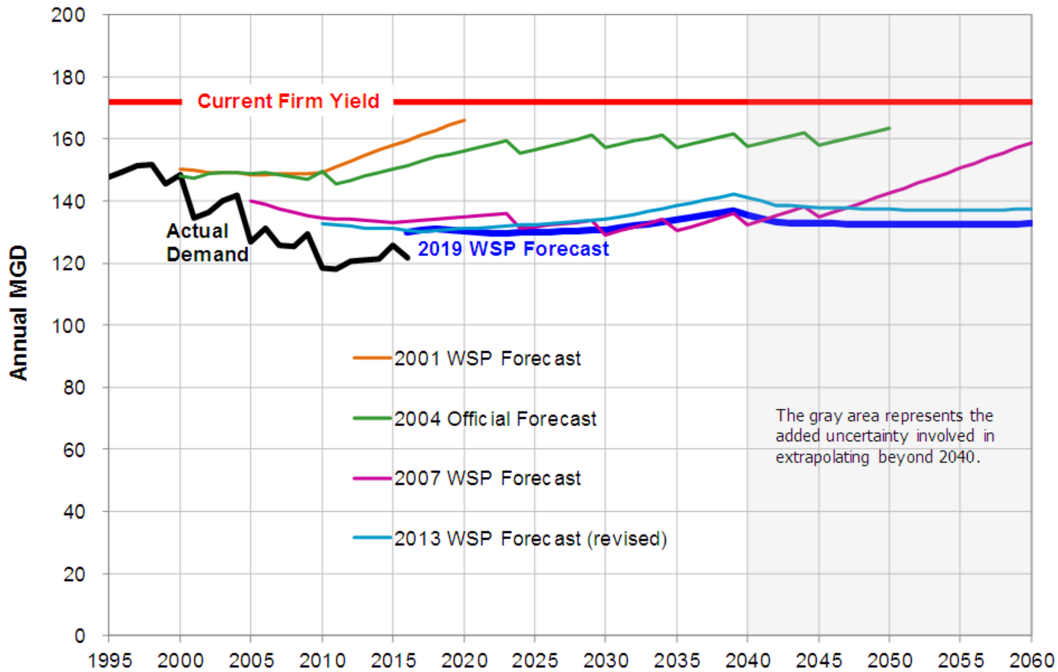
Water Use

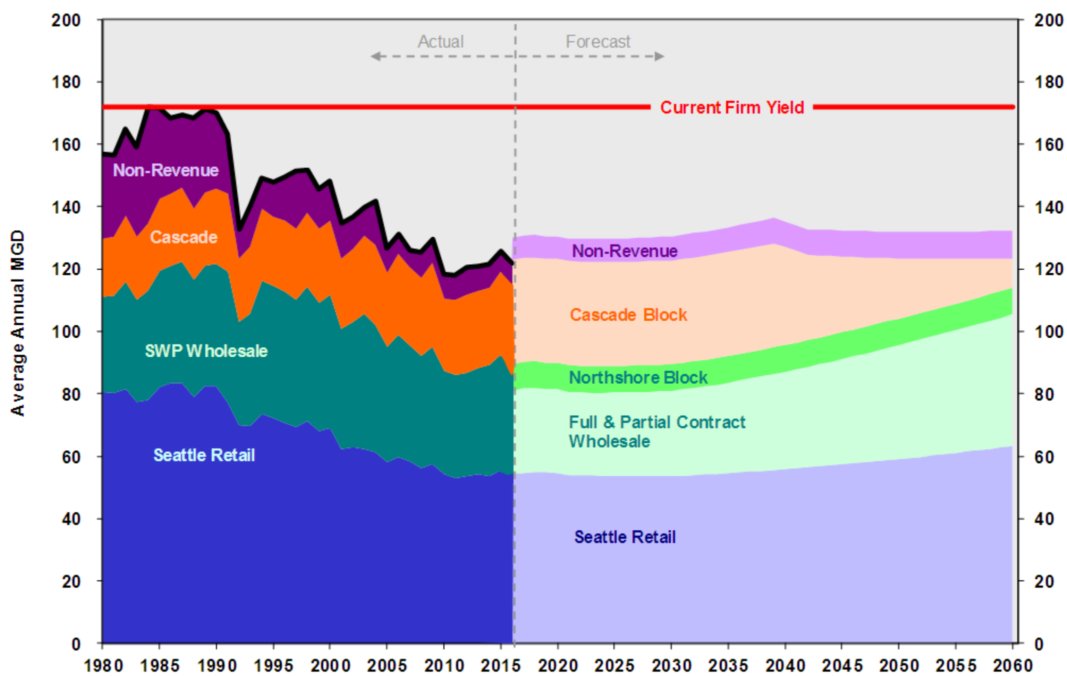
- The total population currently served by SPU to its retail and wholesale customers in King and south Snohomish County is about 1.4 million.
- Approximately one-half of the water is sold to SPU retail customers and one-half is sold through wholesale contracts to 19 municipalities and special purpose districts, plus Cascade Water Alliance, who in turn provide the water to their own retail customers.
- Since 1990, total water use has decreased by 28 percent while the number of people being served has increased by the same percentage.
- From 2016 to 2040, the number of households is forecast to increase by 18 percent in the SPU retail service area and by 29 percent in the service areas of SPU's full and partial wholesale water contract holders. Employment is forecast to grow by 29 and 43 percent, respectively, over the same period.
- Total demand is forecast to remain relatively flat through 2030 before rising gradually to a peak of 137 million gallons per day (mgd) in 2039. By 2060, total water demand

from SPU's system is forecasted to have ramped back down to 133 mgd. See the graphs below.

- The primary factors that influence the demand forecast consist of the declining block contract with Cascade Water Alliance and continued reductions in water use by customers.

SPU's Water Demand Forecast





Note: Forecast demand is higher than actual demand in 2016 because the forecast includes all block contract amounts, whereas the actual demand by Cascade and Northshore has been less than their block contract amounts.

Water Conservation

- This plan sets a goal to keep the total average annual retail water use of Saving Water Partnership[1] members under 110 mgd through 2028 despite forecasted population growth by reducing per capita water use.

Water Supply

- The Cedar River supplies approximately 60 to 70 percent of SPU's customer demand for water, and the South Fork Tolt River provides the remainder.
- The current firm yield estimate for the SPU water supply system is 172 mgd, which meets SPU's 98 percent reliability standard for 87.5 years of reconstructed historic inflows.
- Given the new demand forecast and current firm yield estimate for SPU's existing supply resources, no new source of supply is needed before 2060.
- Based on lessons learned from the 2015 drought response, SPU updated its Water Shortage Contingency Plan to allow the SPU General Manager/CEO to authorize the Advisory Stage to begin planning and coordination activities in advance of requesting customer actions.

Climate Change and Future Supply Outlook

- Updated analysis shows that SPU's water supply system will be increasingly vulnerable to climate change, and SPU identified several adaptation strategies and options to mitigate these impacts. There is a large degree of uncertainty in the timing and magnitude of climate impacts on supply vulnerability, but the trend and range of potential outcomes indicate that planning for increased system resiliency should remain a top priority in coming years.
- SPU will remain engaged in future research on climate change by conducting new assessments on a periodic basis to identify potential impacts and plan for adequate water supply while ensuring that decisions do not result in unnecessary or premature financial and environmental costs for the region.
- SPU also plans to continue investigations of climate adaptation strategies to increase resilience in the water supply watersheds to reduce the future risk of catastrophic wildfire in the face of potential effects of climate change.

Planned Infrastructure and Operational Improvements

- SPU identified infrastructure improvement needs for the water supply system that include Landsburg Dam Flood Passage Improvements and various dam safety studies and projects at the South Fork Tolt Dam and Lake Youngs Cascades Dam.
- SPU will complete analysis of options to improve water supply resiliency under climate change.

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[1]*Since January 2012, Saving Water Partnership members have included SPU, Northshore Utility District, Cedar River W&SD, City of Bothell, City of Duvall, City of Mercer Island, City of Renton, Coal Creek Utility District, Highline W.D., Olympic View W&SD, North City W.D., Soos Creek W&SD, W.D. 20, W.D. 45, W.D. 49, W.D. 90, W.D. 119, W.D. 125, and Woodinville W.D.*

Water Quality and Treatment

The SPU water system includes water treatment facilities for the Cedar and South Fork Tolt source waters, in-town disinfection facilities at reservoirs and well sites, and a state-certified water quality laboratory. SPU also manages a cross-connection control program to protect drinking water quality.

Drinking Water Quality

- SPU continues to meet drinking water quality regulations and other aesthetic criteria (i.e., taste and odor).
- SPU's source protection practices (including public ownership and restricted access to the watersheds), water treatment facilities, and distribution system practices have provided excellent quality water that ensures compliance with current and future regulations.
- SPU's corrosion control ensures that water delivered to customers meet lead and copper requirements, and plans to replace service lines with lead components through its service line replacement program.
- SPU will revisit the risk-cost analysis of public access on the Kerriston Road if there is an increase in trespass in the area to determine if additional land acquisition is the preferred approach for mitigating the risk of impairing Cedar source water quality.
- SPU will continue to monitor and characterize limnological conditions in Lake Youngs as it affects Cedar supply operations and treated water quality.
- SPU will operate the water supply system to bypass Lake Youngs to avoid problematic algae from entering the water system.
- SPU will continue efforts to prevent aquatic nuisance and invasive species from being introduced into SPU's drinking water supplies.

Reservoir Covering/Burying

- SPU will evaluate the need to retain non-potable emergency storage at Roosevelt and Volunteer Reservoirs as part of SPU's water system seismic study.
- SPU will replace the floating covers on Bitter Lake and Lake Forest Park Reservoirs which are nearing the end of their useful life – in particular Lake Forest Park Reservoir.

Water Treatment Facilities

- SPU will be evaluating contract extension options for the Tolt and Cedar Water Treatment Facilities that are in long-term Design-Build-Operate (DBO) contracts, and plan for upgrades as these facilities age.

Water Transmission System

The regional and sub-regional water transmission systems include approximately 193 miles of large-diameter pipes, seven covered reservoirs, 14 pump stations, seven elevated tanks and standpipes, and 131 wholesale customer taps with meters. These systems deliver water from the supply sources to the retail and wholesale service areas.

Service Delivery

- SPU has met the wholesale contract requirements for pressure and flow, and there have been no unplanned outages of the transmission pipelines that have exceeded SPU's service level for maximum outage durations.

Transmission Infrastructure

- SPU plans to mitigate the risk of pipe failure in the slide area between the Regulating Basin and Tolt Water Treatment Facility through continued slope monitoring, additional geotechnical data collection, periodic internal inspections, and biannual leak testing, and by implementing additional capital improvements and pipeline stress relief measures when appropriate.
- SPU will continue to implement cost-effective cathodic protection projects for older steel transmission pipelines to protect them from corrosion and extend their service lives well into the future.
- SPU will perform internal video inspection of all lockbar pipelines, and develop a specific plan for their rehabilitation, slip-lining, or replacement, depending on pipeline condition, capacity, and seismic considerations.
- Based on the water system seismic vulnerability study, SPU will improve the overall water system's performance following a major earthquake.

Water Distribution System

The distribution system contains more than 1,630 miles of water mains, six covered reservoirs, two out-of-service open reservoirs, 16 pump stations, six elevated tanks and standpipes, 17,000 valves, and 19,000 fire hydrants, as well as more than 191,000 service lines and meters serving individual residential and non-residential properties in the retail service area.

Service Delivery

- SPU consistently responded to reported distribution system problems within one hour more than 90 percent of the time.
- SPU plans to improve operational response and customer service by using information from a water main shutdown block analysis in project and emergency shutdown plans.

- The average age of water mains is 71 years, but the rate of water main leaks and breaks remains low, averaging 9 reported leaks or breaks per 100 miles per year in the distribution system.
- While SPU's distribution system leakage was 5.4 percent for 2014 through 2016, which is well below the state standard of 10 percent.

Distribution Infrastructure

- SPU will continue to proactively replace or rehabilitate water mans based on criticality and leak/break history.
- SPU will resume critical valve preventative maintenance and exercising program to ensure adequate and reliable control of the water distribution system grid.
- Based on the water system seismic vulnerability study, SPU will improve the overall water system's performance following a major earthquake.
- SPU will continue to work with the Seattle Fire Department and Shoreline Fire Department to improve fire hydrant maintenance and testing practices, better coordinate communication, and prioritize fire flow improvement projects.
- SPU will continue working with developers where water main replacements or upgrades in redevelopment areas are required to meet current fire flow requirements and water main standards.
- Over the next decade, SPU will need to address impacts to the water system from transportation projects, particularly Move Seattle levy projects.

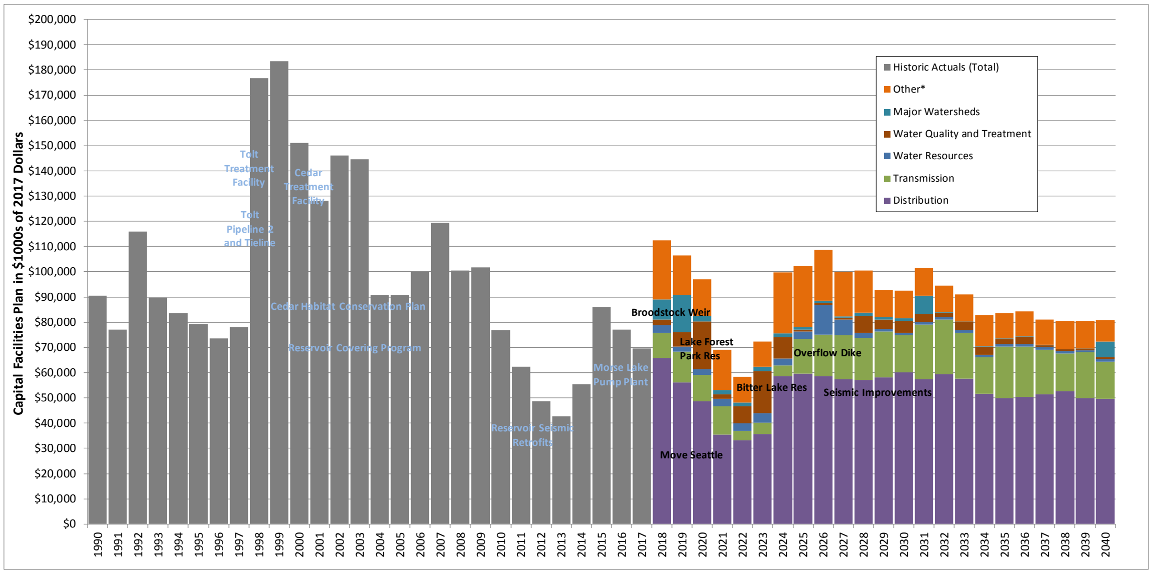
Capital Improvement Budget and Financial Program

Implementation of this plan requires completion of capital projects, programs, and operations and maintenance activities. SPU uses an asset management approach in selecting which capital improvement projects go forward. The cost estimates presented in the plan are subject to change as the projects are further developed and analyzed, and ultimately require budget approval of the Seattle City Council.

Capital Facilities Plan

- SPU's Capital Facilities Plan totals to almost $2 billion from 2019 through 2040 (in 2017 dollars).
- Capital spending is expected to be highest in the earlier years, and on the order of what was spent in the late 2000s, due to significant expenditures associated with the Move Seattle transportation levy (Distribution). See graph below.
- Additional increases starting in 2024 are for watermain rehabilitation in the Distribution system and seismic improvements in the Transmission and Distribution systems.

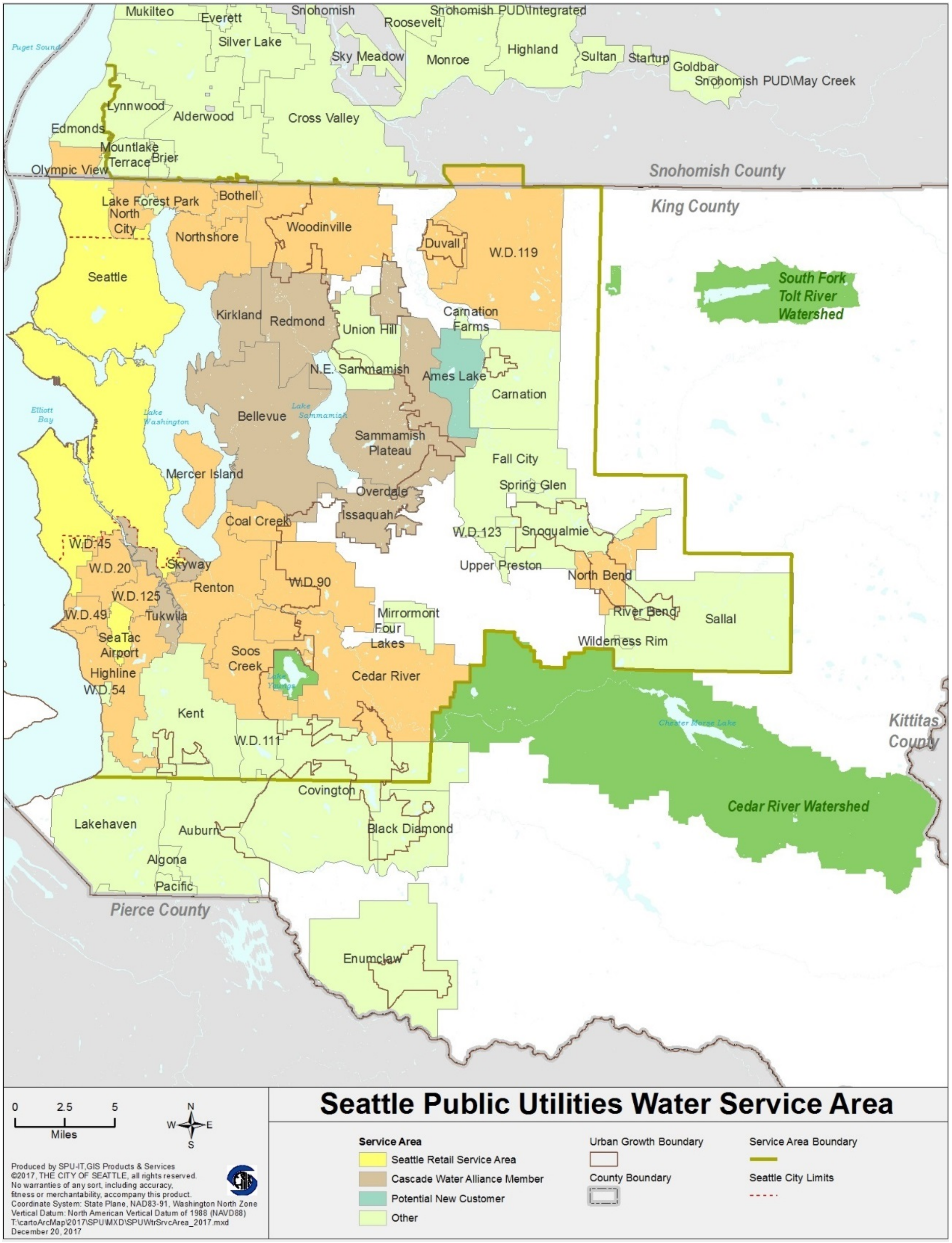
Historic and Proposed Capital Facilities Plan Spending through 2040
(2018-2023 Adopted CIP, plus 2024-2040 Estimate, in thousands of 2017 dollars)



* Other includes Fleets, Facilities, Security, Information Technology, SCADA and other miscellaneous projects.

Conclusion

SPU has been making, and continues to make, significant investments to protect public health, comply with federal and state regulations, and replace aging infrastructure. While SPU has invested in major regional facilities in the past decades, the need is now shifting to significant capital investments to rehabilitate the distribution system and to improve system performance after an earthquake. Implementation of this water system plan will help to ensure that SPU meets its mission to provide efficient and forward-looking utility services that keep Seattle the best place to live and work for everyone.



The entire *2019 Water System Plan* can be found at:
www.seattle.gov/util/WaterSystemPlan

CHAPTER 1

INTRODUCTION

Seattle Public Utilities (SPU) provides drinking water to a service area population of 1.4 million within the greater Seattle metropolitan region of King County and portions of southern Snohomish County. This *2019 Water System Plan* describes the near- and long-term plans for the regional water system in accordance with Washington State Department of Health (WDOH) requirements. The focus of this plan is on updates to the water system and programs since completion of the *2013 Water System Plan* and plans for the next 10 years.

To provide context for this plan, this introductory chapter includes a brief history and description of the existing water system and of four core business areas that comprise SPU's water line of business. In addition, this chapter presents an overview of SPU's policies that guide activities for the water system. A summary is provided of SPU's customer service levels for the water system. The chapter also describes the current planning environment, including how this plan is consistent with other relevant planning efforts. Finally, the introduction summarizes the organization of this plan and describes how it meets the requirements of the Washington Administrative Code (WAC).

1.1 SPU'S DRINKING WATER LINE OF BUSINESS

SPU's mission is to provide efficient and forward-looking utility services that keep Seattle the best place to live and work for everyone.

The overarching mission for SPU is to provide efficient and forward-looking utility services that keep Seattle the best place to live and work for everyone. In addition to operating Seattle's regional drinking water system, SPU provides surface water drainage, wastewater, and solid waste services to residents and businesses of Seattle. This plan covers SPU's drinking water line of business. This section provides background on the water system and the water utility's organizational structure.

1.1.1 History of Water Business

Since 1901, the Cedar River has provided water for Seattle. Initially, there was a diversion dam and transmission pipeline on the lower Cedar River at Landsburg and a timber crib dam at Cedar Lake–later renamed Chester Morse Lake. In 1914, a higher masonry dam was constructed to create storage for Seattle's water supply and hydropower generation. Additional pipelines were added between 1909 and 1954 to meet growing demands for water. Today, the Cedar River supplies 60 to 70 percent of SPU's customer demand for water.

In the late 1950s, several King County suburban communities began to look to Seattle as a source of their drinking water. In response, Seattle began selling water wholesale to these communities, who, in turn, supply it to their own customers.

Although the City began developing its water rights on the Tolt River in 1936, the source was first put to use in 1964. The first phase of the Tolt development was on the South Fork Tolt River, where a reservoir and pipelines were built to increase Seattle's water supply. The South Fork Tolt now provides approximately 30 to 40 percent of the City's water supply.

In 1985, the City began development of two well fields, now called the Seattle Well Fields, north of SeaTac Airport, within the City of SeaTac. These well fields are available to meet the demand for water, especially during the summer peak water use season and emergencies, under temporary water right permits.

1.1.2 System Description

Today, SPU's regional water system is the largest in Washington State. SPU serves 743,800 people in its retail service area and provides water to 19 wholesale customers, plus Cascade Water Alliance, who together deliver SPU water to an additional residential population of approximately 700,000. The water from the Cedar and South Fork Tolt Rivers is treated by ozonation/ultraviolet light and ozonation/filtration, respectively. The Seattle Well Fields are available during peak water use seasons and during emergencies.

SPU's water is delivered to Seattle retail service connections and to SPU wholesale customers through a network of approximately 1,820 miles of transmission and distribution system pipelines. SPU also provides untreated water from the Cedar River Watershed to the City of North Bend to mitigate streamflow impacts of their water supplies.

SPU is not a Satellite System Management Agency, and will not operate nor be responsible for Group A water systems owned by other parties, even if these are within the City of Seattle.

Figure 1-1 shows the major components of the Seattle Regional Water Supply System and the areas currently served by SPU and its wholesale customers.

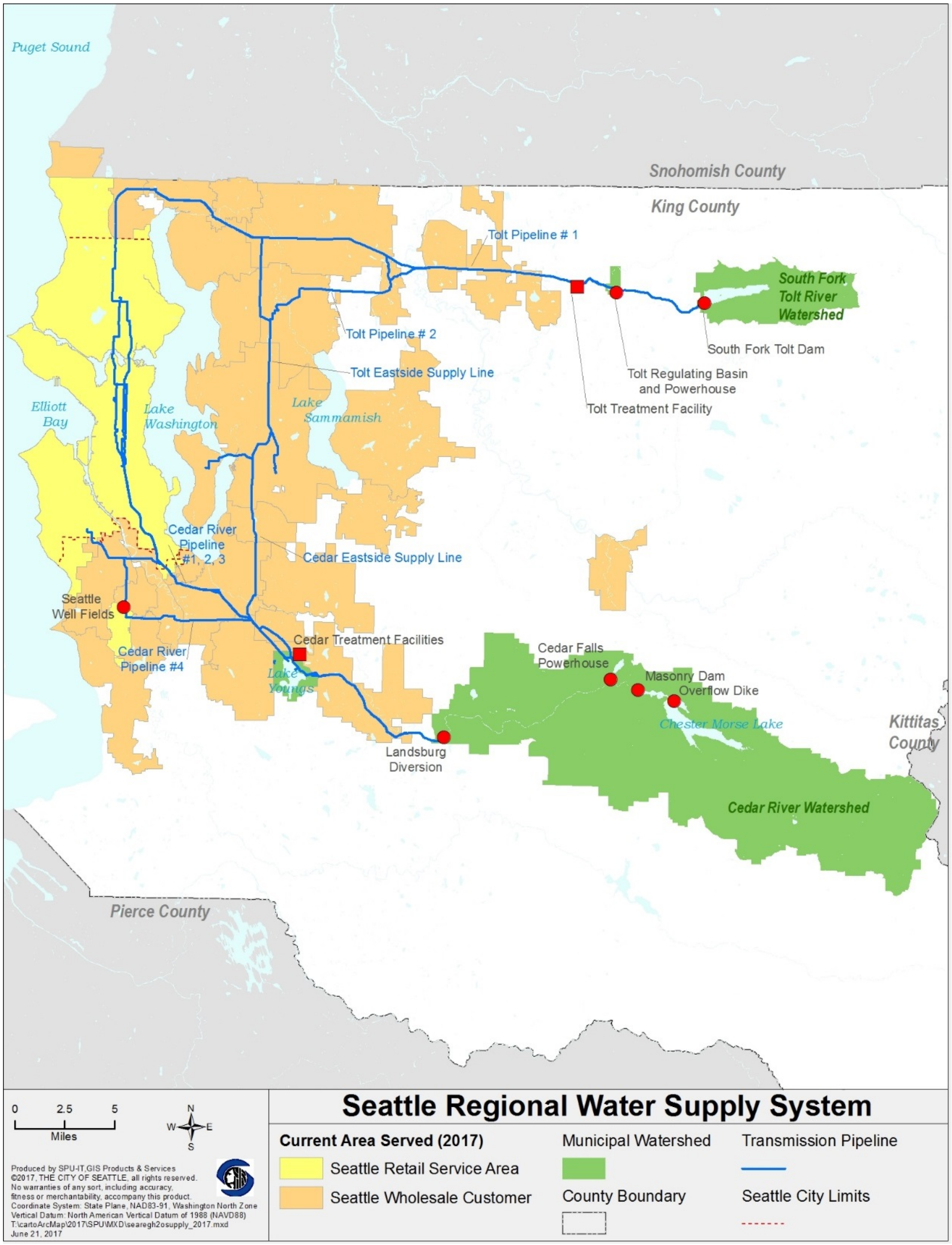


Figure 1-1. Seattle Regional Water Supply System

1.1.3 Business Areas

SPU's water line of business is divided into four business areas: Major Watersheds, Water Resources, Water Quality & Treatment, and Transmission & Distribution.

SPU's water line of business is divided into four core business areas that are focused on key components or sub-systems of its water system. These consist of Major Watersheds, Water Resources, Water Quality and Treatment, and Transmission and Distribution. In addition to the core business areas, there are business areas that are common to and shared by the lines of businesses other than water within SPU. Examples include areas such as Information Technology, Fleets, and Facilities. By organizing the line of business in this manner, SPU is better able to articulate the performance objectives of each sub-system and create accountability in meeting those objectives. The core business areas are described more fully below.

1.1.3.1 Major Watersheds Business Area

The Major Watersheds business area covers management of the South Fork Tolt and Cedar River Municipal Watersheds and Lake Youngs Reservation. Activities are conducted to ensure that source water quality and environmental stewardship goals are met. These activities include stewardship and restoration of watershed land, maintenance of and improvements to watershed bridges and roads, inspection and patrol operations to limit access into the watersheds, operation of the Cedar River Watershed Education Center, limited recreation areas management, and other activities related to protection of source drinking water and natural resources in the watersheds. Watershed operations adhere to protocols established in the most recent *Watershed Protection Plan*, and the *Cultural Resources Management Plan* provides guidelines for protecting cultural resources. In addition, the Major Watersheds business area oversees implementation of watershed land management plans, including the Cedar River Watershed Habitat Conservation Plan (HCP), the Tolt Watershed Management Plan, the Bonneville Power Administration (BPA) settlement agreement, and the Muckleshoot Indian Tribe Settlement Agreement. The business area also provides coordination with salmon recovery plans.

1.1.3.2 Water Resources Business Area

The Water Resources business area consists of the programs and projects whose purpose is to plan for and ensure sufficient water is available to meet anticipated demands. One critical function of this business area is real-time management and operation of mountain reservoir and river facilities for water supply, instream resource protection, and flood management, as well as hydropower generation. The programs of the Water Resources business area include instream resource management, sockeye hatchery operations, water conservation, dam safety, and water rights. The Water Resources business area also performs water supply and demand forecasting, conservation program planning, reclaimed water/water reuse analysis, development of new sources of supply when needed, climate change vulnerability assessments, and infrastructure planning for water supplies.

1.1.3.3 Water Quality and Treatment Business Area

The Water Quality and Treatment business area covers SPU's drinking water quality and treatment programs, projects, services, and capital assets from the source to customer taps. Key functions of this business area include managing SPU's drinking water regulatory compliance, operation of SPU's water quality laboratory, oversight of the Tolt and Cedar Water Treatment Facilities and their contract operations, implementation of SPU's cross-connection control program, responding to water quality complaints, and overseeing water quality capital projects.

1.1.3.4 Transmission and Distribution Business Area

The Transmission and Distribution business area is comprised of programs and projects affecting the regional and sub-regional transmission systems, which serve both SPU and its wholesale customers, and the distribution system, which serves only SPU's own retail customers. Business area activities include planning and oversight for transmission and distribution pipelines and appurtenances, and operation and maintenance (O&M) of the transmission and distribution pipelines, storage facilities, pump stations, wholesale customer taps, and appurtenances. The Transmission and Distribution business area provides oversight and coordination with related programs, such as seismic analysis and cathodic protection. Billing meter and transportation-related projects that impact both the water transmission and distribution systems are overseen by this business area.

1.2 GUIDING POLICIES

Revised and updated guiding polices for SPU's water business areas were developed and adopted for the *2007 Water System Plan*, and are being carried forward into this plan. These policies are summarized in the table below; see policies for additional details.

Table 1-1. Policies to Guide SPU's Water System Activities

Policy Title (Number)	Policy Statement
Asset Management (WTR-110)	Use Asset Management principles to guide all capital and O&M financial decisions to deliver services effectively and efficiently.
Environmental Stewardship (WTR-120)	Protect and enhance the environment affected by the utility as it carries out its responsibilities to provide drinking water.
Security and Emergency Preparedness (WTR-130)	Institute and maintain appropriate safeguards to protect against security risks and sustain emergency response readiness to ensure the continuity of drinking water services, including fire protection service.
Meeting Customer Expectations (WTR-140)	Provide retail and wholesale drinking water service that responds to changing customer expectations centered on providing reliable, high-quality water, and guided by asset management principles.
Water Service Area (WTR-220)	Continue providing service within the service area boundary as defined in the most recent *Water System Plan*, allowing for new wholesale customers within that area at SPU's discretion.
Regional Role and Partnerships for Water (WTR-230)	Be a leader in seeking regional cooperation and efficiencies that benefit the customers of SPU, other water utilities, and the environment.
Planning for Uncertainty in Water Supply and Demand (WTR-240)	Base supply investment strategies on future outlooks for supply and demand that incorporate an evaluation of uncertainties using the best available analytical tools.
Water Supply Reliability (WTR-250)	Plan to meet full water demands of "people and fish" under all but the most extreme or unusual conditions, when demands can only be partially met.
Water Resource Selection (WTR-260)	In planning to meet future customer demand, select new sources of supply from all viable options, including conservation programs, improvements to system efficiencies, use of reclaimed water, and conventional supply sources, based on triple-bottom-line analysis.
High-Quality Drinking Water Provision (WTR-500)	Manage drinking water quality from the water source to the customer taps in coordination with wholesale customers to protect public health, comply with drinking water quality regulations, and maintain and improve public confidence in the drinking water quality.
Watershed Protection (WTR-610)	Control human activity and be prepared to respond to emergencies in the municipal watersheds to maximize protection of drinking water source quality.
Transmission System Redundancy (WTR-310)	Consider redundancy in the transmission system on a case-by-case basis, with decisions based on an evaluation of net present value.
Access to Seattle Regional Water System (WTR-320)	Evaluate requests for access to the Seattle regional water system using the *Access to Seattle Water System Guidelines*, based on the unique characteristics of the water that would be moved through the system.
Distribution System Redundancy (WTR-410)	Consider redundancy for the distribution system on a case-by-case basis, with decisions based on an evaluation of net present value.

1.3 Customer Service Levels

SPU first documented its service levels objectives and targets in its *2007 Water System Plan*. Since then, SPU has tracked its performance relative to those targets. These efforts are part of SPU's asset management initiative as outlined in the *2007 Water System Plan*.

Service levels are statements of desired performance outcomes that are of high priority to customers.

Service levels are statements of desired performance outcomes that are of high priority to SPU's customers or required by regulators. Often these service levels go beyond minimum regulatory requirements. Service levels are largely within the control of SPU and have performance level data that can be accurately and consistently collected and audited. SPU utilizes service level objectives – broad statements of intent – to establish the direction of each of its business areas while using service level targets to establish annual or longer term goals which can be measured through performance outcomes. Service levels are used by SPU to manage its assets, including making decisions on renewal/ replacement and O&M practices.

The *2007 Water System Plan* provided levels of service targets to achieve the following objectives:

- Meet the environmental requirements of our water rights and water supply operations.
- Meet water use efficiency goals to ensure wise use and demonstrate good stewardship of limited resource.
- Promote a high level of public health protection and customer satisfaction with drinking water quality.
- Provide agreed-upon service to wholesale customers.
- Provide adequate pressure for drinking water supplies.
- Respond quickly and effectively to water distribution system problems.

For the most part, SPU has been meeting the service level targets since 2006. More information is provided in the chapters that follow.

1.4 Planning Requirements

The SPU regional water system is categorized as a Group A community water system with 1,000 or more services and must prepare a water system plan (WSP) for Washington State Department of Health review and approval per Chapter 246-290-100 of the Washington Administrative Code (WAC). These plans must be updated and submitted at least every 10 years. This section describes the planning requirements, as well as how this plan is consistent with other plans.

Note that this water system plan does not cover the Group A water system at Seattle’s Cedar Falls Headquarters. That system, as well as other water systems serving outlying SPU facilities, has a separate operating permit and different planning requirements.

1.4.1 WSP Requirements

According to the WAC, the purposes of water system plans are to:

- Demonstrate the system's operational, technical, managerial, and financial capability to achieve and maintain compliance with relevant local, state, and federal plans and regulations.
- Demonstrate how the system will address present and future needs in a manner consistent with other relevant plans and local, state, and federal laws, including applicable land use plans.

The contents of a water system plan are governed by WAC 246-290-100(4). A checklist provided as an appendix lists the plan contents required by the WAC and identifies the specific chapters or appendices of this plan where that required information can be found.

The WAC also provides for a “document submittal exception” process that allows a purveyor to proceed with new distribution mains without submitting construction documents to WDOH for review. This process requires a WDOH-approved water system plan that includes standard construction specifications for these types of projects. SPU is requesting such an exception for new distribution mains. Information needed to support this request is provided in the appendices, including SPU’s design and construction guidelines.

WAC 246-290-108 requires that this *Water System Plan* be consistent with local plans and regulations. Consistency review and certification have been obtained from those local governments with jurisdiction over areas where SPU provides retail water service, which includes the cities of Seattle, Shoreline, Lake Forest Park and Burien (see appendix). This consistency review covers:

(a) Land use and zoning within the applicable service area;

(b) Ten-year growth projections used in the demand forecast;

(c) Utility service extension ordinances of a city or town when water service is provided by the water utility of the city or town;

(d) Provisions of water service for new service connections; and

(e) Other relevant elements related to water supply planning as determined by WDOH.

King County has its own consistency review process.

1.4.2 Consistency with Other Plans

SPU is committed to working together with other water providers and regional jurisdictions to address water issues.

In planning to meet future demand, it is necessary to coordinate with other planning efforts to ensure consistency. WDOH has determined that plans that may contain elements requiring local government consistency review include Coordinated Water System plans, Regional Wastewater Plans, Reclaimed Water Plans, Groundwater Area Management Plans, and Capital Facilities Elements of Comprehensive Plans. Other plans that SPU coordinates with include the water system plans of SPU's wholesale customers and adjacent water purveyors, watershed plans and salmon recovery plans. Each of these plans and their relevance to SPU's water resources and water system planning is described below.

1.4.2.1 Coordinated Water System Plans

Three of the four coordinated water system plans (CWSPs) in King County are for areas served by the SPU regional water system, including east King County, south King County, and Skyway/Bryn Mawr. (The fourth CWSP is for Vashon.) A small portion of SPU's retail service area lies within the Skyway/Bryn Mawr Critical Water Service Area, and Shorewood Apartments, located on Mercer Island and served by SPU, is within the East King County Critical Water Service Area. SPU worked with the regional water associations responsible for developing those plans to ensure coordination with SPU planning. SPU staff also maintains regular contact with the East King County Regional Water Association on issues related to SPU's water system plan.

1.4.2.2 Wholesale Customers' Individual Water System Plans

As SPU's wholesale customers update their water system plans for their own water supply and distribution systems, SPU staff coordinates with them so that their water system plans maintain consistency with SPU's *Water System Plan*. For most customers, this includes SPU review of their draft plans in the following key areas:

- Assumptions about the quantities and pressures available from SPU transmission lines.
- Demand forecasts to ensure consistency of population forecasts among Seattle and its wholesale customers.
- Responsibilities that the customer shares with SPU, such as distribution system water quality monitoring.
- Conservation programs.

SPU does not comment on water system plan demand forecast and conservation elements for wholesale customers now purchasing water through the Cascade Water Alliance because SPU is not involved with Cascade planning in these areas.

Since the *2013 Water System Plan*, SPU has reviewed or provided input and comments on water system plans from Bellevue, Bothell, Cedar River, Coal Creek, Lake Forest Park, Mercer Island, Northshore, Redmond, Renton, Skyway, Olympic View, Soos Creek, Tukwila, and Water Districts 49, 90, and 125.

1.4.2.3 King County Comprehensive Plan

Most of SPU's service area is within incorporated areas of King County. A very small part of its retail service area is in unincorporated King County. These areas are located south of the City of Seattle boundary and form portions of the North Highline and West Hill Potential Annexation Areas. In total, fewer than 4,800 customers are located in unincorporated King County. Additionally, SPU's surface water supplies originate in unincorporated King County.

SPU's *2019 Water System Plan* aims to be consistent with applicable policies in the *King County Comprehensive Plan* and *King County Countywide Planning Policies*, both of which were updated in 2016.

1.4.2.4 City of Seattle's Commprehensive Plan

A goal of the City of Seattle is to provide safe, reliable, and affordable utility services that are consistent with the City's aims of environmental stewardship, race and social equity, economic opportunity, and the protection of public health.

Seattle's Comprehensive Plan, *Seattle 2035*, relates to this water system plan with regards to providing safe, reliable and affordable utility services within the city. The comprehensive plan is a 20-year vision and roadmap for how the city will grow while preserving and improving neighborhoods. Planned population increases and changes in land uses are important to how SPU conveys water and make capital investments throughout the distribution system. Key goals and policies in the plan related to city-owned utilities cover service delivery, resource management, facility siting and design, and coordination with the right-of-way.

Although amendments are made annually, the last major update to the comprehensive plan was adopted in 2016. Seattle's Comprehensive Plan remains consistent with the regional growth management strategy (*Vision 2040*) and the *King County Countywide Planning Policies*, and this water system plan is consistent with the goals and policies of Seattle's Comprehensive Plan.

1.4.2.5 Adjacent Purveyors

A number of water purveyors within SPU's water service area and adjacent to existing SPU wholesale customers are not themselves current SPU customers. These include Water District 54, Lakehaven Utility District, City of Kent, City of Auburn, Water District 111, Covington Water District, Mirrormont, Northeast Sammamish Water District, Union Hill, Ames Lake, Carnation, Fall City, City of Mountlake Terrace, and several other smaller purveyors. When water system plans for these systems are received, SPU reviews them for compatibility and consistency in areas such as assumptions about water demand forecasts, transmission needs, and water quality issues.

1.4.2.6 Purveyors Beyond the Boundaries of SPU's Service Area

As a regional water supplier, SPU was an active participant in the *2009 Water Supply Outlook* and the *2012 Regional Water Supply Update*, produced by the Water Supply Forum for the three-county region of Snohomish, King, and Pierce Counties. SPU continues to be an active member on the Forum, which helps ensure coordinated water supply planning throughout the region and between the three major utilities in central Puget Sound: Everett, Tacoma, and Seattle. SPU is currently participating in the resiliency studies being conducted by the Forum.

1.4.2.7 Regional Wastewater and Reclaimed Water Plans

In 2017, King County initiated a new strategic planning effort for four renewable resource programs, including recycled water. The Biosolids, Recycled Water, Energy and Technology Strategic Plan (BRET) is expected to identify goals and strategies, alternatives, and action planning for recycled water. SPU will be involved in that planning effort to the extent that King County involves the MWPAAC advisory committee, on which SPU participates. In addition, SPU will coordinate with King County on opportunities to develop projects with reclaimed water from regional treatment plants. Any distribution of reclaimed water by King County or any other provider within the service area will also need to be closely coordinated to ensure water quality, efficient system operation, and financial sustainability and affordability for all water customers in the service area.

King County has indicated that completion of their Reclaimed Water Checklist suffices to meet consistency with these plans. This checklist is included in the appendices.

1.4.2.8 Groundwater Area Management Plans

The Seattle Well Fields and a portion of SPU's retail service area lie within the South King County Groundwater Management Area. However, there are no approved groundwater area management plans applicable to SPU.

1.4.2.9 Watershed Plans

SPU is dedicated to being a leader in protection of the environment.

Watershed plans in the SPU retail service area are the Lake Washington/Cedar/Sammamish Watershed (WRIA 8) Chinook Salmon Conservation Plan (2005) and 10-Year Update (2017), and the Green/Duwamish and Central Puget Sound Watershed (WRIA 9) Salmon Habitat Plan (2005). These plans were adopted as part of the Puget Sound Salmon Recovery Plan and approved by the federal government in 2007. This watershed planning occurred within the framework of RCW 77.85, Salmon Recovery. This is not one of the types of plans for which a water system plan must meet WDOH consistency requirements.

The 50-year Cedar River Watershed HCP that SPU developed was agreed to by federal and state resource agencies in 2000 and is now being implemented. SPU continues to be in compliance with the HCP.

1.4.2.10 Salmon Recovery Plans

Seattle participates in salmon recovery processes conducted under the framework of RCW 77.85 in the Water Resource Inventory Areas (WRIA) associated with its water supply and service area: WRIAs 7 (Snohomish River Basin), 8 (Cedar River/Lake Washington Basin), and 9 (Green River/Duwamish Basin). The WRIA 7, 8, and 9 salmon recovery plans recognize that salmon recovery is a long-term effort and include a scientific framework, lists of priority actions, comprehensive action lists, adaptive management approaches, and funding strategies. The City of Seattle has supported salmon recovery through primary sponsorship and implementation of significant habitat restoration and protection projects, and has also addressed salmon habitat protection through its land use and public outreach policies and programs.

As part of WRIA 7, 8, and 9 salmon recovery efforts, Seattle has been a leader in implementing a number of actions. Examples of these efforts include:

- Lower Cedar River habitat acquisition and restoration projects.
- Shoreline and wetland restoration projects along the south shoreline of Lake Washington and in Elliott Bay.
- Development and distribution of a Green Shorelines Guidebook for Lake Washington property owners.
- Receipt of an EPA grant in 2010 to develop Green Shorelines Incentives.
- Receipt of several grants from 2010 to 2016, partnering with Forterra (formerly Cascade Land Conservancy) and King County Noxious Weed Control Program to eradicate knotweed and other invasive plants, and replant native plants on public and private property in lower Cedar River; and conduct community outreach and education on river and stream restoration.
- Purchase and restoration of the Salmon Bay Natural Area downstream of the Locks for habitat benefits.
- Participation in many research efforts with the goal of ensuring effectiveness of restoration projects in Lake Washington, Elliot Bay and on the Duwamish River.
- Acquisition of habitat lands on the Tolt River by Seattle City Light.

- Implementation and primary fiscal sponsorship of the Tolt River Floodplain Reconnection Project, in partnership with King County and multiple grant funders.
- Funding over several years to Tulalip Tribes for juvenile salmon research on the Snoqualmie River.
- Protective land management practices in the Seattle-owned, Cedar River Municipal Watershed to preserve water quality and the natural ecological processes that promote healthy river conditions throughout the Cedar River Basin.
- Fish passage facilities at the Landsburg Dam that reopen over 20 miles of stream habitat for salmon in the protected Cedar River Municipal Watershed.
- Protective stream flow management practices that provide beneficial stream flows for all salmon and steelhead life stages in the Cedar and South Fork Tolt rivers.
- Implementation of the Cedar River Sockeye Salmon Hatchery Program and associated Adaptive Management Plan guided by oversight bodies composed of representatives from federal, state, tribal and local natural resource agencies, academic experts and citizen stakeholders.
- Contributing partner through the Saving Water Partnership to the annual Salmon SEEson salmon-viewing opportunities for the public late summer-fall throughout WRIAs 8 and 9.

The Cedar River Watershed HCP covers many of the costs for the projects recommended in the WRIA 8 plan for the Upper and Lower Cedar River. Staff has successfully leveraged other funding so more can be accomplished. The HCP also provided funding for improving fish passage at the Hiram Chittendon Locks.

1.5 Plan Organization

SPU has organized its water utility into the four business areas described previously, and this plan generally follows that organizational structure. The exception are that Transmission and Distribution each have their own chapter, and the Major Watersheds business area does not have its own chapter. SPU's watershed programs and plans to protect drinking water quality are covered in Chapter 3, Water Quality and Treatment, and consistency with watershed and salmon recovery plans are described earlier in this chapter. Each of the next four chapters cover a business area and are divided into the following sections:

- A section summarizing SPU's accomplishments since completion of the *2013 Water System Plan*.
- A service level section that describes SPU's performance in meeting the service levels for that business area.
- A description of the facilities that the business area manages, and the practices it follows in operating and maintaining those facilities. This section focuses on changes since the *2013 Water System Plan*.
- A summary of needs, gaps, and issues that face that business area in the next 20 years and beyond, but with a focus on the 2019-2028 planning period.
- A summary of the plans and actions the business area will be undertaking or continuing as it moves forward to address the needs, gaps, and issues in the next 20 years and beyond.

The last two chapters describe the plan for implementing the actions, including details on the costs and financing approach for plan implementation.

Appendices to this plan are contained in a separate volume as listed in the Table of Contents and should be considered part of this *2019 Water System Plan.*

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CHAPTER 2

WATER RESOURCES

SPU's Water Resources business area focuses on the programs and projects that ensure SPU's customers and instream resources will have sufficient water to meet their needs, both in the present and for the foreseeable future. One important function of the business area is the real-time management and operation of mountain reservoir and river facilities for municipal use while meeting instream flow requirements, supporting hydropower generation, and managing floods. Water resource concerns also include forecasting future water demands, planning for the water conservation program, and evaluating current supply capacity and the need for future additional supply sources and new water rights. The business area also addresses issues related to dam safety and infrastructure maintenance and improvements.

Chapter 2 describes how SPU is prepared to meet water demands in the foreseeable future even with the uncertainties surrounding the potential impacts of a changing climate and population growth.

2.1 ACCOMPLISHMENTS SINCE 2013 WSP

Since completion of the *2013 Water System Plan*, SPU has accomplished the following activities in the water resources business area:

- Water Conservation: Met the Water Use Efficiency Goal to reduce per capita water use so that total average annual retail water use of members of the Saving Water Partnership is less than 105 million gallons per day (mgd) from 2013 through 2018 despite forecasted population growth.
- Morse Lake Pump Plant: Completed the construction of the Morse Lake Pump Plant and refurbished one of the temporary pump plants for use as a backup.
- Trust Water Right Donation: Donated 22,403 acre-feet per year of the Cedar River Water Right Claim into the State Trust Water Right Program to benefit instream flows in the Cedar River below Landsburg Diversion, per the 2006 Muckleshoot Indian Tribe Settlement Agreement.
- South Fork Tolt Ring Gate: Refurbished the Ring Gate and associated components, including replacement of the hydraulic

fluid suitable for use over the SPU's drinking water; recoating of the Ring Gate, structural supports, and metallic parts; repair of leaking lifting and gripping systems hydraulic system components; and replacement of the electrical control system.

2.2 Service Level Performance

In managing its water resources, SPU has established service levels that are consistent with its regulatory requirements and environmental commitments. In particular, SPU's water resources service levels give emphasis to instream flows and water conservation. By meeting these service levels, SPU has high confidence in having adequate water supply to meet all customer demands. Table 2-1 summarizes these service levels.

Table 2-1. SPU's Service Levels for Managing Water Resources

Service Level Objective	Service Level Target
Meet the environmental requirements of our water rights and water supply operations.	Meet instream flow requirements and performance commitments in tribal, regional, state, and federal agreements and permits.
Meet water use efficiency goals to ensure wise use and demonstrate good stewardship of limited resource.	Reduce per capita water use from current levels so that total average annual retail water use of members of the Saving Water Partnership is less than 105 mgd from 2013 through 2018 despite forecasted population growth.

SPU has been in compliance with all minimum flow specifications and supplemental flow targets for its Cedar and South Fork Tolt River water supplies, with the exception of some downramping events on the Cedar River, in which water levels fell more quickly than prescribed by the Cedar River Watershed Habitat Conservation Plan (HCP). All events have been reported to the Instream Flow Commission and corrective action described and taken. To date, SPU has also met other performance commitments of the Cedar River Watershed HCP and Muckleshoot Indian Tribe (MIT) Settlement Agreement that do not involve instream flows, including limits on diversions from the Cedar River.

In addition, SPU has achieved its water conservation goals through 2016. Additional information on these achievements is provided in Section 2.3.3. The service level targets for water use efficiency will be updated with the Water Use Efficiency Goal described in Section 2.4.1.1 of this plan.

2.3 Existing System and Practices

The total population currently served by SPU and its wholesale customers in King and south Snohomish County is about 1.4 million.

The total population currently served by SPU and its wholesale customers in King and south Snohomish County is about 1.4 million. To provide water to the residents and businesses in its service area, SPU operates and maintains supply facilities associated with its surface water sources and well fields. This section provides an overview of the area to which SPU provides water service. SPU's water demands, including changes over time, and recent water conservation programs are then summarized. The section also summarizes the City's water rights and the quantity of water that can be reliably provided to the service area, or the firm yield of its supply sources. The section concludes with a description of operational changes and maintenance needs for the water supply system.

2.3.1 Service Area Characteristics

SPU's retail service area encompasses 98 square miles that includes the City of Seattle and portions of the cities of Shoreline, Lake Forest Park and Burien, as well as portions of unincorporated King County south of the City of Seattle. SPU also provides retail water service to Shorewood Apartments on Mercer Island and SeaTac Airport. The *2013 Water System Plan* noted a proposed transfer of the area known as the Greenbridge Notch (Wind Rose) from SPU's retail service area to Water District 45, but that area remains in SPU's retail service area.

Besides serving retail customers, SPU provides wholesale water to area cities and water districts, who in turn deliver water to their customers' taps. Figure 2-1 shows these different customer types and service area boundaries, which, in general, includes the City of Seattle, the suburban areas immediately to the north and south, and similar areas extending east of Lake Washington to slightly beyond North Bend.

2.3.1.1 Changes in Demographics

Growth in population, households and employment waxes and wanes with the business cycle. The dot-com bust in the early 2000s was followed by a modest recovery, and housing bubble, that ended in the financial crash of 2008 and Great Recession. More recently, the national economy has been gradually recovering while the local economy – especially Seattle – has boomed. This can be seen in the graphs in Figure 2-2, below, of annual growth rates for households and employment. King County

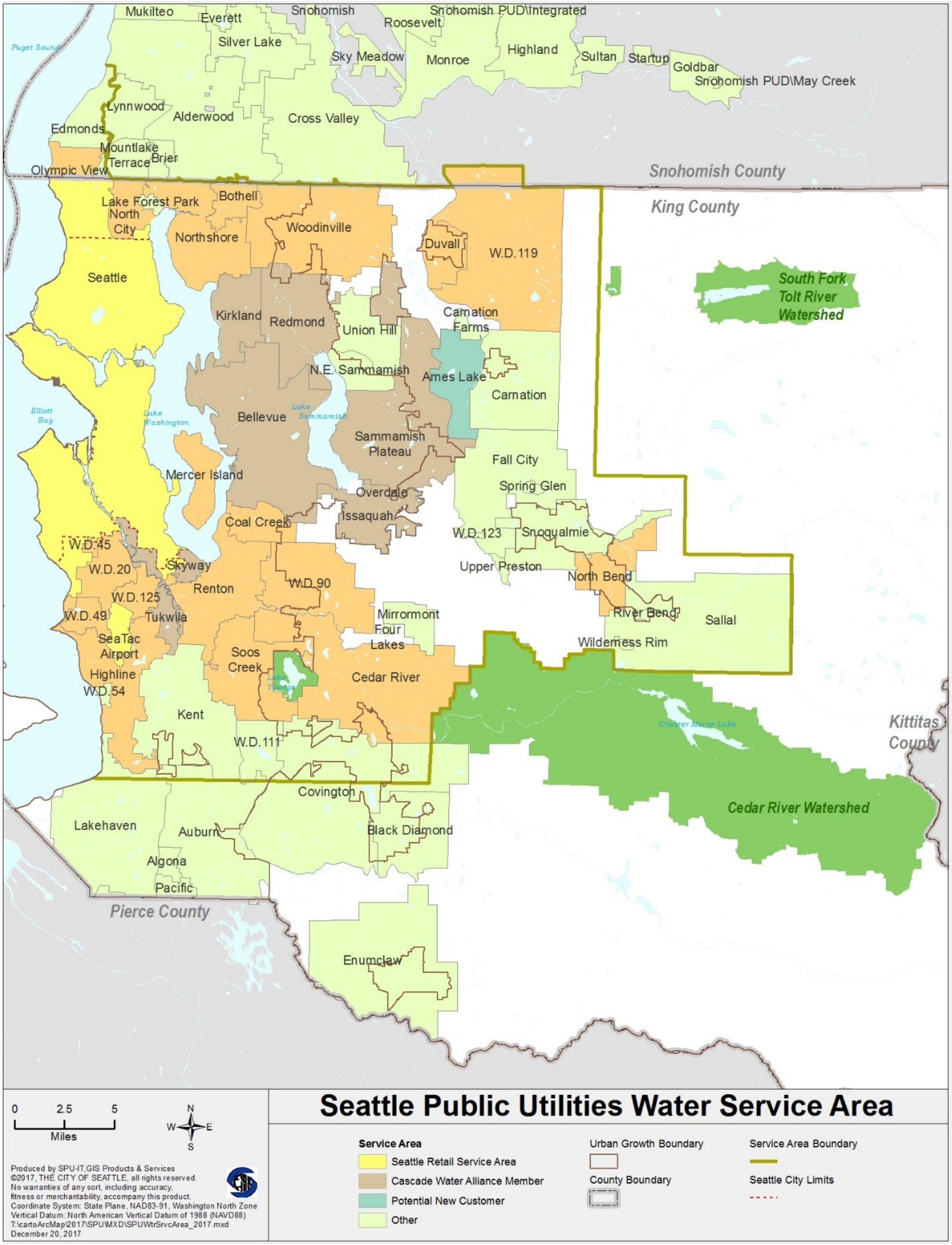


Figure 2-1. SPU's Water Service Area

employment declined in the early 2000s, recovered a bit, fell in 2009, and has been growing since 2011. There is a parallel pattern in population and households, but their growth rates are less volatile.

Growth in the areas surrounding Seattle (wholesale service area) have historically exceeded growth in the city itself (retail service area). That pattern reversed itself in 2013 and since then, Seattle has been growing rapidly, both in absolute terms and relative to the rest of the county. The graphs in Figure 2-2 and Table 2-2, below, show the changes in population, households and employment in King County and the Seattle retail service area.

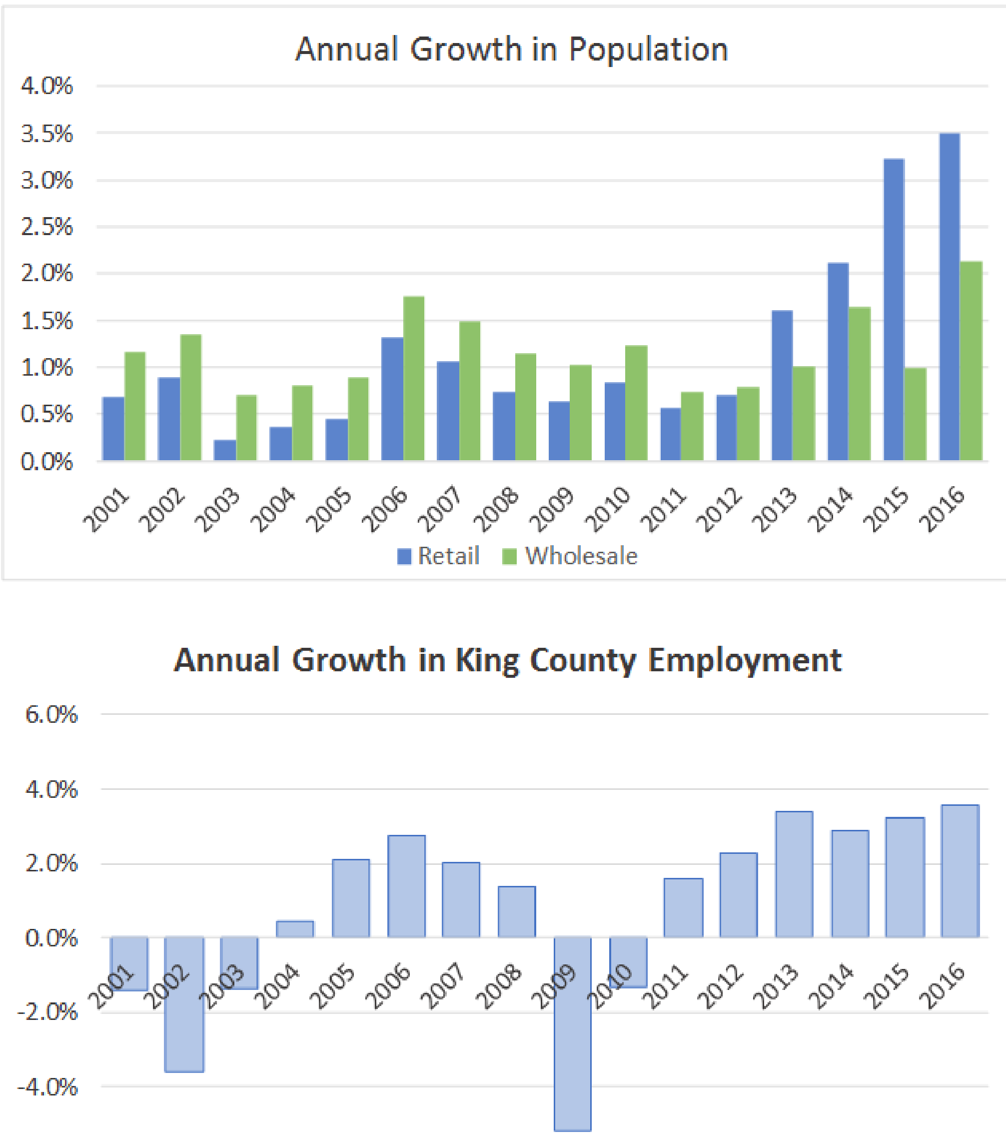


Figure 2-2. Annual Growth in Population and Employment

Table 2-2. Demographic Changes

	Population[1]		Households[1]		Employment[2]	
	King County	Seattle Retail	King County	Seattle Retail	King County	Seattle Retail
2000	1,737,379	617,104	711,046	280,191	1,151,214	569,311
2010	1,931,249	662,635	789,232	304,815	1,181,537	509,171
2016	2,105,100	743,796	859,504	324,844	1,375,054	592,115
Change						
2000-2010	193,869	45,530	78,185	24,623	30,322	-60,141
2010-2016	173,850	81,160	70,271	20,028	193,516	82,943
2000-2016	367,721	126,692	148,458	44,653	223,840	22,804
% Change						
2000-2010	11.2%	7.4%	11.0%	8.8%	2.6%	-10.6%
2010-2016	9.0%	12.2%	8.9%	6.6%	16.4%	16.3%
2000-2016	21.2%	20.5%	20.9%	15.9%	19.4%	4.0%
Annual %						
2000-2010	1.1%	0.7%	1.0%	0.8%	0.3%	-1.1%
2010-2016	1.4%	1.9%	1.4%	1.1%	2.6%	2.5%
2000-2016	1.2%	1.2%	1.2%	0.9%	1.1%	0.2%

1 U.S. Census: 2000 and 2010, estimate 2016
2 Puget Sound Regional Council covered employment estimates

2.3.1.2 Retail Customers

SPU delivers water directly to a population in its retail service area of more than 743,800, approximately 81,000 more people than in 2010. This increase has resulted from increased population density from development of vacant property and redevelopment of property to higher densities.

2.3.1.3 Wholesale Customers

SPU's wholesale customers, excluding North Bend, provide SPU water to a resident population of about 700,000. Current Seattle wholesale customers, listed in Table 2-3, include 19 municipalities and special purpose districts, plus Cascade Water Alliance.

In addition to the above, the City of Edmonds and Lake Forest Park Water District have emergency intertie contracts with SPU covering all types of emergencies. SPU also has an emergency water sales agreement with the City of Renton to provide water to the Seattle Regional Water Supply System from Renton.

Table 2-3. SPU Wholesale Water Customers

Full Requirements Contract Holders	
• Bothell, City of	• Water District No. 20
• Cedar River Water and Sewer District	• Water District No. 45*
• Coal Creek Utility District	• Water District No. 49
• Duvall, City of	• Water District No.119
• Mercer Island, City of	• Water District No.125
• North City Water District	• Woodinville Water District
• Soos Creek Water and Sewer District	
Partial Requirements Contract Holders	
• Highline Water District	• Renton, City of
• Olympic View Water and Sewer District	• Water District No. 90
Block Contract Holders	
• Cascade Water Alliance (Cascade)[1]	• Northshore Utility District
Mitigation Water	
• North Bend, City of[2]	

1 Individual members of the Cascade Water Alliance are the cities of Bellevue, Issaquah, Kirkland, Redmond, Tukwila, Sammamish Plateau Water, and Skyway Water and Sewer Districts.

2 Purchases mitigation water from Boxley Creek that is not treated.

*Effective February 2019, W.D. 45 was assumed by W.D. 20 and no longer exists; this change is not reflected in this WSP.

Since the last of the 1982 contract holders signed new contracts in 2011, SPU now provides regular municipal water service to its wholesale customers under three contract types:

- Full Requirements Contracts. Thirteen of SPU's wholesale customers, as shown in Table 2-3, now receive all of their water supply under full-requirements contracts. These contracts extend to 2062, establish wholesale water rates, and include a provision for an operating board to address issues related to the Seattle water supply system.

- Partial Requirements Contracts. As shown in Table 2-3, four of SPU's wholesale customers purchase water from SPU under a partial requirements contract. These utilities have their own sources of supply with which they meet a portion of their demand and depend on Seattle for the rest. Contract provisions pertaining to expiration dates, wholesale rates, Operating Board membership, etc., are identical to the full requirements contracts.

- Block Contracts. In 2003, SPU signed long-term contracts for specified amounts of water ("block contracts") with the Cascade Water Alliance (Cascade), whose members are listed above in a footnote to Table 2-3, and Northshore Utility District (Northshore).

- SPU's contract with Cascade is a declining block contract, which was last amended in July 2013. Under this contract, SPU will provide an average annual fixed block of 33.3 mgd to Cascade through 2039. The block will then be reduced by 2 mgd per year for the three years beginning in 2040, and 1 mgd per year thereafter until it reaches 5.3 mgd in 2064. Cascade chose to not participate on the Operating Board and the regional conservation program.

- Northshore's block contract is for 8.55 mgd on an average annual basis for the duration of the contract, which is expected to meet all the district's water supply needs into the future. Northshore provides water directly to its retail customers and participates on the Operating Board and in the regional conservation program.

2.3.2 Historical Water Consumption

Are people using less water?

Yes! Today, people in SPU's regional water supply system use 28% less water than they did in 1990 while the population grew by the same percentage.

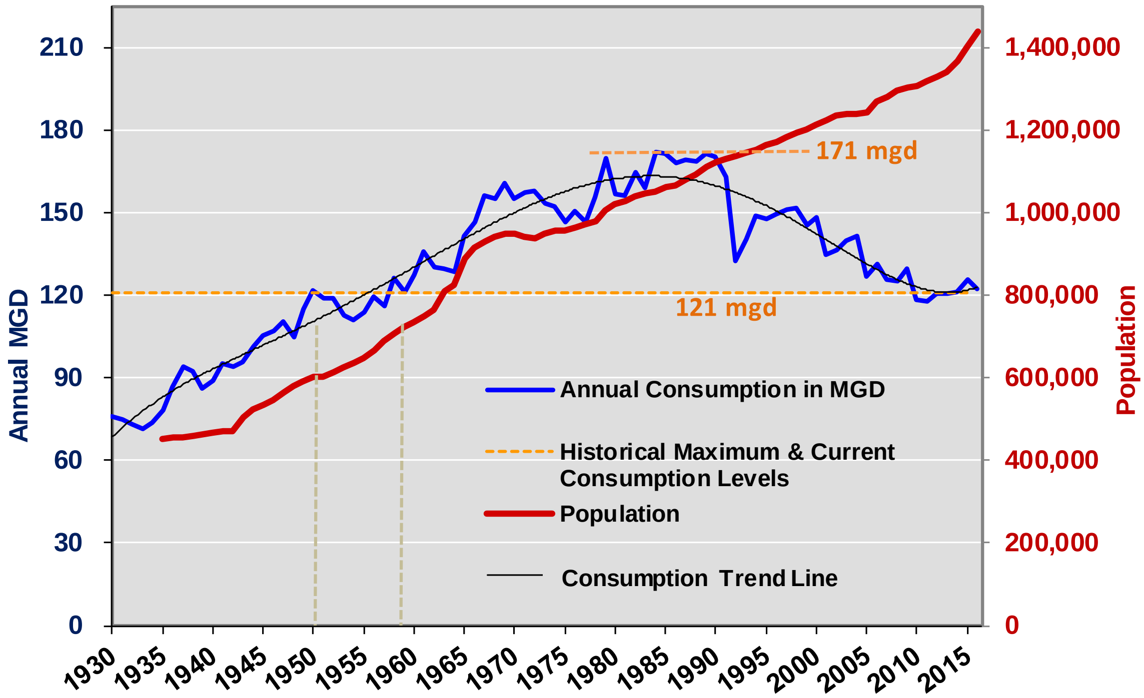
For most of Seattle's history, water consumption increased along with its population. However, that link was broken around the late 1980s when consumption reached its highest level. Since then, water consumption has steadily declined despite continued population growth. Currently, consumption is lower than it has been since the 1950's when the population serviced was only half what it is now.

Figure 2-3 displays Seattle system water consumption and service population since 1930. While population has steadily risen, water demand leveled off during the 1980's before dropping off sharply in 1992 due to a drought and mandatory curtailment measures. Since then, the combined effects of higher water and sewer rates[1], new federal and state plumbing codes, utility conservation programs, and improved system operations have kept water consumption significantly below pre-1992 drought levels. Between 1990 and 2016, consumption decreased by 28 percent while population increased by the same percentage. Total water consumption *per person* is now 44% less than it was in 1990.

After more than 20 years of steady decline, water consumption has leveled off in the past five years at about 121 mgd (weather-adjusted). This suggests that the current rate at which water use efficiency is improving (due to efficiency codes, conservation

[1] Seattle's sewer rates are based, in part, on water use, so that using less water may result in a lower sewer bill, thereby increasing a retail customer's incentive to conserve water.

programs, and other factors) is roughly in balance with the forces putting upward pressure on water consumption (growth in population and the economy).



Note: Population is adjusted to reflect the proportion of resident service area population actually using SPU water (i.e., excludes those that receive water from other sources).

Figure 2-3. Population Growth and Water Consumption from SPU Sources

Peak water demand has fallen even more than annual average demand since the 1980's when hot summer weather could produce peak day consumption of over 330 mgd. In the last 10 years however, peak day consumption has averaged around 200 mgd even on the hottest days. Peak month and peak week consumption have also been trending downwards over the past twenty years, but not as steeply as peak day consumption.

2.3.3 Water Conservation Programs

SPU has had a long-standing commitment to water conservation. SPU began its water conservation program in 1981, with a regional program for SPU and its wholesale water customers focusing on education for the residential sector. Over the years, the program has been expanded to add elements for all customer sectors and to go well beyond education.

The program has been modified in focus areas and intensity over time to reflect the changing drivers for conservation. In the early years, conservation programs helped educate customers about efficient water use and successfully built an ethic of stewardship. Later, conservation programs helped to decrease water use when the need for a new source of supply was forecast.

SPU's water conservation program includes both a regional program and a City of Seattle specific program, as described further below. Collectively, the programs offer a comprehensive set of services that help residents and businesses use water wisely. The services include education, technical assistance, and financial incentives.

SPU's conservation program fulfills a variety of legal requirements, commitments and stakeholder expectations including the following:

- Washington State Water Use Efficiency Rule
- 2000 SPU Cedar River Habitat Conservation Plan
- 2006 SPU Muckleshoot Indian Tribe Settlement Agreement

There are several key underlying principles for the conservation program, including the following:

- No Sacrifice: Conservation is a long-term effort to maximize the efficient use of water; it should not result in a loss of service or sacrifice by customers.
- Customer Choice: Conservation is a voluntary choice by customers.
- 3-Prongs: Conservation should include education, technical assistance, and financial incentives.
- Comprehensive: Conservation should provide opportunities for all customer classes, include both hardware and behavior measures, and include both indoor and outdoor measures.
- Regional: The program should provide opportunities across all service areas.
- Cost Share: Financial incentives should include a cost share with customers.
- Beyond-Code: Financial incentives should focus on water use rates that go beyond the plumbing code.
- Partners: Partnerships should be leveraged to reduce costs when possible.
- Equity: Opportunities to reach under-served populations should be sought out.

The conservation program has been leveraged for drought curtailment several times over the decades. While there is a significant difference between long-term conservation and short-term curtailment, having an established conservation program has been a key component of the response strategy during droughts when customer water curtailment was necessary.

2.3.3.1 Regional Conservation 2013-2018

SPU implements a regional water conservation program on behalf of itself and 18 of its wholesale customers[1]. The program is branded as the Saving Water Partnership.

Management of the Saving Water Partnership program is performed jointly by SPU and the wholesale customers. The strategic direction of the program, including the goal, broad focus areas, and budget levels, is decided by the Seattle Water Supply System Operating Board. Program design and implementation is provided by the Conservation Technical Forum, which includes staff-level employees from SPU and the wholesale customers. SPU staff provide a base-level implementation of the programs across the Saving Water Partnership service area, as well as an additional effort within SPU's service area. Similarly, wholesale customer staff are responsible for specific outreach and implementation within their service areas.

Additionally for SPU's retail service area, the customer-based Water System Advisory Committee provides additional customer input and feedback on conservation goals and programs.

Selection of measures for the conservation program is based on numerous considerations including the following:

- Understanding of national fixture and appliance codes and standards,
- Reviews of regional conservation potential analysis,
- Participant and program evaluations and research to assess program effectiveness, and

[1]Since January 2012, Saving Water Partnership members have included SPU, Northshore Utility District, Cedar River Water and Sewer District, City of Bothell, City of Duvall, City of Mercer Island, City of Renton, Coal Creek Utility District, Highline W.D., Olympic View Water and Sewer District, North City W.D., Soos Creek Water and Sewer District, W.D. 20, W.D. 45, W.D. 49, W.D. 90, W.D. 119, W.D. 125, and Woodinville W.D.

- Opportunities for partnerships to leverage water utility funds.

An avoided cost of supply is not a formal consideration because the demand forecast has shown that a new source of supply is not needed until sometime after 2060.

The measures included in the 2013-2018 regional Saving Water Partnership program are shown in Table 2-4.

Table 2-4. 2013-2018 Saving Water Partnership Conservation Program Measures

Education and Technical Assistance
• Classroom presentations for K-12 grade students • Outreach at community festivals and events • Water efficient gardening classes for residents • Garden hotline to answer questions about water-efficient gardening and other topics • Landscape professional training • Gardening brochures and fact sheets • Technical assistance to residential and commercial customers on irrigation efficiency • Technical assistance to commercial customers on indoor efficiency • Website full of information, tips, rebate information, etc (www.savingwater.org) • How-to-videos on conservation topics • Conservation hotline (206-684-SAVE)
Financial Incentives
• Toilet rebates for single family, multifamily, and commercial customers • Irrigation system rebates for single family, multifamily, and commercial customers • Urinal rebates for commercial customers • Commercial dishwasher rebates • Commercial ice machine rebates • Commercial food steamer rebates • Coin-operated clothes washer rebates • Cooling tower improvement rebates • Rebates up to 50% of installed cost for all other commercial water-related equipment

2.3.3.2 Seattle-Only Conservation 2013-2018

SPU has implemented a low-income water conservation program in the City of Seattle since 2001. The program originated with City Council Ordinance 120532 (also referred to as the Initiative 63 Settlement Ordinance), which established the "Everyone Can Conserve" program. The program committed the City to pursue conservation beyond the regional program in SPU's retail service area focusing on low-income housing through 2010. The program was successful and has continued post-2010 as part of the City's sustained efforts to help low-income customers manage their water and sewer bills.

The low-income water conservation program features free fixtures and installation for qualified single family and multi-family customers. The primary target fixtures are toilets and common-area clothes washers, although showerheads and faucet aerators are also included.

From program inception though the end of 2016, the Seattle low income water conservation program has served over 6,000 single family households and nearly 20,000 multifamily households. The cost of the program has averaged approximately $650,000 dollars annually between 2013-2016.

2.3.3.3 Water Use Efficiency Goal and Program 2013-2018

SPU worked with the Operating Board to set a six-year regional Water Use Efficiency goal for 2013 to 2018. The drivers for the 2013-2018 regional goal were to:

- Ensure core capacity is available to deliver conservation programs that prepare the utility to be resilient for curtailment events and future supply challenges from climate change, as well as help customers use water wisely
- Preserve customers' ethic of conservation as one element of stewarding our water resources and the environment
- Meet regulatory and contractual requirements.

The official 2013-2018 regional Water Use Efficiency goal was:

> "Reduce per capita water use so that the total average annual retail water use of members of the Saving Water Partnership was less than 105 mgd from 2013 through 2018, despite forecasted population growth."

The regional goal was formally adopted by SPU when the City Council adopted SPU's *2013 Water System Plan*. The governing body of each of the other 18 members of the Saving Water Partnership also adopted the regional goal.

The Saving Water Partnership achieved its goal every year since 2013. The total average annual retail water use of members of the Saving Water Partnership in 2016 was 94.4 mgd. Annual reports for other years can be found at www.savingwater.org. The goal and SPU's performance towards the goal are submitted to WDOH annually and are reported to SPU's retail customers in SPU's annual Drinking Water Quality Report.

Achievement of the regional goal is accomplished by customers who change their behavior and/or install efficient equipment. Customers engage in these efficiency measures for a variety of reasons including concern for the environment, desire to save money, and availability of new fixtures and appliances that meet higher efficiency codes and standards. Attainment of the regional goal includes water savings in the following three categories:

- Conservation Program: Water savings that result from the Saving Water Partnership program, as well as the Seattle-only low income program.
- Codes and Standards: Water savings that occur as customers replace older, less-efficient fixtures with new, more-efficient models that meet or exceed federal or state codes or standards. These savings are also achieved as new buildings are built using efficient code-compliant equipment.
- Independent: Water savings that result from customers who make efficient choices, independent of utility-sponsored programs or codes and standards.

2.3.4 Existing Water Supply

To meet the water demand of its customers, SPU operates and maintains two surface water sources of supply, each of which has associated infrastructure (such as reservoirs, dams, pump stations, and pipelines) and two well fields. This section describes the capacities of each of Seattle's water sources and provides information concerning the City's water rights and firm yield.

2.3.4.1 Supply Sources

Seattle obtains approximately 60 to 70 percent of its raw (untreated) drinking water supply from the Cedar River and most of the remaining 30 to 40 percent from the South Fork Tolt River. Seattle's two well fields are available to provide peak season and emergency supply. Tables showing historic production from these sources is included in the appendices. Additional information about each supply source is included below. The few changes that have occurred since the *2013 Water System Plan* are noted.

Cedar River. The Cedar River Municipal Watershed is located in the Cascade Range within southeast King County and comprises 91,500 acres of forest, streams, wetlands and lakes that provide habitat for a variety of fish and wildlife species. The watershed contains the 1,680-acre Chester Morse Lake, formed behind Masonry Dam. The reservoir stores 13 billion gallons (40,000 acre-feet) between elevations 1563 and 1538 feet. As noted in the

2013 Water System Plan, the normal refill level of 1563 feet was authorized after completion of the Cedar Moraine Improvements. Also, as described in later sections, the Morse Lake Pump Plant was recently installed to more reliably access water stored below elevation 1538 feet.

Water stored in Chester Morse Lake flows downstream to the Landsburg Diversion Dam and fish passage facility, which is located about 14 miles downstream from the Masonry Dam. Here, some of the water is diverted through pipelines to Lake Youngs Reservoir while the remainder supports instream resources in the Cedar River. Lake Youngs Reservoir, with a useable storage capacity of approximately 1.5 billion gallons (4,600 acre-feet), provides additional storage and regulates flows to the Cedar Water Treatment Facility.

Some of the Cedar River source water is lost from Masonry Pool, the portion of the reservoir between the Overflow Dike and Masonry Dam, via seepage into a moraine on the Pool's northern bank. Water seeps out of the Masonry Pool at different volumes depending on the surface water elevation in the reservoir and Masonry Pool. When water is relatively abundant, it fills an underground "reservoir" or aquifer, and a portion returns to the river in about four weeks. This aquifer return flow provides cool water to the Cedar River in the summer which is beneficial for instream resources. About 75 to 80 percent of the water that leaks from Masonry Pool is "stored" in this way and finds its way back to the Cedar River, while the remainder ends up in the Snoqualmie River basin. Some of this seepage is discharged through Hobo Springs. In 2009, piping was installed to divert water from Hobo Springs to Boxley Creek for the city of North Bend to mitigate use of their wells on the Snoqualmie River. The amount of water provided was 0.09 mgd in 2016.

South Fork Tolt River. The South Fork Tolt River Municipal Watershed is located about 13 miles east of Duvall in King County and comprises approximately 12,000 acres, with over 8,300 acres owned by the City and the remainder owned and managed by the U.S. Forest Service. The South Fork Tolt Reservoir, which went online in 1964, provides 18.3 billion gallons (56,160 acre-feet) of storage. Water from this reservoir is conveyed to the Tolt Regulating Basin and the Tolt Water Treatment Facility. To provide beneficial flows and water temperatures for instream resources in the river downstream of the dam, releases are made from different depths using existing intake gates.

Seattle Well Fields. In addition to the major surface water supplies, Seattle operates two small well fields in the City of SeaTac to provide drought capacity and emergency supply, as needed, under a temporary water right permit. The Riverton well field has two wells, and the Boulevard Park well field has one well. In total, the three wells can supply up to 10 mgd for approximately four months. Without the wells, firm yield, described below, would fall by approximately 1 mgd.

2.3.4.2 Water Rights

Seattle holds various water rights for use of water from the Cedar River and South Fork Tolt River, as well as permit applications for the Seattle Well Fields. Also, Seattle has water right applications on file with the Washington State Department of Ecology (Ecology) for potential future sources of supply, as indicated by the Water Rights Evaluation contained in the appendices.

In 2016 and as agreed to in the 2006 Settlement Agreement between the City of Seattle and the Muckleshoot Indian Tribe, SPU donated 22,403 acre-feet per year, the equivalent of 20 mgd over the course of a year, of its Cedar River Water Right Claim into the State Trust Water Right program. The donated quantity is a portion of the Cedar River Water Right Claim above the diversion limits agreed to with the Tribe. The purpose of this 35-year donation is to benefit instream flows in the Cedar River below the Landsburg Diversion Dam.

Also, SPU received a water right permit in 2007 to capture and put to use rainwater that falls on rooftops of structures in the combined and partially separated sewer basins of the City of Seattle. Captured rainwater can be used for non-potable municipal purposes on that property and offset the need for potable water. This permit includes a map for those properties covered. Reporting for the water permit occurs with updates to SPU's water system plans, with the current report provided in the appendices.

An evaluation of specific Seattle water right claims, permits, and applications as called for in WDOH planning guidelines is included as an appendix. Forecasts indicate that Seattle does not need to apply for any new water rights within the next 20 years.

2.3.4.3 Firm Yield and Supply Reliability

Firm yield is the amount of water that SPU is able to supply system-wide at a given delivery pattern while meeting the supply reliability standard, instream flow requirements, treatment and transmission capacity, and other system constraints, including diversion limits for the Cedar River as set forth in the 2006 Agreement with the Muckleshoot Indian Tribe and the Cedar River Trust Water Right. Firm yield is expressed as an average annual delivery rate in million gallons per day (mgd) from all sources operating conjunctively. Calculating firm yield for SPU's existing supply sources is critical to ensuring that SPU can meet existing and future demands reliably. The firm yield can be compared to long-term forecasts of water demand to determine when new sources or additional conservation programs need to be online to maintain the desired level of supply reliability. Firm yield calculations are also useful in determining the quantity of water that can be expected from a potential new source of supply.

Firm yield of SPU's water supply is estimated to be 172 million gallons per day.

SPU uses a computer simulation model to calculate the firm yield from its existing water supply sources and potential new water sources. This model is known as the Conjunctive Use Evaluation (CUE) model. The model is used with 87.5 years of reconstructed historic flow records that takes into account past weather and hydrologic variability to produce a system-wide firm yield estimate. SPU's supply reliability standard is 98 percent. Therefore, SPU's firm yield is the amount of water that is assured for delivery in all but the driest 2 years without lowering reservoirs below normal minimum operating levels. The firm yield calculation was updated in 2016 to include inflow datasets from October 1928 through March 2016 and to represent current operating conditions, namely the use of the current early spring refill target of elevation 1563 feet by March for Chester Morse Lake and the use of a revised monthly demand distribution based upon the actual demand of 2006 through 2014. The firm yield estimate also assumes use of the Seattle Well Fields. The result was that the combined firm yield of all SPU supplies is currently estimated to be 172 mgd.

2.3.5 Operations

The surface water supply facilities on the South Fork Tolt and Cedar Rivers are operated primarily for water supply and protection of instream resources, but are also used for hydroelectric power generation and flood management. The reservoirs are drawn down and refilled each year. Reservoir and river operations have changed little since the *2013 Water System Plan.* The most significant change was installation of the new Morse Lake Pump Plant to improve reliability of that system. Also, the upper flow levels used to prevent scour of salmon redds were raised, as described below.

The groundwater supply facilities at the Seattle Well Fields are also available, if needed. The wells were last used in 2015, and groundwater elevations measured since the *2013 Water System Plan* are provided in the appendices.

Should a drought or other water supply emergency occur, SPU would activate the Water Shortage Contingency Plan (WSCP), an updated of which is contained in the appendices. The WSCP was last activated in 2015, and based on lessons learned from that response, SPU has updated its WSCP as described below.

2.3.5.1 Morse Lake Pump Plant

The Morse Lake Pump Plant (MLPP) project, completed in 2017, replaced two existing 120-mgd floating barge-mounted pump stations with a new, more energy-efficient 240 mgd floating pump station to improve the reliability of water supply from the Chester Morse Reservoir, meet municipal demands, and manage flows for instream resources in the Cedar River during dry weather conditions. Additionally, one of the existing 120-mgd floating barge-mounted pump stations was refurbished to serve as a backup. These facilities provide access to water stored below elevation 1538 feet in Chester Morse Lake that would otherwise not be available by gravity flow.

The new MLPP is a floating structure consisting of modular steel pontoons that form the 80-foot by 40-foot barge and four submerged axial-flow pumps with in-line fish screens. The pumps provide a cumulative 240 mgd pumping capacity through four 48-inch diameter, 500-foot long discharge pipelines that convey water through the discharge dike where it flows by gravity to Masonry Pool. To facilitate rapid deployment and demobilization of the pump plant and minimal use of a dive team, the platform design incorporates guide cones, allowing easier plant docking with permanently stationed pipelines. During operations, electrical service is supplied using a rental diesel generator and the project-supplied trailer-mounted substation, and transmitted through permanently installed submerged and buried cables.

When the pump plants are not in use, they are moored in a Chester Morse Reservoir cove where it is protected from frequent high-wind and-wave conditions. The system is mobilized either for periodic testing or infrequent pumping operations. When pumping operations are needed, the MLPP is transported to an operating position where it is docked with submerged pipelines near its outlet to draw additional water from below the outlet level and discharge dike during low reservoir conditions (below approximately elevation 1538 feet).

2.3.5.2 Scour Protection Levels

Whenever possible, SPU limits releases to the Cedar and South Fork Tolt Rivers to levels that prevent scour of redds (salmon egg nests) which would cause loss of the eggs. In coordination with the Instream Flow Commission, SPU completed a salmon redd scour study on the Cedar River which changed the redd scour threshold to 2200 cfs from 1800 cfs at the U.S. Geological Survey (USGS) Renton Gage (12119000). Similarly, SPU worked with the Tolt Fish Advisory Committee (TFAC) to complete a 2-year salmon redd scour study on the South Fork Tolt River which increased the year round 550 cfs redd scour threshold to 1100 cfs from September 2 to January 14 and 900 cfs from January 15 to September 1 at USGS Gage 12148300. It is notable that the 350 cfs redd scour threshold in the South Fork Tolt River at USGS Gage 1214800 was determined to no longer be needed. The new thresholds provide SPU with more flexibility to release water during the flood management period.

2.3.5.3 Water Shortage Contingency Plan

The Water Shortage Consistency Plan (WSCP) provides guidelines for SPU to manage water supply and demand in the event of a water shortage. The plan enables SPU to maintain essential public health and safety and minimize adverse impacts on economic activity, environmental resources and the region's water use preferences. Water shortages could result from forecasted, progressive events such as droughts, as well as unforeseen, static events such as system failures like a major infrastructure break. The WSCP has four water shortage response stages – Advisory, Voluntary, Mandatory, Emergency – which are typically implemented progressively depending on the magnitude of the water shortage, unless more aggressive action is warranted.

SPU last activated its WSCP in 2015. Based on lessons learned from that event, SPU has revised its plan for inclusion in this *Water System Plan*. A key change allows the SPU General Manager/CEO to authorize the Advisory Stage to begin planning and coordination activities in advance of requesting customer actions. The City of Seattle Mayor, upon recommendations from the SPU GM/CEO, authorizes the Voluntary and Mandatory Stages in which customer actions are requested. The revised WSCP is included in the appendices and provides more details on response actions.

2.3.6 Maintenance

SPU has developed Asset Management Plans (AMPs) as part of its asset management process. Each AMP covers a class of assets or facilities, and describes the condition, performance, failure history, and cost of maintenance and renewal for those assets. AMPs are 3- to 5-year planning documents that provide a framework to assess the current status of a category of assets and guide their management, including operation, maintenance, renewal/replacement strategies, and capital investments. AMPs are updated and refined periodically.

AMPs involving water resources assets and facilities include:

- Tolt Watershed Reservoirs and Dams (2013)
- Lake Youngs Reservoir and Dams (2010)

An AMP will also be developed for the facilities at Landsburg.

Each of these AMPs ensure that the dams are maintained for operability and safeguard against damage or failure in large floods, earthquakes, malevolent acts, and general deterioration from aging. The Dam Safety Section of the Washington State Department of Ecology (Ecology) or, for the Tolt Dams, the Federal Energy Regulatory Commission (FERC) regulate the maintenance of Seattle's dams to ensure continued safe performance. Both Ecology and FERC require regular inspections of these dams and related infrastructure, such as spillway gates and dam failure warning systems. These inspections can result in requirements for maintenance work or major capital improvements.

2.4 Needs, Gaps, and Issues

Needs, gaps, and issues facing the Water Resources business area include appropriately planning for water supply in the face of uncertainty around the potential impacts from a changing climate and improving water supply infrastructure and operational practices to make the best use of existing supplies. The Water Use Efficiency Goal and program for the 2019-2028 time period is also described, along with an updated water demand forecast. Each of these specific issues is discussed in the following section, along with how SPU plans to address them.

2.4.1 Future Water Demand and Supply

There are uncertainties affecting both future water demand and future water supply. Future water demand is dependent on population growth, income, conservation, climate, weather, and other factors, such as changes in water appliance efficiency standards. Future water supply depends on the condition of water supply infrastructure, operating constraints, climate, the feasibility of developing new supplies as needed, and other factors, such as legal and regulatory issues. SPU has developed water demand forecasts and analyzed future water supply using frameworks that incorporate these relative uncertainties. The results of SPU's analyses are described in the following sections.

2.4.1.1 Water Use Efficiency Goal and Program 2019-2028

Towards the end of the 2013-2018 regional program, the Operating Board reassessed the drivers for the regional conservation program and set the goal, broad focus areas, and budget levels for the 2019-2028 regional conservation program.

The demand forecast continues to indicate that a new source of supply is not needed before 2060. This is due, in part, to reductions in per capita demand that offset the impact of population growth on total water use.

The Operating Board identified the following as the current drivers for conservation:

- Maintain a cushion between demand and supply,
- Ensure conservation capacity (staff expertise and industry partnerships) is available to deliver conservation services, as well as to respond to droughts and supply disruptions,
- Help customers use water wisely and manage their bills,
- Preserve the customer water conservation ethic,
- Be good stewards of our water resources and environment, and
- Meet regulatory, contractual, and stakeholder requirements and expectations.

The Saving Water Partnership's regional 2019-2028 Water Use Efficiency Goal is to:

Keep the total average annual retail water use of Saving Water Partnership members under 110 mgd through 2028 despite forecasted population growth by reducing per capita water use.

This new regional goal has a higher threshold than the previous 2013-2018 goal. The increase from 105 mgd to 110 mgd reflects extension of the goal time period to cover the next 10 years, as well inherent uncertainties in demand forecasting. The new goal still represents significant conservation within the context of continued population growth forecast for the 2019-2028 time period.

As with the previous goal, the new goal will capture all demand-side water savings from the conservation programs, codes and standards, and independent savings. Also, the 2019-2028 regional program will build on the strengths and successes of the 2013-2018 regional program; however, the focus areas will be modified slightly to reflect more recent priorities of the Operating Board. The 2019-2028 regional program will maintain the same total budget as the 2013-2018 program.

The specific program measures will be similar to the 2013-2018 program measures shown in Table 2-4, however the focus will shift slightly away from financial incentives and towards more education and technical assistance. The shift slightly away from financial incentives reflects the reality that the program has achieved considerable savings historically, the region does not need significant water savings from conservation in the near term, and plumbing codes and standards continue to contribute to savings. The shift towards more education relates to the objective of preserving the conservation ethic. First, existing customers require reinforcement of conservation messages in order to maintain their conservation ethic. Second, the significant influx of new people to the region means that additional efforts may be necessary to build up their conservation ethic. The cumulative savings for the regional program over the 10-year period is estimated to be 1.0 mgd.

SPU will also continue its low-income water conservation program for its retail customers.

2.4.1.2 Water Demand Forecast

Long-term water demand forecasting is critical for water system planning. SPU has updated and improved the Demand Forecast Model developed for the *2007 and 2013 Water System Plans*. This model incorporates the best features of various model types found in the applicable literature. Like simple “fixed flow factor” models, the new SPU model is easy to understand and has relatively modest data requirements. However, like more complex econometric models, the model reflects the impacts of variables such as price, income, and conservation on water use factors over time. This approach takes advantage of past econometric analyses to provide estimates of how price and income can affect demand. The model incorporates estimates of the impacts of passive savings on the water use factors over time, as described below. More information on the model, data sources and assumptions is provided in an appendix.

SPU's official water demand forecast is presented in Figure 2-4 along with earlier forecasts. The various components that add up to the total demand forecast are shown in Figure 2-5. The demand forecast is slightly lower than the revised *2013 Water System Plan* forecast, and remains considerably below SPU's current firm yield of 172 mgd until well after 2060. Total demand is forecast to remain relatively flat through 2030 before rising gradually to a peak of 137 mgd in 2039. At that point, the Cascade block is scheduled to begin stepping down. Over the two decades that follow, water demand is forecast to decline as the annual 1 mgd reductions in Cascade's block more than offset what would otherwise be a modest amount of growth in demand. By 2060, total water demand from SPU's system is forecasted to have ramped back down to 133 mgd. Given the current firm yield estimate for SPU's existing supply resources, this forecast indicates that no new source of supply is needed before 2060.

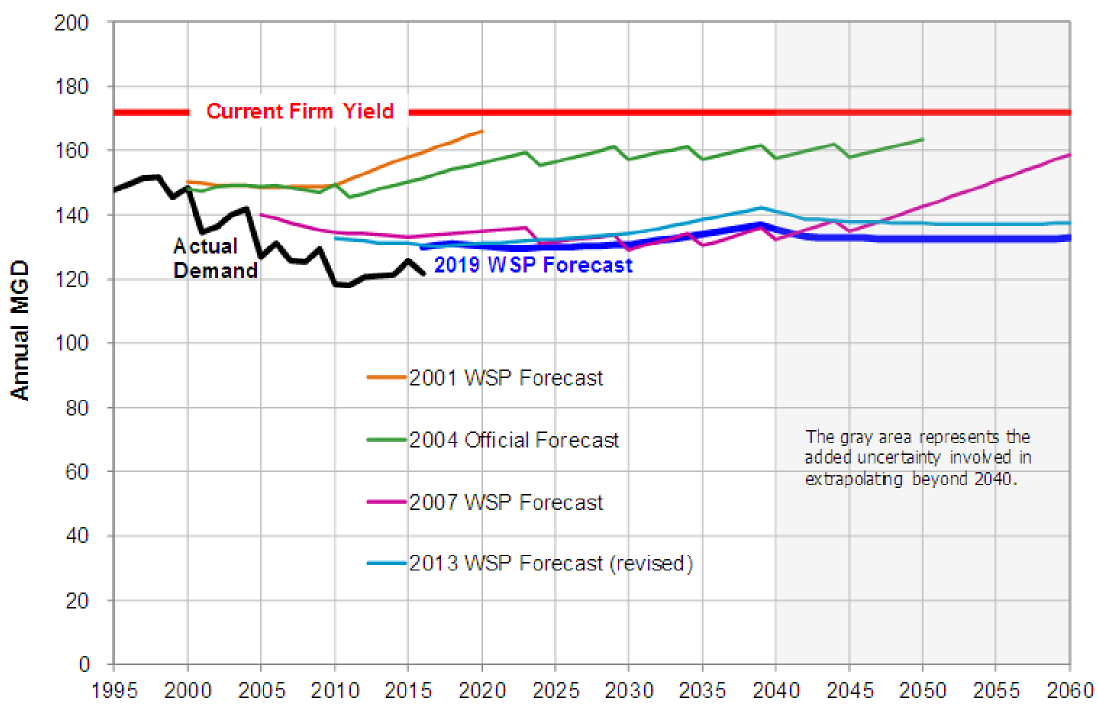


Figure 2-4. SPU's Official Water Demand Forecast

Note: Forecast demand is higher than actual demand in 2016 because the forecast includes all block contract amounts, whereas the actual demand by Cascade and Northshore has been less than their block contract amounts.

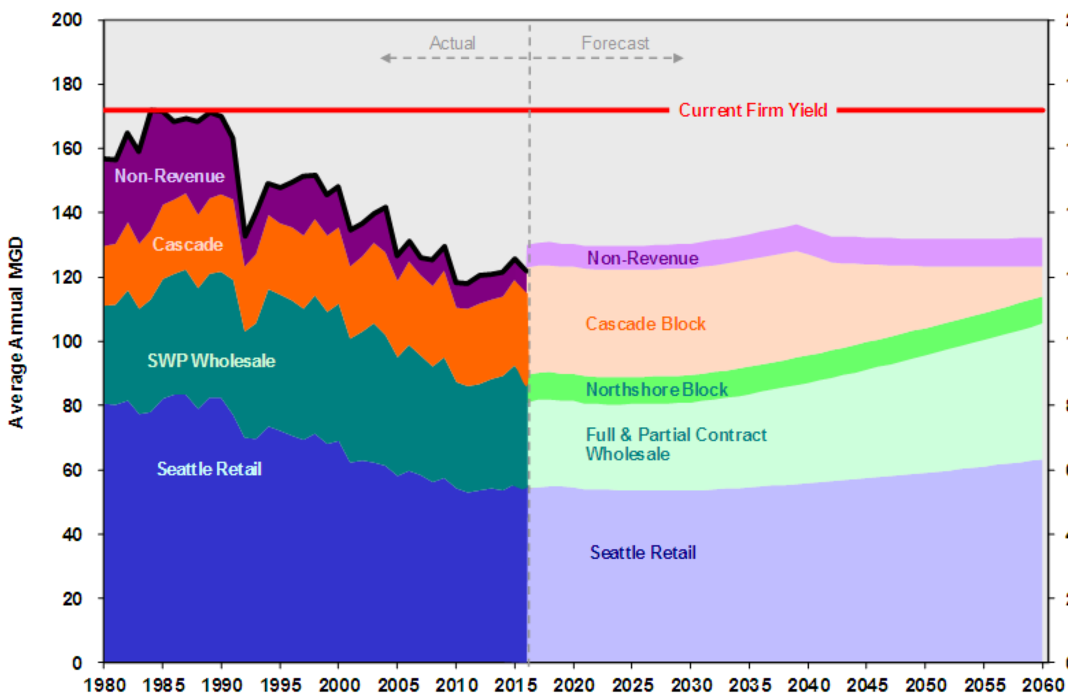


Figure 2-5. Components of Actual and Forecasted Demand

Peak demands are also forecasted to remain below historic high levels. Assuming that peak day demands will be twice as high as average day demands, peak day demand is forecast to reach a high of 273.5 mgd in 2039 and then decline as the Cascade block is stepped down.

SPU's new official water demand forecast is based on a number of changes, particularly in the following key areas:

- Future Conservation Goals and Programs. The forecast includes the impact of the 2019-2028 Water Use Efficiency Goal and Program, described in the previous section.
- Codes, Standards & Market Transformation. The forecast includes reductions in water use due to codes, standards and market transformation. These include purchases of new plumbing fixtures and appliances that meet federal codes adopted in 1992, 2001, 2002, 2011 and 2015[1]. The standards portion of savings in the forecast reflects the current proportion of fixtures and appliances sold in the market that exceed code, meeting the more stringent Energy Star, Water Sense, and

1 The US Department of Energy adopted a two-phase clothes washer efficiency standard in which the first phase was effective March 7, 2015, and the second, more stringent phase, will become effective January 1, 2018.

Consortium for Energy Efficiency standards. Finally, market transformation refers to how those proportions are expected to continue shifting in the direction of higher efficiency over time.

- Block Contracts. The block supply amounts to be provided by SPU to Northshore and Cascade are included in the forecast as stated in the contracts.
- Potential New Wholesale Customers. The demand forecast includes potential supply of 0.5 mgd to Ames Lake Water Association for meting future needs in their service area.
- Non-Revenue Water. Combined transmission and Seattle distribution system non-revenue water is assumed to increase from 7 mgd in 2016 to 9 mgd by 2060. This increase is expected to be caused by the increasing number of leaks that are likely to occur as the distribution system ages.

Forecasting future water demand with certainty is impossible. The official water demand forecast is based on forecasts of income, water prices, households, and employment, all of which are subject to uncertainty. Additional uncertainty surrounds the forecast model's assumptions about price elasticity, income elasticity, and future conservation (the model assumes no programmatic conservation past 2028). These uncertainties were modeled by estimating probability distributions for each source of uncertainty. These distributions became inputs to an aggregate uncertainty model employing a Monte Carlo simulation[1] to characterize uncertainty associated with the official demand forecast.

The results of the Monte Carlo simulation are displayed in Figure 2-6. The green bands indicate the range of uncertainty associated with the official forecast. Each band represents a 10 percent increase (from the band immediately below it) in the probability that actual demand will be equal to or less than the level shown. For example, the bottom of the lowest band represents the 10th percentile, meaning that there is an estimated 10 percent chance that actual demand will be at or below that level (i.e., 107 mgd in 2060) and, thus, a 90 percent chance it will be above. The top of the uppermost band is the 90th percentile, corresponding to an

[1] A Monte Carlo simulation calculates multiple scenarios of a model by repeatedly sampling values from the probability distributions for the uncertain variables. The data generated from the simulation can be represented as probability distributions or confidence intervals. Because the method is based on random chance, it was named after the city of Monte Carlo which is known for its gambling.

estimated 90 percent probability that actual demand will be at or below that level (i.e., 163 mgd in 2060).

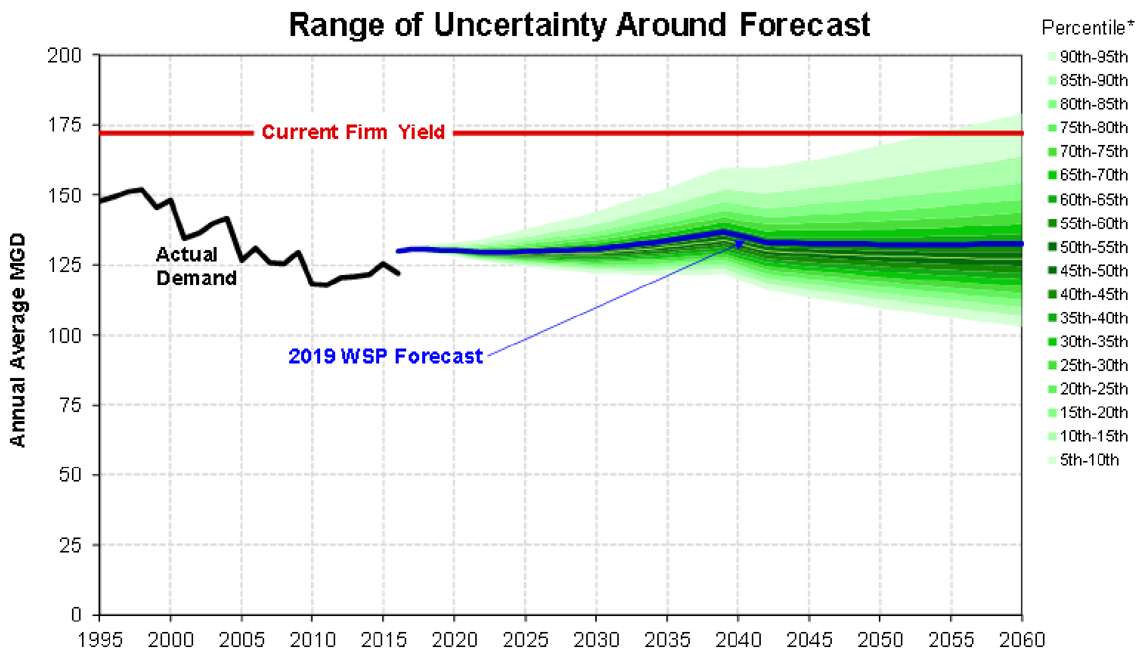


Figure 2-6. Uncertainty in Water Demand Forecast[1]

This type of analysis provides insight into the uncertainty that surrounds the various inputs to the demand forecast model. It estimates a more than 90 percent probability that a new source will not be necessary before 2060 given the range of uncertainty in demand that was tested and current firm yield based on historic inflows.

SPU also considers the uncertainty of discrete events that produce significant and sometimes abrupt changes in customer demand. Assigning a probability of occurrence to these events is difficult. These uncertainties are examined through scenario planning in which the outcome of those events occurring is considered. For example, an increase in demand could occur if a wholesale customer's own source of supply is significantly less than forecasted and the wholesale customer chooses to have SPU provide for its additional needs. SPU monitors such developments so that adjustments to the forecast can be made when appropriate.

[1] Percentiles represent the probability that actual demand will be less than the value shown. Ranges reflect uncertainty in projected household, employment, price and income growth, price elasticity, income elasticity, and conservation. Note that the official forecast is at about the 58th percentile.

2.4.1.3 Climate Change and Future Supply Outlook

Climate variability and climate change are uncertainties that SPU considers in ensuring that current and future water demands for people and fish are met. Climate variability and climate change are often used interchangeably, but for purposes of distinction, climate variability is used here to refer to a phenomenon that is cyclical in nature, while references to climate change denote persistent change that is largely human induced. Having managed the water supply system for more than 100 years, SPU is accustomed to providing adequate and reliable service in the face of climate variability.

Climate change is caused by an increase in heat-trapping atmospheric gases, known as greenhouse gases. Climate change can alter weather patterns and affect air temperatures, humidity, evaporation, cloud cover, rainfall, snowfall, snowpack, and runoff, in terms of averages, extremes, timing and distribution. The timing and magnitude of these changes and their effect on SPU's water supply and demand is uncertain but better understanding of the implications of climate change for SPU is a programmatic area of focus within SPU. SPU's policies for Supply Reliability and Planning for Uncertainty require that the potential impacts of long-term climate change on water supply and demand be addressed in developing supply investment strategies based on the most current knowledge and a wide range of climatic conditions.

The climate analysis reflected in this *Water System Plan* is a product of a collaborative research project between SPU and the Climate Impacts Research Consortium (CIRC), a NOAA-funded climate research group housed at Oregon State University. The research project was referred to as PUMA – Piloting Utility Modeling Applications. The PUMA project builds off of SPU's previous climate studies, the results of which were also reflected in previous water system plans. For the PUMA project, CIRC downscaled meteorological projections from the 20 different Global Climate Models (GCMs), paired with two Representative Concentration Pathways (RCPs), to several different point locations in the Central Puget Sound area. The resulting dataset was then used by SPU to create climate-altered streamflows and test the sensitivity of SPU's water supply under a range of plausible future conditions. For this *Water System Plan*, the analysis focuses on a 50-year time period from 2000 to 2050 using RCP 8.5, which is the scenario with the greatest concentration of greenhouse gases.

The ensemble of future climate projections shows an increasing trend in average temperatures across all seasons (Figure 2-7). Warmer winter temperatures would result in more precipitation falling as rain and less as snow, resulting in declining snowpack over time. While projections show little to no trend in average annual precipitation, several models suggest an amplification of current seasonal patterns; winter precipitation may increase and summer precipitation may decrease in the future. The variability in annual precipitation is expected to increase in the future, which would result in drier and wetter years than have been observed historically. The potential for anomalously dry winters in combination with warmer winter temperatures in the future creates the possibility that there will be years in the future that SPU is unable to meet reservoir refill targets in the spring.

The regional average annual streamflow hydrograph is characterized by two peaks. The first peak occurs in the late fall when the rainy season begins. Flows are reduced as temperatures cool and a greater portion of precipitation falls as snow which accumulates as snowpack. The second hydrograph peak occurs in the spring as temperatures rise and snowmelt runs off to the stream. It is important to note that any given year will look different than the generalized average hydrograph because of variability in weather patterns from year to year.

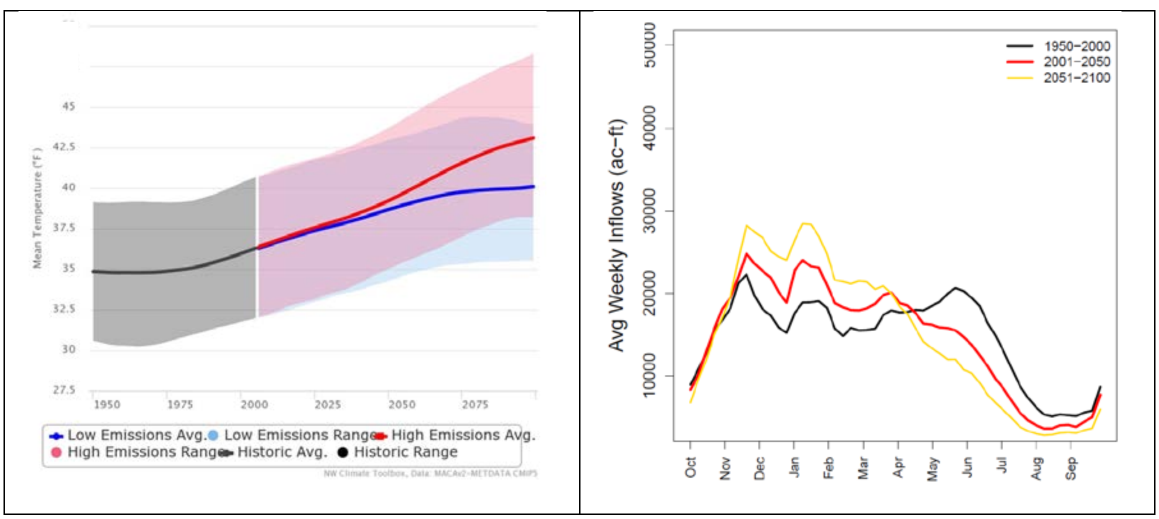


Figure 2-7. Air Temperatures and Streamflows Under Climate Change Scenarios[1]

[1] Left-hand graph: Historic average temperatures (in grey) and projections of future temperatures under two emissions scenarios through 2100. Right-hand graph: Total average weekly inflow supply as calculated by 20 GCMs for three time periods.

Seattle's watersheds are more sensitive to warming temperatures than other mountain watersheds due to their maritime geography. In a single storm event, it is common that precipitation falling at higher elevations is snow while rain falls at the lower elevations. Increased temperatures without a change in total amount of annual precipitation would result in similar total annual streamflow to what has occurred historically, but with a shift in the seasonality of peak inflows. On average, in the future more precipitation will fall as rain instead of snow in the winter leading to increased winter flows, less snowpack accumulation, and earlier snowmelt driven flows in the spring. In the most severe scenarios, winter temperatures may be sufficiently warm to eliminate the snowpack altogether resulting in a single winter peak in the hydrograph (Figure 2-7). Forecasted declines in summer precipitation would result in lower summer flows.

The future climate scenarios suggest that the primary impact of climate change on flow regime will be more frequent temperature-driven droughts due to low snowpack and/or early snowmelt which generally leads to an extended summer dry season. Increased variability in precipitation could lead to more severe conditions in extreme years when the temperature-driven drought conditions are combined with low winter precipitation or later return of fall rains than has been observed historically.

A shift in seasonality of the annual streamflow hydrographs would effectively extend the reservoir drawdown season with more of the annual inflow occurring during flood season, when excess water is released from the reservoirs to keep reservoir water levels lower for flood management purposes, and less flow occurring in the spring when the reservoirs are typically refilled. The extended drawdown season will result in a greater draw from storage, which could be further exacerbated by decreased summer flows and potential increases in water use by customers due to hotter, drier summer weather.

Recent analysis shows that SPU's water supply system will be increasingly vulnerable to the seasonal hydrologic shifts associated with climate change. Hydrologic vulnerabilities are identified for each of the 20 GCM scenarios analyzed by comparing average historical inflows to a GCM's individual year from the near future (2000-2050) in which SPU is unable to meet water demands for people and fish. In 14 of the scenarios indicative of increased vulnerability, total spring inflows (April- June) are outside of the historic range of inflow variability, and 17 of these scenarios have summer flows (July-September) that are less than the historic average. The combination of low spring flows and below average summer flows occur in 13 of the 20 scenarios that indicate an increasing system vulnerability. The table below shows the adaptation strategies that can be used with the existing system to address one or more of these vulnerabilities.

Table 2-5. Potential Adaptation Strategies to Address Climate Change Vulnerabilities

Vulnerability	Adaptation Strategies
Low snowpack and spring flows	• Early reservoir refill • Higher reservoir refill
Low summer flows	• Lower reservoir drawdown
Low spring and summer flows	• Early reservoir refill • Higher reservoir refill • Lower reservoir drawdown • Optimize use of reservoir storage

There are several ways to implement these adaptation strategies by operating the existing system differently. Many of these adaptations have been partially implemented in the past to help get through the toughest historic years. These potential operational changes include:

Early Reservoir Refill

- Dynamic Reservoir Management: Store more water in the reservoirs when snowpack and soil moisture conditions in the Cedar and Tolt watersheds indicate flood risks are lower than normal and supply conditions would likely be poor. This practice has been used since the mid-1990's and shown to be successful.
- Early Refill (prior to June 1st) and Dynamic Reservoir Management: Begin refill earlier based on estimates of snowpack and soil moisture conditions in the Cedar and Tolt watersheds.

Higher Reservoir Refill

- Higher Refill of Chester Morse Lake: Refill to elevation 1566 feet, 3 feet above historic maximum fill, adding 11 percent more storage in the Cedar system without new infrastructure or changes to water rights. Further analysis is needed to determine the cost and feasibility of this option, including the impacts of the higher refill level on tributary fish habitat, forest inundation, road impacts, flood management, moraine seepage and dam safety.
- Higher Refill of Chester Morse Lake and Overflow Dike Improvements: Optimize higher refill by modifying the

Overflow Dike to include a maximum elevation of 1554 feet to better manage seepage losses. Further analysis is needed to determine if a replacement for the flashboards would be beneficial and to assess potential environmental impacts of higher pool levels during the pool split period.

Lower Reservoir Drawdown

- Cedar Drawdown: Access storage in Chester Morse Lake below elevation 1538 feet more frequently using Morse Lake Pump Plant.
- South Fork Tolt Reservoir Drawdown (modest): Draw an additional 20 feet to elevation 1690 feet, adding 18 percent more storage in the Tolt system without new infrastructure or changes to water rights.
- Lake Youngs Drawdown (modest): Use 5 feet of storage in Lake Youngs to meet water demands.

Optimize Use of Reservoir Storage

- Tolt/Cedar Transfer Capacity: Improve ability to deliver Tolt water south to what would otherwise be served by the Cedar system to maximize the use of combined system storage.

While the operational changes listed above can partially mitigate the potential impacts of climate change on water supply availability, initial analysis suggests that even with these operational adaptations the system faces increasing vulnerability by the end of the century, primarily due to warmer temperatures extending the summer dry period. More severe vulnerabilities could be caused by the increased variability in precipitation combined with rising temperatures. These increased vulnerabilities may lead SPU to construct new supplies, as described below in Section 2.4.1.4, which will require significant investments. There is a large degree of uncertainty in the timing and magnitude of climate impacts on supply vulnerability, but the trend and range of potential outcomes indicate that planning for increased system resiliency should remain a top priority in coming years.

The above analysis does not assess the effect of climate change on several key factors that influence water supply, water demands, watershed resources, and supply operations. For example, climate change impacts on water quality, particularly the frequency of high turbidity events and algal blooms that can be disruptive to supply operations, have not been evaluated but can reduce supply availability. Impacts from more frequent and severe high flow events on properties downstream of reservoirs and instream resources (i.e. redd scour) have not been evaluated. These issues are a sampling of topics SPU intends to explore as part of its sustained engagement with the research community and professional organizations.

Moving forward, SPU will pursue the following:

- Actively manage reservoirs based on real-time watershed conditions and weather forecasts.
- Install additional monitoring soil moisture monitors and high elevation temperature monitoring stations to improve watershed moisture tracking (soil) and high elevation temperature to support dynamic reservoir management.
- Update the analysis of the adaptation options to include considerations of cost, environmental impacts, policy implications, in addition to gains in water supply.
- Continue tests to monitor and assess environmental and dam safety considerations associated with routinely refilling Chester Morse Lake to 1566 feet.
- Identify and plan for additional adaptation and new supply options with an emphasis on building system resilience under a range of potential scenarios.
- Identify indicators that can be tracked and used to help determine when to pursue more complex and expensive adaptation or new supply options.
- Continue developing and fostering collaborative partnerships with academic researchers and professional organizations in order to obtain actionable science[1] that SPU can use to enhance our knowledge base, build institutional capacity and inform planning for future climate change.

Given the dynamic nature of climate research, SPU is committed to remaining engaged in future research, conducting new assessments on a periodic basis to identify potential impacts and system vulnerabilities, and planning for adequate water supply

[1] The following is a definition for actionable science developed by the U.S. Department of Interior's Advisory Committee on Climate Change and Natural Resources Science. "Actionable science provides data, analyses, projections, or tools that can support decisions regarding the management of the risks and impacts of climate change. It is ideally co-produced by scientists and decision makers and creates rigorous and accessible products to meet the needs of stakeholders."

while ensuring that decisions do not result in unnecessary or premature financial and environmental costs for the region.

2.4.1.4 Future Supply Opportunities

While the firm yield update indicates that no new supply is needed well into this century to meet forecasted demand, the climate change analysis indicates that SPU may need to construct new sources of supply to address increasing vulnerabilities. The supply alternatives identified in previous water system plans remain as opportunities for SPU to consider, as well as additional alternatives, should key triggers indicate the need to develop a new supply source. The new supply alternatives include:

- Permanent Cedar Drawdown: Access storage in Chester Morse Lake below elevation 1538 feet for normal supply using Morse Lake Pump Plant.
- South Fork Tolt Reservoir Drawdown (aggressive): Draw an additional 50 feet to elevation 1660 feet, the lowest intake level, which may require changes at the Tolt Water Treatment Facility.
- Lake Youngs Drawdown (aggressive): Use 28 feet of storage in Lake Youngs to access to an additional 17,390 acre-feet, which will likely require the addition of filtration at the water treatment facilities.
- North Fork Tolt River Diversion: Construct a small diversion on the North Fork Tolt in addition to drawdown of the South Fork Tolt to elevation 1660 feet.
- Snoqualmie Aquifer: Development of the Snoqualmie Aquifer with new river intake, filtration plant, pump station, and an interconnection to SPU's Tolt pipeline.
- Cedar High Dam: Construct a new and higher dam at the current Overflow Dike location.
- Desalination: Construct a desalination plant to use saltwater pumped from Puget Sound.
- Reclaimed Water: Develop one or more reclaimed water projects to reuse wastewater.
- Distributed Systems: Construct multiple, small systems throughout the service area to offset potable water use, such as greywater and rainwater harvesting systems.
- Regional Interties: Construct interties with adjacent regional water suppliers to access water from those sources.

2.4.1.5 Wildfire Risk Management in SPU's Watersheds

SPU acknowledges that a large wildfire in its drinking water supply watersheds could pose a threat to the primary mission of providing high quality drinking water supply as well as to aquatic and terrestrial habitats for fish and wildlife species. Current policy is to aggressively prevent and suppress all wildfires to address this risk. Prevention includes controlling watershed access and restricting activities, while suppression includes initial attack on wildfire starts and support to the Washington Department of Natural Resources, who ultimately is responsible for wildland fire suppression throughout the state.

SPU has conducted substantial work to assess the fire hazard, potential changes in key indicators of changing fire behavior, and benchmarking with other land managers on best practices to manage wildfire risk. The intent of these studies was to understand effect of watershed management on fire hazard, assess potential mitigation strategies to reduce fire hazard, identify gaps in wildfire risk management and prioritize potential actions. The most recent risk assessment indicates that SPU is well situated with respect to fire prevention and suppression strategies relative to similar land managers and water utilities.

Forests in the Cedar and Tolt River Municipal Watersheds are moist west-side forests that are characterized by low frequency fires (every 200 years or so), in contrast to the historically high frequency (every 15 years or so), low severity wildfire of drier forest types on the east side of the Cascades Crest. Forest and fire ecologists point out that ultimately, at some time and place, suppression on the west-side will fail, driven largely by extreme fire weather. Large fires with high severity are characteristic of these west-side forest types, and they may have catastrophic impacts to drinking water supply and ecosystems. Climate science projects increases in fire frequency and area burned along with ecosystem changes. SPU is investigating climate adaptation strategies to increase resilience in its water supply watersheds to reduce the future risk of catastrophic wildfire in the face of potential effects of climate change.

2.4.2 Infrastructure Needs and Improvements

SPU maintains its water resources facilities for safe and reliable operation to ensure water supply is available for its customers. Several studies and infrastructure improvement projects have been identified to improve the reliability and flexibility of the existing water supply system. These projects and studies are described below.

2.4.2.1 Landsburg Flood Passage Improvements

Since the Cedar River flooded in fall 1990, there have been concerns about flood debris, such as large trees uprooted during high flows, blocking the spillway gates at Landsburg Diversion Dam during major floods. SPU is conducting new studies of large woody debris management in the Cedar River and riparian zone. This information will be used to update the evaluation of flood passage at the Landsburg Diversion Dam, which will also consider potential increases in the number of flood events, duration of high flows and more peak flow events due to climate change. SPU will also conduct preliminary engineering and life-cycle cost analyses of options to improve the flood passage capabilities at the dam and reduce the risk of overtopping of the dam during large flood events, which could potentially cause severe erosion of the embankments and place the dam at risk of failure and impede the delivery of water.

2.4.2.2 Lake Youngs Cascades Dam

Water stored in Lake Youngs is impounded by two earth embankments, the Outlet Dam to the south and Cascades Dam to the east, and the perimeter dikes around the lake. A third dam, Inlet Dam, east of Cascades Dam, normally does not store water and was constructed as a backup embankment to retain the reservoir water in case of a failure of Cascades Dam, which shows signs of movement and is considered to be somewhat unstable. As noted previously, SPU plans to conduct further investigations and studies to determine the potential impact on water quality that could be caused by failure of Cascades Dam, particularly with respect to material existing in the area between Cascades Dam and the Inlet Dam.

2.4.2.3 Tolt Valve 15

A leak in the South Fork Tolt Valve 15, which helps control the Tolt reservoir's water level, is interfering with SPU's ability to monitor other leaks through the Dam Spillway Conduit. Monitoring these conduit leaks is the principal means for tracking the stability of the dam's earthen fill. The Federal Energy Regulatory Commission (FERC) has directed SPU to eliminate the leakage through Valve 15 as soon as possible. Design work started in August 2017 with a planned valve replacement in the summer of 2018[1].

2.4.2.4 Tolt Dam Warning System

The South Fork Tolt Dam early warning and performance monitoring systems include numerous components that have reached their end of life and/or no longer have manufacturer support, individual components cannot be separately upgraded to meet current system needs. These systems are part of the Emergency Action Plan (EAP) that SPU and SCL jointly maintain every year and is required by FERC. Design work on replacing the system started in 2017 and with the goal of finishing construction in 2019.

2.4.2.7 Tolt Dam Log Boom

The South Fork Tolt Dam log boom is reaching the end of life and needs to be replaced. The log boom was constructed in 1998 during the Intake Tower seismic upgrade. The log boom consists of a series of clustered plastic logs connected with chain links. Each cluster consists of five plastic logs bundled together and a debris screen fixed on underside of the logs. Replacement of the log boom is planned around 2021.

2.4.3 South Fork Tolt FERC Relicensing Support

The Federal Energy Regulatory Commission (FERC) issued Seattle City Light (SCL) a license to operate the hydropower project at the South Fork Tolt Dam in 1984. The FERC license led to an agreement that established, among other things, requirements for minimum instream flows that impact SPU's water supply operations. The current license expires in 2029, and relicensing a hydropower project using the default licensing process (Integrated Licensing Process) typically takes about five years. SCL will lead the relicensing process in collaboration with SPU. The relicensing process allows stakeholders an opportunity to identify potential issues which could result in studies requiring SPU support. It is not known at this time whether the new license will lead to changes in water supply operations or additional obligations for SPU.

[1] Valve replacement is now scheduled for 2020 or 2021; this delay is not reflected in the Capital Facilities Plan.

2.5 Implementation/Action Plan

In the absence of a need to develop new water supplies for several decades, SPU's implementation/action plans in the Water Resources business area will focus on continuing conservation efforts, pursuing additional work to assess climate change impacts, and completing infrastructure upgrades to water supply facilities. A summary of the implementation/action plan for the Water Resources business area is as follows:

- Keep the total average annual retail water use of Saving Water Partnership members under 110 mgd through 2028 despite forecasted population growth by reducing per capita water use.
- Continue to implement water conservation efforts that help low-income customers in Seattle manage their water bills.
- Pursue the actions identified to address potential climate change impacts on water supply, including:
    - Update the analysis of the adaptation options to include considerations of cost, environmental impacts, policy implications, in addition to gains in water supply.
    - Continue tests to monitor and assess environmental and dam safety considerations associated with routinely refilling Chester Morse Lake to 1566 feet.
    - Investigate raising the Overflow Dike to elevation 1554 feet.
    - Identify and plan for additional adaptation and new supply options with an emphasis on building system resilience under a range of potential scenarios.
    - Identify indicators that can be tracked and used to help determine when to pursue more complex and expensive adaptation or new supply options.
- Continue developing and fostering collaborative partnerships with academic researchers and professional organizations in order to obtain actionable science that SPU can use to enhance our knowledge base, build institutional capacity and inform planning for future climate change.
- Investigate climate adaptation strategies to increase resilience in the water supply watersheds to reduce the risk of changing disturbance patterns, such as extreme precipitation events, extended droughts and large wildfires that could impact forest and stream habitats, water quality and water supply.

- Conduct studies and complete infrastructure improvements to water supply facilities:
    - Complete options analysis to improve the flood passage capabilities of the Landsburg Dam and implement recommendations to reduce the risk of overtopping during large flood events.
    - Complete investigations to determine the potential impact on water quality that could be caused by failure of Lake Youngs Cascades Dam and potential improvements to mitigate this risk.
    - Complete work on South Fork Tolt Valve 15.
    - Replace the Tolt Dam Warning System.
    - Replace the South Fork Tolt Dam log boom.
- Support Seattle City Light in studies need for FERC relicensing of the South Fork Tolt Hydroelectric Project.

CHAPTER 3

WATER QUALITY AND TREATMENT

This chapter of the *2019 Water System Plan* focuses on the Water Quality and Treatment Business Area, which administers SPU's drinking water quality and treatment programs, projects, services, and capital assets from the supply source to the customers' taps. Key functions of this business area include managing SPU's drinking water regulatory compliance, implementation of the cross-connection control program, oversight of the Tolt and Cedar Water Treatment Facilities and their contract operations, ensuring appropriate monitoring of water quality for regulatory and operational purposes, managing distribution system water quality, overseeing water quality and treatment related capital improvement projects, and participating in other water system projects that have the potential to impact water quality. The Water Quality and Treatment business area is unlike other business areas in that its programs affect infrastructure and practices in the Major Watersheds, Water Resources, and Transmission and Distribution business areas. This chapter also includes descriptions of the drinking water regulatory requirements SPU must meet or exceed, as well as SPU's history of compliance.

SPU's water system includes two water treatment facilities for the Cedar and Tolt source waters that provide high levels of treatment prior to transmission and distribution.

3.1 ACCOMPLISHMENTS SINCE 2013 WSP

Since completion of the *2013 Water System Plan*, SPU has implemented the following major improvements in the Water Quality and Treatment business area:

- Laboratory Information Management System (LIMS): Updated LIMS to version 10 at SPU's Water Quality Laboratory in 2015 to ensure continued vendor support and improved reporting capability.
- Security: Enhanced physical security improvements at the Tolt facility.
- Service Agreements: Amended service agreements for the Cedar and Tolt Water Treatment Facilities.
- Cross-Connection Control Program: Upgraded the software system used for tracking compliance of backflow assembly testing required by the Cross-Connection Control Program.
- Landsburg facility: Converted from gas chlorination to hypochlorite at the Landsburg facility to improve safety.

- Lake Youngs Supply Line Standpipes: Extended the elevation of the standpipes to reduce risk of overflow when bypassing Lake Youngs.
- Reservoir Covering/Burying: Disconnected the remaining open reservoirs, Roosevelt and Volunteer, from the water system, while continuing to evaluate their future use for emergency supply and/or potable supply.
- Eastside Reservoir: Sealed the roof to wall joint and improved drainage off the reservoir roof to prevent runoff and seepage from entering the reservoir.
- Coliform Sampling: Increased number of coliform sampling by thirty percent; added sampling stations in multiple pressure zones.
- Fluoride: Reduced fluoride treatment target to 0.7 mg/L in accordance with new federal guidelines and new state regulations.

3.2 SERVICE LEVEL PERFORMANCE

SPU's service level in the Water Quality and Treatment business area focuses on meeting federal and state regulatory requirements. This is captured in a single service level objective and target for drinking water quality as shown in Table 3-1.

Table 3-1. SPU's Service Level for Managing Water Quality and Treatment Assets

Service Level Objective	Service Level Target
Promote a high level of public health protection and customer satisfaction with drinking water quality.	Meet all health-related and aesthetic regulations administered by the WDOH Drinking Water Program for the Seattle regional water system.

SPU's service level target is to meet health-related regulations (i.e., primary maximum contaminant levels and treatment requirements), aesthetic regulations (i.e., secondary maximum contaminant levels), and other aesthetic criteria (i.e., taste, and odor). SPU has been successful in meeting this service level with the exception of a treatment technique violation and one missed sample at the Tolt Treatment Facility as explained below. SPU has a Reservoir Covering Plan approved by Washington State Department of Health (WDOH) that was completed ahead of schedule (see Section 3.3.6.1). More information on how SPU is meeting regulations is provided in the remainder of this chapter.

3.3 EXISTING FACILITIES AND PRACTICES

SPU's water system includes drinking water treatment facilities for the Cedar and South Fork Tolt source waters, treatment and intake screening facilities at Landsburg, intake screening facilities at the Tolt Regulating Basin, and in-town disinfection facilities at reservoirs and well sites. Each of these facilities is operated and maintained to ensure that the potable water SPU delivers to its customers meets high public health and aesthetic standards.

To achieve its water quality and treatment service level, SPU has expended a great deal of effort over the past decades and continues to make concerted efforts to ensure compliance with WDOH drinking water regulations. SPU operates its facilities, monitors water quality at those facilities, and engages in a number of practices designed to bring safe, high-quality drinking water to its customers. This section summarizes SPU's record of regulatory compliance, identifies SPU's treatment facilities, and summarizes its operation and maintenance practices to ensure excellent water quality and a high level of customer satisfaction.

3.3.1 Regulatory Requirements and Compliance

Federal and state statutes and administrative regulations require the utility to meet certain water quality criteria and performance standards. The following subsections identify the standards and requirements that SPU must achieve and summarize SPU's performance in meeting those standards and requirements.

3.3.1.1 Total Coliform Rule

The Total Coliform Rule (TCR) requires monitoring to demonstrate that a water system is operating and maintaining its distribution system in a way that minimizes the risk of bacterial intrusion or regrowth. SPU collects required monthly samples from its retail service area distribution system and tests for coliforms, which are naturally present in the environment and are used as an indicator of whether other, potentially harmful, bacteria may be present. As system improvements, especially better disinfection facilities and covered reservoirs, have been implemented, SPU's success in meeting the total coliform rule requirements have improved greatly.

As indicated by Figure 3-1, below, SPU has been continuously in compliance with the TCR. Since the startup of the Cedar Water Treatment Facility in August 2004, SPU has been well within the regulatory requirement of less than 5 percent of samples with detectable total coliform for its distribution system. For the past 10 years, the highest percent positive occurred in July 2008, at 2.1 percent.

Over the past 10 years, there have been almost 30,000 coliform samples collected. Of those 30,000 distribution samples, 35 have been positive for total coliform, and two have been positive for *E. Coli*. (both in 2010). All follow-up sampling for the *E. Coli* positive samples showed no indication of contamination, and compliance with the TCR was met. Public notification was not required.

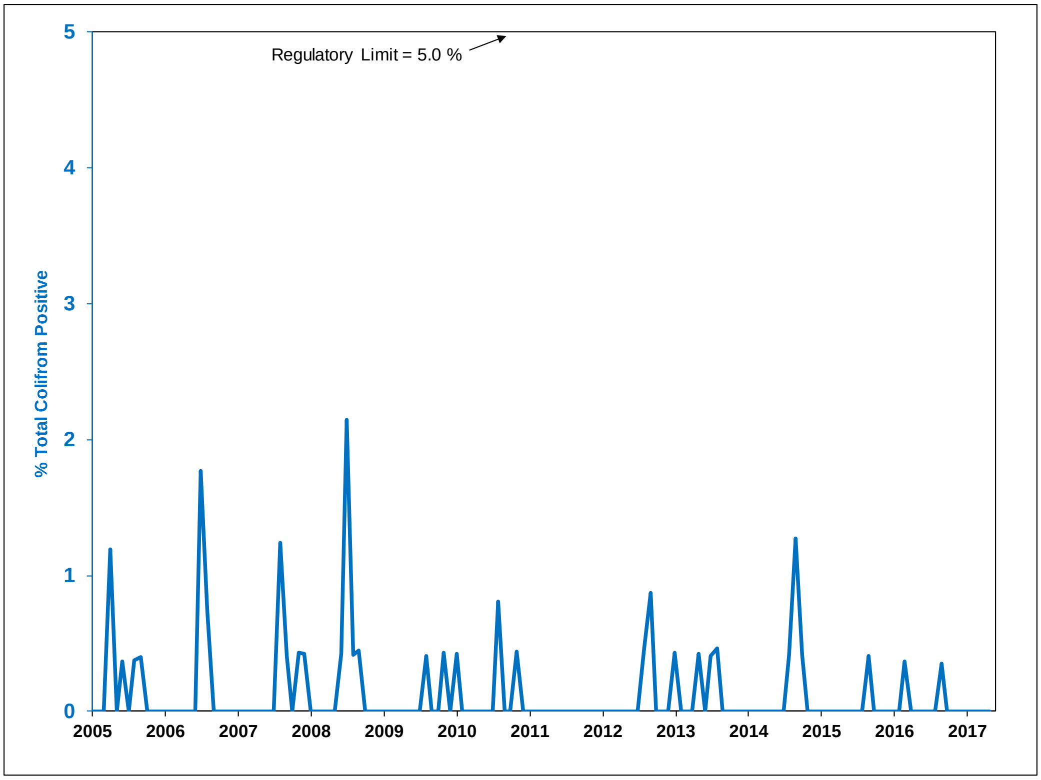


Figure 3-1. Monthly Coliform Data from SPU's Distribution System

In addition, 10 new sampling locations have been installed within the distribution system. All 10 locations represent small pressure zones or areas not covered by the existing sites. The total number of TCR sampling sites in the distribution system is now 73, which covers over 99 percent of the service connections.

Also, new since the previous *Water System Plan* is the Revised Total Coliform Rule, now in effect. The new rule should not have any major impacts to SPU's TCR program, but would require a Level 1 assessment if more than 5 percent of the samples are positive for total coliform in a month, or repeat samples are not collected as required. A Level 2 assessment would be required if an *E. Coli* MCL violation occurs, or if a second Level 1 assessment is triggered within a rolling 12-month period. The triggers for Level 1 and Level 2 assessments have not occurred in the SPU distribution system since the new treatment plants for the Cedar and Tolt supplies came on-line.

3.3.1.2 Surface Water Treatment Rule

The Surface Water Treatment Rule (SWTR) contains disinfection and filtration requirements for all public water systems that use surface water supplies. Several revisions to the original rule have been made since 1989, with the latest revision being the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR).

Tolt Supply. Since completion of the Tolt Treatment Facility in 2001, the supply from South Fork Tolt River has been required to meet all the regulatory treatment standards for a surface supply using filtration and disinfection. The Tolt Treatment Facility operations contract includes water quality performance requirements that meet and, in most cases, exceed the regulatory filtration and disinfection requirements. Since startup, the Tolt Water Treatment Facility has had one treatment technique violation (17 minutes of elevated turbidity in 2015) and one minor monitoring violation (one missed bromate sample in 2016); neither situation presented a risk to public health.

Cedar Supply. Construction of the Cedar Water Treatment Facility was completed in 2004. The Cedar River supply has a regulatory designation known as a “Limited Alternative to Filtration” (LAF), which authorizes SPU to operate the Cedar source without filtration treatment. LAF status is granted because Cedar source water is produced from a watershed that is in public ownership and control, with no residential, commercial or industrial development, and the treatment system employs a multi-stage disinfection process that provides greater protection against microbial contamination than can be provided by traditional filtration and chlorine disinfection. The Cedar supply continues to operate in compliance with the LAF criteria and is the only system in the country with this regulatory designation.

Like the Tolt Water Treatment Facility, the Cedar Water Treatment Facility operations contract includes water quality performance requirements that meet and, in most cases, exceed regulatory requirements. Since it began operating in 2004, the Cedar Water Treatment Facility has experienced no treatment violations.

Long Term 2 Enhanced Surface Water Treatment Rule. The LT2SWTR, focuses on controlling *Giardia* and *Cryptosporidium* in surface water supplies. This rule affects the Seattle water system in two ways: source monitoring for *Cryptosporidium* and covering of open distribution reservoirs. The second round of source monitoring for *Cryptosporidium* was completed in March 2017. The results for both the Cedar and Tolt were in the lowest category (highest quality), so no changes are needed to the existing treatment provided.

The LT2ESWTR also requires that open, treated-water reservoirs be covered or provided with treatment on the outlet. The last open reservoir in Seattle was taken out of service in 2013.

3.3.1.3 Groundwater Rule

The Groundwater Rule was issued in November of 2006 and went into effect in 2009. SPU uses its wells for production purposes as a seasonal source dependent on supply conditions and system demand. SPU last used its wells for production in 2015. SPU's wells draw from a deep aquifer that is well protected from contamination. When the Seattle Wells are next used, SPU's plan for compliance is to conduct triggered source water monitoring as necessary. While not part of the current regulatory compliance strategy, chlorine contact time for disinfection of viruses is achieved in the pipelines a short distance from the wells.

3.3.1.4 Disinfection By-Products Rule

In general, SPU's high quality source water and upgraded treatment result in low concentrations of disinfection by-products (DBPs), such as trihalomethanes (TTHMs) and haloacetic acids (HAAs), by-products that can result from reactions between chlorine and natural organic matter. Trihalomethane and haloacetic acid monitoring results for the distribution system since the Stage 2 Disinfectant/Disinfection By-Products Rule went into effect in 2012 are shown in Table 3-2, below.

Compliance with the Stage 2 DBP Rule is now based on a Locational Running Annual Average (LRAA), instead of a system wide average. The LRAA calculated each quarter for each sampling location must be below the MCLs for HAAs and TTHMs. The MCLs are 60 ug/L for HAAs, and 80 ug/L for TTHMs. The table below shows that the highest LRAA for HAAs was 48 ug/L, and the highest LRAA for TTHMs was 62 ug/L, both well below the MCLs.

Table 3-2. Disinfection By-Product Levels under the Stage 2 DBP Rule (since 2012)

Site	Typical Source	HAAs, LRAA, ug/L			TTHMs, LRAA, ug/L		
		Minimum	Maximum	Average	Minimum	Maximum	Average
A-2	Tolt	31	44	37	26	41	32
A-3	Tolt	32	40	36	25	38	31
A-4	Tolt	26	41	31	28	42	33
B-3	Tolt	32	48	37	25	48	33
B-4	Tolt	27	42	34	29	62	41
C-5	Tolt	30	42	35	26	41	30
D-1	Cedar	28	37	32	22	36	30
D-2	Cedar	23	33	27	29	40	34
E-2A	Cedar	23	34	29	21	31	26
F-4	Tolt	30	40	34	25	41	31
G-1	Cedar	34	44	38	27	36	31
G-2	Cedar	18	33	22	28	37	33
Average				33			32

The SPU distribution system easily meets the MCLs a majority of the time, but occasionally has high results during by-passing of Lake Youngs, or when the Tolt Reservoir is drawn down low (followed by a large rain event). These events usually only affect results for 1 quarter, and SPU can help mitigate the impacts by switching supplies if needed.

3.3.1.5 Lead and Copper Rule

SPU's source and distribution water contains no significant amounts of lead or copper. Household plumbing, however, is often made of copper, and household systems can include components containing lead, such as lead-tin solder and leaded-brass fixtures. These components can leach lead and copper into the water. SPU reduces the risk of potential lead and copper leaching by continuously treating its source water to specific optimized corrosion control targets for pH and alkalinity.

The SPU Regional Lead and Copper Monitoring Program was divided into four sub-regions in 2005. Compliance for Seattle has been based on samples collected from the SPU's direct service area only since 2005. Compliance for the other sub-regions (Bellevue, Tolt Wholesale, and Cedar Wholesale) is based on results from those sub-regions.

The Lead and Copper Rule requirement is to be below 15 ug/L for lead, and below 1,300 ug/L for copper, with both at the 90th

percentile. Seattle's 90th percentile lead levels for the last two rounds of monitoring (2013 and 2016) were 3.0 and 3.1 ug/L, well below the lead action level. For copper, Seattle's 90th percentile levels for the two most recent rounds were 104 and 146 ug/L. These levels have allowed Seattle to conduct reduced monitoring for lead and copper. Fifty samples are now collected once every three years from qualified homes in the SPU direct service area. The next sampling period for the SPU sub-region will occur in 2019.

Because compliance for this rule is based on a regional program, SPU also tracks the 90th percentile levels for the other sub-regions. The lead 90th percentile for the last 6 years has been below 5.0 ug/L for all sampling rounds and sub-regions. The copper 90th percentile has also been well below the action level, generally less than 200 ug/L for each sampling round.

Compliance for the Lead and Copper Rule is also determined by Water Quality Parameter monitoring. This monitoring demonstrates optimized corrosion control treatment. SPU must maintain finished water pH and alkalinity within ranges set by DOH. The target pH for water leaving the Cedar and Tolt Treatment Facilities is 8.2, with a minimum of 7.9. The target alkalinity level for water leaving the Tolt Treatment Facility is 19 mg/L, with a minimum of 15 mg/L. The Cedar system does not have an alkalinity target. The minimum pH for the distribution system is 7.6, while the minimum alkalinity for the distribution system is 15 mg/L.

Compliance for the treatment plants is based on a calculated daily average. Compliance for the distribution system is based on monitoring at 10 locations distributed throughout the regional system, and currently occurs on a quarterly basis. This frequency is considered reduced monitoring. SPU qualifies for reduced monitoring by having maintained optimal corrosion control treatment for at least three consecutive years. Water Quality Parameters cannot be outside the ranges set by the state for more than nine days in any 6-month monitoring period. SPU has met this requirement since optimized corrosion control treatment was fully implemented in 2003.

3.3.2 Other Water Quality Monitoring

SPU conducts a range of other regulatory and non-regulatory water quality monitoring throughout the water system.

Source Monitoring. SPU conducts source monitoring for hundreds of potential contaminants, including inorganic chemicals, volatile organic chemicals, synthetic organic chemicals, and radionuclides. None of the SPU water sources have had chemical concentrations near the compliance limits for any of these contaminants.

Closed Storage Monitoring. Throughout the year, SPU monitors the quality of water within covered storage facilities as part of its routine water quality monitoring program. The information guides system operations, reservoir turnover, spot disinfection, and decisions about when to take facilities out of service for cleaning or other actions. Covered storage facilities are typically sampled bi-weekly for chlorine residual and microbial parameters. Closed storage with booster chlorination are equipped with online chlorine analyzers.

Taste and Odor Sampling. Taste and odor testing is conducted bi-weekly by a trained flavor profile analysis panel at SPU. The testing monitors and characterizes changes in tastes and odors associated with the source waters and water leaving the treatment plants. These test data are used to ensure source treatment performance criteria are met.

Emerging Contaminants. Emerging contaminants are not regulated, they are generally new to drinking water scientists, and there is typically limited information about their occurrence and health effects. EPA requires water systems to perform monitoring for some of these contaminants in order to learn about their occurrence. In addition, SPU has chosen to test for other emerging contaminants for its own information and to inform the public. Details of this monitoring are described later in this chapter.

Miscellaneous Monitoring. SPU also conducts extensive water quality monitoring at the Landsburg Diversion on the Cedar River, Chester Morse Lake, Lake Youngs, the Tolt Reservoir, and the Tolt Regulating Basin. Nutrients, algae, and other basic chemical and physical parameters such as pH, temperature, total organic carbon, ultraviolet absorbance, dissolved oxygen, reservoir stratification, and visibility throughout the water column are monitored. This water quality information is used to better understand the conditions in the water bodies, to learn about potential shifts or changes with significance to the drinking water supply, and to inform decisions about water treatment and other system operations.

3.3.3 Source Water Protection Programs

SPU's finished water quality is excellent, in part, because of Seattle's substantial efforts to protect its water sources. Those source protection efforts are described below.

3.3.3.1 Watershed Protection

The primary tool for maintaining source water quality is Seattle's extensive watershed ownership, which allows SPU to restrict human access and activities within the watersheds. SPU has adopted watershed protection programs for the Cedar River and South Fork Tolt River Municipal Watersheds, including the Lake Youngs Reservation, to ensure that SPU's source water remains of high quality and free from contamination. These programs are described in SPU's *Watershed Protection Plan*, which details Seattle's ongoing efforts to control activities that have the potential to adversely affect water quality in both of its surface water supplies. The November 2017 update of this plan was approved by WDOH in April 2018.

3.3.3.2 Wellhead Protection

While the two municipal watersheds supply nearly all of SPU's raw drinking water, SPU has access to groundwater from the Riverton Heights wellfield and the Boulevard Park well, located in the City of SeaTac, for seasonal and emergency use. As part of the *2001 Water System Plan*, SPU prepared and WDOH approved a wellhead protection program, including an inventory of potential contaminants. SPU regularly updates the potential contaminant inventory and sends notification letters to businesses handling or storing potential contaminants within or near the wellhead protection area, as well as to agencies that have influence over activities in the wellhead protection area, including the City of SeaTac and King County Department of Natural Resources and Parks, Groundwater Protection Program. These letters contain maps of the wellhead protection area boundaries and steps that businesses can take to protect the groundwater supply from contamination.

Since the *2013 Water System Plan*, the WDOH susceptibility designation for the Riverton Heights wellfield was changed to "high" from "low" due to the low level detection of dacthal, as described below. The Boulevard Park well designation remains "low" which allows SPU to reduce the frequency for monitoring of some parameters.

3.3.4 Source Water Quality Summary

Water quality characteristics of the raw water from each of SPU's sources, including its three wells, are shown in Table 3-3, below.

Table 3-3. Water Quality Characteristics of SPU's Source Water 2012-2017

Surface Water Sources	Cedar River/Landsburg		Cedar River/Lake Youngs Outlet		South Fork Tolt River/Regulating Basin	
Parameter and Unit	Average	Typical Range	Average	Typical Range	Average	Typical Range
Turbidity, NTU	0.6	0.3 – 1.2	0.4	0.2 – 0.6	0.6	0.2 – 0.9
Temperature, °C	9	5 – 13	12.9	6 - 20	8.7	3 - 14
pH	7.6	7.4 – 7.8	7.7	7.3 – 8.2	7.2	6.9 – 7.4
Alkalinity, mg/L as $CaCO_3$	22	15 - 30	20	17 - 23	6.5	5.8 – 7.1
Conductivity, umhos/cm	54	40 - 70	56	49 - 63	23	20 - 27
UVA (@254 nm), cm-1	0.026	0.01 – 0.04	0.017	0.01 – 0.022	0.05	0.04 – 0.06
Total Organic Carbon, mg/L	0.78	0.4 – 1.1	0.8	0.7 – 1.0	1.3	1.2 – 1.5
Total coliform, per 100 mL	433	66 – 1046	186	0 - 2400	124	4 - 305
Fecal coliform, per 100 mL	11	0 - 26	<1	0 - 1	<1	0 - 1

Groundwater Sources	Boulevard Well		Riverton Wells	
Parameter and Unit	Average	Typical Range	Average	Typical Range
Temperature, °C	11	10 - 13	11	9 - 12
pH	7.0	6.9 – 7.1	7.6	7.4 – 7.9
Alkalinity, mg/L as $CaCO_3$	150	140 - 170	88	84 - 94
Hardness, mg/L as $CaCO_3$	148		83	
Conductivity, umhos/cm	333	313 - 343	223	204 - 245

Contaminants of concern that have been identified in the groundwater sources include radon in all of the wells, and trace levels of dacthal mono- and di-acid degradates in the Riverton Wells which were first detected in 2003. Radon is a naturally-occurring element found in groundwater sources. Dacthal is an active ingredient in herbicides and is found in soils wherever it is used. These contaminants are currently not regulated by the EPA.

3.3.5 Source Treatment Facilities

As described below, treatment facilities located at both surface water sources and at the well locations are operated to provide high-quality finished water to the regional system.

3.3.5.1 Cedar Supply Treatment Facilities

SPU operates two facilities to treat Cedar River source water, the Landsburg Water Treatment Facility and the Cedar Water Treatment Facility.

Why is fluoride added to our water?

We add fluoride at the request of our customers for dental health.

Fluoridation of Seattle's water began in 1970 after a referendum vote in 1968 directed the City to fluoridate the drinking water. SPU provides a fluoride level of 0.7 parts per million according to requirements issued by the State Board of Health.

Public health, dental, and medical authorities overwhelmingly support drinking water fluoridation as safe and effective method of tooth decay prevention. The U.S. Centers for Disease Control have proclaimed drinking water fluoridation as one of the 10 great public health achievements of the 20th century. For more, see www.cdc..gov/fluoridation

Landsburg Water Treatment. At the Landsburg Water Treatment Facility, SPU fluoridates and chlorinates the Cedar supply. Prior to the construction of the Cedar Water Treatment Facility at Lake Youngs in 2004, the Landsburg Water Treatment Facility was the primary disinfection site for water from the Cedar River watershed. The chlorine addition at Landsburg now serves to minimize microbial growth in the transmission pipeline between Landsburg and Lake Youngs and to aid in the control of new organisms (e.g., algae from Chester Morse Lake and lower watershed) entering Lake Youngs.

In 2015, a new operations building was constructed at Landsburg and at that time the gas chlorination facilities were replaced with a liquid, sodium hypochlorite facility. The gas chlorine system was outdated and did not meet building, fire, and safety code requirements. The purpose of the new system remains the same as the former – to apply chlorine to the water – but the new system is safer for the treatment operators and surrounding environment. Along with the new building and hypochlorite system, the SCADA system was modernized and expanded.

Cedar Water Treatment Facility. The Cedar Water Treatment Facility uses ozone, UV light, and chlorine applied in series to ensure inactivation of *Giardia*, *Cryptosporidium*, and viruses. The ozone process also improves the taste and odor of the water from this source. Lime is added at the facility to reduce the corrosivity of the water. The facility has a capacity of 180 mgd.

The Cedar Water Treatment Facility is operated and maintained under contract by CH2M with oversight from SPU. The operations contract began in late 2004. In both 2019 and 2024, the 15- and 20-year marks of the contract, SPU will have the option to renew the existing contract for 5 more years, hire another operations contractor, or use SPU staff to operate the treatment facility. In 2029, the operations contract will expire and a new contract or new operations arrangement will be needed.

Recent upgrades to equipment at the Cedar Water Treatment Facility include work on the UV inlet valves and replacement of the SCADA system and PLCs.

3.3.5.2 Tolt Water Treatment Facility

The 120-mgd ozonation and direct filtration treatment facility for the South Fork Tolt River water began operation in 2001. The facility also provides fluoridation, chlorination, and adjustment of pH and alkalinity for corrosion control.

The Tolt Water Treatment Facility is operated and maintained by American Water CDM with oversight from SPU. The 15-year operations contract began in 2001 and, in 2016, SPU chose to exercise a provision to extend the contract for 5 more years. In 2021, SPU will again have the same 5-year contract renewal option. In 2026, the operations contract will expire and a new contract or new operations arrangement will be needed.

3.3.5.3 Well Field Treatment Facilities

Both well locations include sodium hypochlorite disinfection to provide chlorine residual in the distribution system, fluoridation, and sodium hydroxide addition for corrosion control. Although sodium hydroxide addition is not required, it makes the well water quality more consistent with treated water from the Cedar River, with which it is blended before delivery to SPU customers. Treatment equipment at the well sites is generally in very good condition.

3.3.5.4 Overall Finished Water Quality

The water quality characteristics of treated water as it enters SPU's transmission system are shown in Table 3-4.

Table 3-4. SPU's Finished Water Quality Characteristics

Surface Water Sources	Cedar/Lake Youngs (2012-2017)		Tolt River (2012-2017)	
Parameter and Unit	Average	Typical Range	Average	Typical Range
Turbidity, NTU	0.4	0.2 – 0.6	0.07	0.06 – 0.09
Temperature, °C	12.9	6 – 21	9.7	4 – 15
pH	8.2	8.1 – 8.3	8.2	8.1 – 8.3
Alkalinity, mg/L as $CaCO_3$	22	18 - 26	19	18 – 21
Conductivity, umhos/cm	65	57 - 73	60	57 - 62
UVA (@254 nm), cm^{-1}	0.012	0.008 - 0.016	0.008	0.007 - 0.010
Chlorine residual, mg/L	1.5	1.4 – 1.7	1.5	1.4 – 1.6

Groundwater Sources	Boulevard Park Well (2012-2015)[a]		Riverton Wells (2012-2015)[a]	
Parameter and Unit	Average	Typical Range	Average	Typical Range
Temperature, °C	11	10 - 13	11	9 - 12
pH	8.2	7.7 – 8.7	8.25	8.1 – 8.5
Alkalinity, mg/L as $CaCO_3$	124	122 - 126	82	80 - 84
Conductivity, umhos/cm	387	344 - 447	235	222 - 256
Chlorine residual, mg/L	1.5	0.9 – 1.7	1.4	1.2 – 1.6

[a] Wells are used infrequently, so data set is relatively small. Wells were not used in 2016 and 2017.

Why did we have to cover the reservoirs?

Federal regulations require that all treated drinking water reservoirs be covered. SPU installed floating covers on two reservoirs, and is replacing its other open reservoirs with underground structures that both improve the quality and security of our water system and provide 76 acres of new open space for everyone to enjoy.

3.3.6 In-Town Storage Facilities

SPU operates several water storage facilities downstream of its Cedar and Tolt Water Treatment Facilities, including covered reservoirs, standpipes and elevated tanks. SPU operates these facilities to ensure that water quality within the distribution system is protected. SPU has established a regular program of inspections for the reservoirs and reports the results of the surveys to WDOH upon request.

3.3.6.1 Reservoir Covering/Burying

SPU completed its open reservoir covering program, although the long-term use of two out-of-service open reservoirs is under evaluation. The approach for covering the open reservoirs was consistent with the *2007 Water System Plan*, and focused on replacing the SPU open reservoirs with new buried structures to improve water quality, increase security, and create new public open space opportunities. Although new park space was created on top of the new buried Lincoln, West Seattle, Myrtle, Beacon and Maple Leaf reservoir sites, the paramount purpose of these sites remains as the storage and distribution of city water supplies and the safety of the drinking water. The replacement projects represent a significant amount of effort and expense. Table 3-4 summarizes the covering program and completion dates.

Table 3-5. Schedule for Covering or Upgrading In-Town Open Reservoirs

Reservoir	Open Reservoir Size (million gallons)	Covered Reservoir Size (million gallons)	Completion
Bitter Lake	21.5	21.3	2001[a]
Lake Forest Park	60	60	2003[a]
Lincoln	20	12.7	2006
Myrtle	7	4.86	2008
Beacon	61	48.12	2009
Roosevelt	50	See below[b]	TBD
West Seattle	68	29.21	2010
Maple Leaf	60	61.06	2012
Volunteer	20	See below[b]	TBD
Total	367.5	237.25	

[a] Floating cover replacement options, including buried storage, are being evaluated as the floating covers approach the end of their useful life.

[b] Roosevelt and Volunteer Reservoirs were removed from service on April 1, 2013, following the completion of the new buried Maple Leaf Reservoir—see text below for more information.

The last two open reservoirs, Roosevelt and Volunteer, were removed from service in 2013. The need to retain emergency storage at these locations is being evaluated as part of SPU's water system seismic study that is currently underway. That analysis may indicate the need to keep these uncovered reservoirs for emergency storage, which would entail a different set of design and operations and maintenance considerations compared to the potable reservoirs in service. In the future, these reservoirs may be needed as potable water storage, in which case they would be covered.

Lake Forest Park and Bitter Lake Reservoirs were the first two reservoirs to be covered, receiving floating covers between 2001-2003. The floating covers were expected to have a useful life of 20 years. Recently however, at Lake Forest Park, the beginning of some degradation of the cover material has been noted, resulting in an increased number of repairs. SPU has initiated a project to replace the floating cover with a new cover. The schedule for the Lake Forest Park Reservoir cover replacement project construction is currently 2020-2021.

The Bitter Lake Reservoir cover is still holding up well, allowing a cover replacement for this facility to be deferred until after the completion of Lake Forest Park Reservoir cover replacement. Because of this property's topographic conditions and the need to maintain existing reservoir water surface elevation, SPU will explore a number of alternative replacement options in addition to the buried reservoir option similar to what SPU has constructed in other parts of the City. These alternatives will include other hard cover approaches, replacing the existing floating cover, and replacing the reservoir with one or two circular s tanks near street grade (surrounded by open space). While schedule for planning, design and construction has not yet been fully vetted, construction may begin in 2022-2023, or later, given the current good condition of the cover.

In collaboration with Seattle Parks and Recreation (and the City of Lake Forest Park, for that reservoir), SPU is conducting an analysis of the public open space and recreational opportunities associated with each of these reservoir upgrade/replacement options.

3.3.6.2 Water Quality Enhancements at Storage Facilities

Some of SPU's enclosed storage facilities were constructed with a common inlet and outlet, or were otherwise designed without considering the optimal water flow conditions needed to maintain water quality by avoiding stagnant conditions. When major maintenance or upgrades are performed on tanks and standpipes, such as interior painting, SPU has been making modifications to improve water-quality management when appropriate. Upgrade methods include separation of inlets and outlets, installation of mixing systems, multiple level sample taps, and sodium hypochlorite injection points.

3.3.6.3 In-Town Reservoir Treatment

Additional chlorination is provided at some of SPU's in-town storage reservoirs to ensure that chlorine residual is maintained in the drinking water supply until it reaches customer taps. SPU's addition of filtration treatment on the Tolt supply back in 2001, along with the reservoir covering program that is now complete, have reduced the amount of chlorine addition in the distribution system previously necessary. The treatment involves addition of sodium hypochlorite to increase the residual chlorine. At some reservoirs, hypochlorite is generated on-site, while at other reservoirs it is delivered to the reservoir site. The hypochlorite equipment is maintained and repaired on an ongoing basis; for example, pump repair and replacement of hypochlorite generation cells. A list of the chlorination facilities is provided in the treatment facilities inventory in the appendices.

3.3.7 Operations

SPU undertakes a number of activities to ensure that its customers receive high-quality drinking water. Operations activities include water quality monitoring, preventing or eliminating cross connections, responding to customer complaints, storage reservoir cleaning, testing and flushing water mains, and maintaining transmission pipeline water quality. Each activity is summarized below.

3.3.7.1 Comprehensive Water Quality Monitoring Summary

A comprehensive monitoring plan was updated in 2017 and is included as an appendix. The Comprehensive Water Quality Monitoring Summary covers the entire water system, from the watersheds through the transmission and distribution systems to the customer taps. The monitoring plan addresses the following:

- Monitoring requirements under state and federal drinking water regulations.
- Future regulations, which are currently under development at the federal level.

- Non-regulatory monitoring, which SPU conducts for informational purposes and to assist in operating the water system.
- Sampling procedures.
- Managing laboratory information.
- All parameters, locations, and frequency of monitoring conducted by SPU.

3.3.7.2 Cross-Connection Control Program

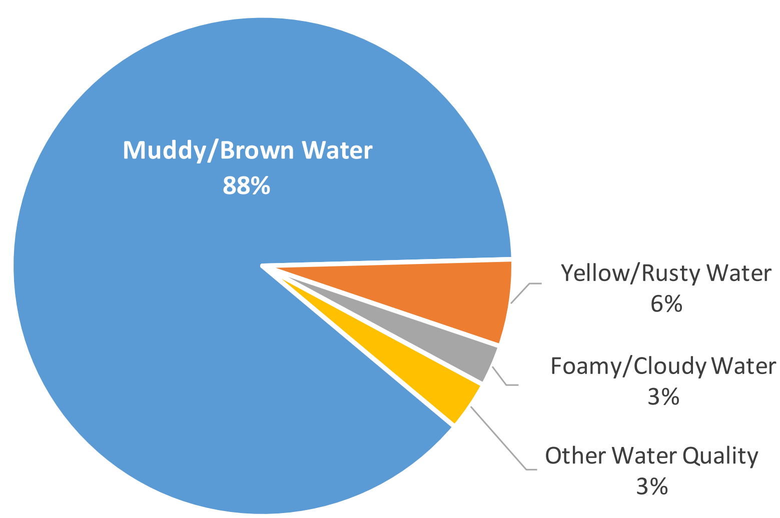
SPU implements a cross-connection control program to protect the quality of the drinking water supply from cross connections. Within Seattle and the retail service area south of Seattle, SPU's cross-connection program is a joint undertaking with Seattle's Department of Construction and Inspection (SDCI), the Seattle Fire Department (SFD), and Public Health Seattle-King County (PHSKC). Within the City of Shoreline, SPU works with Shoreline city staff members. The program implements all elements of Washington Administrative Code 246-290-490 and includes authority to require that backflow protection be installed or that any cross-connections be eliminated. If water supply protection compliance or backflow assembly testing compliance is not demonstrated by the customer, then SPU will lock out/disconnect the water service at the meter and assess fines to the customer's utility bill. The cross-connection control policy and procedures were included with the *2013 Water System Plan*.

Backflow assemblies for known existing potential cross connections and any new assemblies associated with construction are tracked for testing compliance by SPU. Additionally, SPU staff conduct proactive inspections of existing properties to identify possible cross connections. However, SPU does not have a comprehensive mechanism to identify and definitively confirm whether every individual service connection is free of cross connections. For example, lake water irrigation systems fall under the category of Unapproved Auxiliary Supplies (UAS). Lake front properties that have known UAS are required to have back flow assemblies and maintain annual testing on them, and SPU tracks testing status with these customers. Given there is not an absolute guarantee that every lakefront property with irrigation is documented, the approach to identify such UAS when a new water service connection with an irrigation system is installed. SPU staff then monitor these sites for backflow protection requirements. Additionally, private-side plumbing connections and other plumbing changes downstream of existing water service connections, such as irrigation systems, are evaluated and inspected by PHSKC plumbing inspectors. PHSKC share their findings, to include UAS occurrences, with SPU Utility Service Inspectors who in turn follow up with direct notice to the customer and enforcement as appropriate.

Under the cross-connection control program, SPU oversees more than 27,000 backflow assemblies owned by customers within SPU's retail service area. In 2009, SPU implemented a new database for management of the cross-connection control program, and starting in 2015 there were significant improvements made to both data management and field inspection efforts that have improved data and reporting accuracy, as well as allowed for expanded re-evaluations of known hazards.

3.3.7.3 Customer Complaint Response

SPU has procedures for responding to complaints and problems reported by its retail customers about drinking water quality. The vast majority of complaints concern discolored water, mostly described as muddy/brown but also as yellow/rusty. Discolored water comes from internal pipe rust and sediment getting stirred up. It is an inconvenience, but primarily represents aesthetic issues rather than contamination of the water supply. From 2011 through 2015, an average 1,500 water quality complaints were received per year. Figure 3-2, below, shows the breakdown of the types of complaints for that period.



Note: Data for 2011 thru 2015.

Figure 3-2. Types of Water Quality Complaints

SPU retail customers with water quality concerns, water service problems, or questions contact the SPU Call Center during normal business hours and the SPU Operations Response Center after hours and on the weekends. Calls that involve water quality concerns or that identify high priority problems–calls that concern public health issues or safety risks–are passed on to an inspector who will investigate the problem until it is resolved.

The process for receiving complaints puts the customer in immediate contact with SPU staff and provides SPU with up-to-date knowledge of where the complaints are coming from, the nature of the complaints or problems, and how many calls are being received from a given area of Seattle. SPU logs the complaint information in a computer system and is able to bring these complaints up on a map for further analysis. Because the cause of a problem is usually not known at the time a complaint is called in, improvements are planned to allow revision of complaint data after follow up with the customer so that if the probable cause of the problem is determined, it can be noted and tracked.

3.3.7.4 Transmission and Distribution Storage Facility Cleaning

A key to maintaining water quality after the treated water enters the transmission and distribution system is making sure that storage facilities are regularly cleaned. Cleaning requires draining of the facility and employs high-pressure washing equipment to wash walls and remove sediment buildup; then the facility is disinfected, refilled and sampled before being returned to service. Approximate cleaning frequency for closed storage facilities is shown in Table 3-6, below. These cleaning frequencies may be adjusted based on inspections. Facilities that store Cedar water are on a more frequent cleaning schedule than those that receive Tolt water because the Cedar supply is not filtered.

Table 3-6. Treated Water Storage Facilities Cleaning Schedule

Type of Reservoir	Frequency of Cleaning
Elevated tanks or standpipes	3-5 years - Cedar supply and/or if interior coating is in poor condition 10-15 years - Tolt supply
Hard-covered reservoirs	3 -5 years - Cedar supply Variable - Tolt supply[1]
Floating covered reservoirs	Variable – Tolt supply[1]
Floating covers (top of cover only)	1 time per year

[1]Cleaning frequency depends on dive inspection results.

3.3.7.5 New Water Main Testing

New mains are disinfected and tested as detailed in Section 7-11.3(12) of the City's *Standard Specifications for Municipal Construction*.

3.3.7.6 Water Main Flushing

The primary objective of SPU's water main flushing program is to improve water quality in the distribution system and to reduce customer complaints regarding discolored water. For the past decade, SPU has mainly conducted spot flushing in areas with low chlorine residual or in areas with a high number of customer complaints.

In 2016, SPU re-established a unidirectional flushing (UDF) program in the north end of West Seattle. Over the summer, crews flushed 21 miles of predominantly unlined cast iron pipe in the north end of the 498 pressure zone in response to numerous customer complaints of discolored water. The UDF program for West Seattle was developed from scratch and included the following items: purchase of new flushing equipment, water quality sampling and flushing training for the crews, coordination with drainage and wastewater staff to approve location for discharge of water, documentation and mapping of flushing loops, development of communication protocols for internal staff and public and collection of regular water quality samples throughout flushing program.

In the summer of 2016, SPU also conducted a pilot program using the Neutral Output Discharge Elimination System (NO-DES) technology in the Arbor Heights area of West Seattle. This truck-mounted system allows flushing of a water main without discharging water onto the ground. Hose is connected to two fire hydrants and water is pumped in a unidirectional pattern through two truck-mounted filter vessels. The pump can be manipulated to control velocity through the loop. On-board analyzers measure pressure, flow and turbidity. This system also allows the user to inject chlorine into the system if necessary. For the SPU distribution system, the NO-DES technology was effective, but not without problems. The roughing and polishing filters clogged faster than anticipated and slowed the overall progress. However, in three days, the crews flushed approximately 5 miles of pipe and removed an estimated 150 pounds of sediment.

In the fall and winter of 2016 and 2017, SPU participated in a Water Research Foundation study related to distribution system flushing. The objectives of the study included: determining the applicability of different flushing techniques for microbial control and mitigation; development of standard operating procedures (SOPs) for flushing and data collection; and development of cost versus benefit to support investment of a flushing program. SPU conducted a UDF pilot in the West Seattle 550 pressure zone and a conventional spot flushing pilot in the Beacon Hill neighborhood where low chlorine residuals are observed in the summer. For the study, SPU conducted several weeks of water quality monitoring in the two pilot areas to develop a baseline for a wide array of parameters (microbial, metals, nutrients and field characteristics). Similar parameters were collected and analyzed during the flush profile and at different intervals after the flush to determine how long any beneficial affects observed lasted in system. The results of this program are still being compiled by an outside consultant.

The information collected during all of the flushing work conducted in 2016 is currently being used to compile where SPU will go next in terms of a flushing program. The resources, in the form of crews and vehicles, to execute an expansion of this program would come from existing resources currently dedicated to system maintenance and new service taps. Expanding the flushing program beyond the current approach will require either the addition of new staff or a reduction in construction activity and new service tap requests that frees up existing crews. SPU is currently conducting a workload and resource analysis that will help inform next steps.

3.3.7.7 Water Quality in Transmission Lines

Large-diameter transmission pipelines composed of metal (e.g., steel, ductile iron, cast iron) are often lined with cement mortar to prevent corrosion and deterioration of the metal pipe wall. Cement lining of pipelines can cause the pH in the water to increase (i.e. the water to become more alkaline or basic) when a section of pipeline is taken out of service for repair or maintenance but kept full of water. Although pH is typically not a health issue, unless it becomes extremely low or extremely high, customers may find that water with moderately elevated pH tastes or feels different than that to which they are accustomed. Higher pH can also decrease the effectiveness of chlorine for disinfection. Additional customer concerns could include loss of aquarium fish or adverse impacts on commercial and industrial facilities.

For the temporary situations where water in transmission lines exhibits elevated pH, SPU established the following guidance:

- Water with pH up to 9.5 can be sent to the distribution system.
- If water in the pipeline has pH above 9.5, the pipeline will be flushed.
- In emergency circumstances, the SPU Water Quality Director may allow the pH 9.5 limit to be exceeded.

If future experience shows that the upper pH limit of 9.5 is inappropriate, this guideline will be revised.

3.3.7.8 Distribution System Water Quality

Water quality within the distribution system is monitored a variety of ways. The majority of this monitoring occurs as part of compliance with the Total Coliform Rule. Parameters include total coliform, *E. Coli*, chlorine residual, and water temperature. Total coliform and *E. Coli* results were covered previously in this chapter. Chlorine residual is measured each time a total coliform rule sample is collected. For any chlorine result less than or equal to 0.2 mg/L, a heterotrophic plate count (HPC) test is also conducted. Since 2012, there have been over 3100 HPC tests run on total coliform rule samples from the Seattle distribution system. HPC results for all of these samples have been below 500 cfu/mL, and less than 0.5% of the samples had HPCs above 10 cfu/mL. This indicates very good distribution system water quality, even when chlorine residual is low.

Chlorine residual is also monitored daily at several locations along the transmission pipelines, twice a month at finished water storage facilities, and as part of customer calls, new mains, flushing projects, and main break samples. On average, there are almost 1000 grab samples analyzed for chlorine residual each month. For all total coliform rule samples with chlorine less than or equal to 0.2 mg/L, an alert email is sent to several SPU staff within 24 hours. For any finished water storage facility sample with a chlorine less than 0.6 mg/L, the in-town treatment staff are notified, and the chlorine level is rechecked. If chlorine is less than 0.6 mg/L, the tank is boosted with additional chlorine.

There are a few locations within the distribution system that are known to have low chlorine, usually on a seasonal basis. Data for these locations are plotted each month to analyze short and long-term trends. These trends are used to make decisions on chlorine treatment levels for the primary treatment plants, and in-town re-chlorination systems at storage facilities. Generally, chlorine treatment targets are increased in the summer months when water is warmer, and decreased in winter months. These chlorine trends are also used to determine flushing needs. Areas around sample stands with chlorine consistently less than 0.2 mg/L are flushed whenever possible, during summer and fall months.

Other parameters that are monitored in the distribution system include temperature, pH, and conductivity. Average, minimum, and maximum temperature for the distribution system is calculated monthly, and generally graphed on a seasonal or bi-annual frequency. Conductivity and pH samples are collected throughout the distribution system at roughly 30 locations each week. The pH data is analyzed monthly to determine trends, and compared to treatment plant pH data when results differ from normal.

3.3.8 Maintenance

SPU developed an asset management plan (AMP) for its water treatment facilities at Cedar (Landsburg and Lake Youngs), Tolt, and Boulevard Park and Riverton Heights wells, as well as in-town disinfection facilities, in 2009 and updated in 2013. This AMP describes the infrastructure, their operations and maintenance, relevant service levels, repair and replacement needs, data needs, and other relevant asset information. Additionally, more detailed maintenance activities for the Cedar and Tolt Water Treatment Facilities are covered by the service agreements for those facilities. Some examples of projects at treatment facilities are the upcoming replacement of UV inlet valves at the Cedar facility and evaluation of alternatives for replacing the lime slaker system at the Tolt facility. Routine maintenance of the SPU Drinking Water Quality Laboratory facility is conducted by Seattle Finance and Administration Services. SPU staff complete maintenance, repair, and replacement of laboratory specific equipment and instrumentation.

3.4 Needs, Gaps, and Issues

In the past decades, SPU has made significant capital improvements to ensure that its water is of the highest quality while meeting current and future regulations. In particular, SPU's completion of the Tolt and Cedar Water Treatment Facilities has significantly improved SPU's water quality. However, these facilities are no longer new and will require replacement or rehabilitation of major equipment or components in the upcoming decades. In addition, SPU's activities to cover, bury, or decommission its open reservoirs also demonstrate SPU's efforts towards ensuring excellent water quality in its system.

There are always new challenges for SPU to confront as it strives to meet its high standards for drinking water quality, including changing regulations. The following sections summarize the needs, gaps, and issues facing the Water Quality and Treatment business area and describe the SPU plans to address them.

3.4.1 Water Treatment Facilities Major Maintenance and Potential Upgrades

The existing contracts for the Tolt and Cedar treatment facilities were initiated in 2001 and 2004, respectively, and were intended as long-term, 25-year service agreements. The current contracts cover operations as well as funds scheduled for major maintenance projects. After the contracts expire, it should be reasonably anticipated there will be some increased repair and replacement costs for aging components, such as the ozone generators and chemical piping, and potentially increased operational expenses under new service agreements. The Cedar supply remains unfiltered under the Limited Alternative to Filtration regulatory status. Should regulations or operational conditions change in the future such that filtration need to be added to the treatment process, capital needs would increase. These potential needs have been included in the long-term capital budget.

3.4.2 Future Regulatory Changes

The only regulations currently under development by EPA are for perchlorate and chromium, as well as Lead and Copper Rule (LCR) Long-Term Revisions. EPA has also proposed a rule regarding the use of lead free pipes, fittings, fixtures, solder and flux. The impacts that these regulatory changes could have on SPU are explained below.

Since the *2013 Water System Plan*, one additional staff has been added to the Laboratory Technician group whose primary role is collecting drinking water samples and conducting field data analysis. This need may expand in future years if regulatory sampling requirements increase.

3.4.2.1 Perchlorate

Perchlorate has not been detected in previous sampling, and SPU does not anticipate issues meeting any future perchlorate regulation.

3.4.2.2 Chromium

Total chromium and chromium 6 were included in testing conducted under UCMR3, described in the next section. The levels of total chromium found in SPU's drinking water ranged from <0.2 to 0.33 ug/L. The levels of chromium 6 found ranged from 0.063 to 0.17 ug/L. Since SPU's source waters have no industrial activities that would introduce chromium 6, it is assumed that the chromium 6 is converted from the naturally occurring chromium 3 during the disinfection process.

The current MCL for total chromium is 100 ug/L. Currently chromium 6 is not regulated, but EPA may decide to revise the regulations to include chromium 6 based on its final human health assessment. It is not clear when this assessment will be available.

3.4.2.3 Lead

The LCR Long Term Revisions have been under consideration for several years now. Part of the process included a white paper that provided examples of regulatory options, including lead service line replacement, improving optimal corrosion control treatment requirements, consideration of a health-based benchmark, potential for point-of-use filters, clarifications or strengthening of tap sampling requirements, increased transparency, and public education requirements.

Lead "whips" or "goosenecks" are short , flexible sections of pipe made of lead that were formerly used to connect a galvanized service to a water main.

SPU's compliance with the revisions will depend on which options are finalized. Most of the proposed options should have little to no impact to SPU's compliance status. The biggest change could be the inclusion of services with lead "whips" or "goosenecks" in the sampling pool. SPU's direct service area has an estimated 1000 services with lead whips, which were formerly used as short, flexible connections from a water main to a galvanized service. However, the location of the remaining lead whips is unknown within a group of about 4000 galvanized services within the age range in which lead whips were used. There are approximately 9000 galvanized services remaining overall.

It has been difficult to find services with lead whips in order to conduct the sampling. Also, if the options include required removal of all lead components, including whips, SPU would have to replace all 4000 galvanized services in the appropriate age range to ensure that all lead whips were removed. SPU's current approach is to remove the lead whips when replacing a service line for other reasons or when a lead whip is discovered. SPU is currently discussing the resource needs and time frame associated with potential proactive renewal of all remaining galvanized service lines, including those with potential lead whips.

EPA has also proposed a rule regarding the use of lead-free pipes, fittings, fixtures, solder and flux. The definition of “lead-free” was established in Section 1417 of the Safe Drinking Water Act as having a weighted average of 0.25% lead for wetted surfaces, and 0.2% lead for solder and flux. SPU has already done an inventory of the warehouse, and now uses only lead-free plumbing products. SPU also replaced certain types of large meters because of this new definition, as described in Chapter 4.

3.4.3 Emerging Contaminants of Concern

Emerging contaminants are not regulated, they are generally new to drinking water scientists, and there is typically limited information about their occurrence and health effects. Understanding the significance of emerging contaminants can be difficult and complex given that lack of clear data. EPA takes on emerging contaminants primarily through the Contaminant Candidate List and the Unregulated Contaminant Monitoring Rule. In addition, SPU has made its own efforts regarding some emerging contaminants in order to better understand the quality of SPU’s water supply.

3.4.3.1 Contaminant Candidate List

The majority of the CCL contaminants present relatively low concern to SPU.

The Safe Drinking Water Act directs EPA to publish a Contaminant Candidate List (CCL) every 5 years and EPA finalized the third list (CCL4) in 2016. It includes 97 chemicals or chemical groups and 12 microbiological contaminants. These contaminants occur or are anticipated to occur in public water systems. Contaminants on the CCL4 are not currently regulated and the list does not impose requirements on public water systems. EPA uses the list to prioritize research and data collection efforts to help determine if a contaminant should be regulated.

The majority of the CCL4 contaminants present relatively low concern to SPU because of its excellent source protection practices, modern water treatment facilities, and distribution system practices. Contaminants on the list that have been detected under UCMR3 include chlorate and vanadium. Two that may impact SPU and will be monitored under UCMR4 are manganese and cyanotoxins. SPU will continue to stay up to date on EPA regulatory determinations as well as participate in or stay informed on related studies and national occurrence of emerging contaminants.

3.4.3.2 Unregulated Contaminant Monitoring Rule

The Unregulated Contaminant Monitoring Rule (UCMR) is EPA's program for gathering public water system data on contaminants without current health based standards. Monitoring results are used for determination of future drinking water regulations. EPA requests or requires participation from a utility, depending on its size.

The UCMR monitoring rounds occur on a 5-year cycle, is largely based on the CCL, and the list may contain no more than 30 contaminants. SPU participated in UCMR 1 (conducted 2001-2005), UCMR 2 (conducted 2007-2010), UCMR3 (conducted 2013-2015), and will participate in UCMR4 in the 2018 to 2020 period.

Under UCMR3 monitoring, there were a total of five contaminants detected, and 23 contaminants that were not detected. These were reported in Seattle's 2015 Consumer Confidence Report. The detected contaminants were strontium, vanadium, total chromium, chromium 6, and chlorate. None of these currently have a regulatory limit, and it is not clear when they might be regulated in the future. The non-detected contaminants included several perfluorinated compounds, such as PFOS and PFOA, and several hormones (pharmaceuticals).

UCMR4 monitoring includes 10 cyanotoxins, 9 haloacetic acids, germanium, manganese, 9 pesticides, 3 alcohols, and 3 SVOC's. The only contaminants expected to be detected in SPU's UCMR4 monitoring are those we have already detected, which includes manganese, monochloroacetic acid, trichloroacetic acid, and dichloroacetic acid. The last three are currently regulated under the Stage 2 DBP Rule (covered earlier) as part of the HAA5's. SPU's current levels are below the required limits for HAA5.

3.4.4 Kerriston Road in the Cedar River Watershed

Kerriston Road is a King County road that traverses the northwest portion of the Cedar River Municipal Watershed within the hydrographic boundary for more than two miles. The road provides the only existing access to 322 acres of privately-owned property located outside the northern municipal watershed hydrographic boundary. WDOH has expressed concern about the potential public health and water quality impacts that could result from public use of the road. The 2009 acquisition of the 4,000 acres by King County and the Washington Department of Natural Resources in the Raging River area reduced the total area of privately-owned property accessed by the Kerriston Road by 84 percent, significantly reducing the scale of the potential future development threat and investment to acquire remaining properties.

In 2008 SPU conducted a feasibility study and cost estimates for acquiring the private properties accessed by the Kerriston Road. A portion of the property, about 148 acres, has been purchased. In 2011 SPU conducted a risk-cost analysis to determine if the cost of additional land acquisition to mitigate the risk of public access on the Kerriston Road was warranted. The analysis determined that the risk is extremely low and does not warrant the expenditures required to acquire the Kerriston properties. However, increased trespass in this area may prompt SPU to revisit the risk assessment in the future, and explore other approaches to risk mitigation besides land acquisition, such as entrance gates.

3.4.5 Lake Youngs Water Quality

Lake Youngs is a high quality, oligotrophic lake, meaning it has low nutrient content and low biological productivity. In recent years, SPU has observed some changes in Lake Youngs' water quality, particularly some new dominant algal species and less predictability in the timing of algal blooms. SPU held a workshop of limnology experts in 2009 to look more closely at the water quality data and determine if these changes in algae are indicative of more fundamental or permanent changes in the lake. The expert panel concluded that the types of changes observed are well within normal ranges and do not suggest any significant degradation of the lake.

Algal blooms have been observed in Lake Youngs since the 1920s. Prior to the startup of the Cedar Water Treatment Facility, these algal blooms would cause undesirable tastes and odors in the drinking water. The new treatment facility has eliminated nearly all these effects. Another effect of algae has been that over time it can accumulate on water filters used in homes and businesses. One of the newer dominant types of algae in the lake, *Cyclotella* (recently renamed *Lindavia*) has been found to produce fine filaments that not only clog filters, but accumulate on screens used in the water system. Because of the more problematic nature of these filaments, SPU strives to avoid this algae by bypassing Lake Youngs during a bloom. Since 2008, *Cyclotella* has produced an active bloom in Lake Youngs requiring bypass operations ranging from a few days to several months every year except 2015. Bypass operations are successful in avoiding use of the lake water except during the relatively short periods when the river water is unacceptable due to high turbidity or low UV transmittance from rain storms.

SPU has an extensive lake monitoring program. In response to the changes in the lake and recommendations of the expert panel, SPU added to that program in order to better characterize the lake. Water quality monitoring has been improved with the addition of some sampling and the installation of a remote floating water quality monitoring station on the lake. Six parameters (temperature, turbidity, pH, chlorophyll-a, dissolved oxygen, and conductivity) are measured multiple times each day at depths ranging from just below the surface to 30 meters.

3.4.6 Aquatic Nuisance and Invasive Species

Several aquatic organisms currently create or have the potential to create nuisance conditions in Washington state waters, including SPU's drinking water supplies. Once established in an aquatic system, infestations of these nuisance organisms can be difficult to control and impossible to eradicate, resulting in deleterious effects on water quality and water system operations.

Several aquatic nuisance species are specific targets of SPU's prevention program because of their proximity to the Cedar River, ease of invasion, or significance of impact. The invasive aquatic plant species include: *Eurasian milfoil*, parrotfeather, *Hydrilla*, *Brazilian elodea*, fanwort, water hyacinth, and others. The microorganism species include *Didymosphenia geminate* (didymo), Whirling Disease, and others. The animal species include the zebra mussel, quagga mussel, New Zealand mud snail (NZMS), Chinese mitten crab, and others. All of the aquatic nuisance plant species listed here have been positively documented in freshwaters of Washington State, including NZMS in Seattle's Thorton Creek.

SPU's "Prevention of Aquatic Nuisance Species Plan" outlines general responsibilities of field personnel working in any of the water supply reservoirs and watersheds. A detailed equipment decontamination procedure is included in the plan. In addition to preventing the introduction of aquatic nuisance species, the decontamination procedure is designed to prevent contamination by any biological organism (i.e., plant, animal, or microbe) that is either a native or exotic species and may be terrestrial or aquatic in origin, and by any chemical or petroleum product.

3.5 IMPLEMENTATION/ACTION PLAN

With the completion of the reservoir covering program, SPU has accomplished a great deal since the *2013 Water System Plan*. These actions have supported SPU in meeting drinking water quality regulations. Actions and projects identified in this chapter so that SPU will to continue to meet water quality requirements in the future include the following:

- Evaluate the need to retain non-potable emergency storage at Roosevelt and Volunteer Reservoirs as part of SPU's water system seismic study.
- Replace the floating covers at Bitter Lake and Lake Forest Park Reservoirs.
- Evaluate contract extension options for the Tolt and Cedar Water Treatment Facilities, and plan for upgrades as these facilities age.
- Review distribution system flushing practices and the level of resources allocated to flushing.
- Remove lead whips when these are found while replacing service lines for other reasons or when a lead whip is discovered.
- Stay abreast of EPA and WDOH regulatory development efforts and make adjustments as necessary to ensure that SPU's water quality service level is always met.
- Continue monitoring the science regarding new or emerging contaminants of concern, and continue to monitor source and finished drinking water to determine whether these contaminants are at levels of concern in SPU's supplies.
- Revisit the risk-cost analysis of public access on the Kerriston Road if there is an increase in trespass in the area to determine if additional land acquisition is the preferred approach for mitigating the risk of impairing Cedar source water quality.
- Continue to monitor and characterize limnological conditions in Lake Youngs as it affects Cedar supply operations and treated water quality.
- Bypass Lake Youngs to avoid problematic algae from entering the water system.

- Continue efforts to prevent aquatic nuisance and invasive species from being introduced into SPU's drinking water supplies.

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CHAPTER 4

WATER TRANSMISSION SYSTEM

SPU's water transmission system consists of the large diameter pipelines, storage facilities, pump stations, and related infrastructure that convey raw water to the treatment facilities and treated water to the distribution systems of SPU's wholesale customers and its own retail service area. The water transmission system consists of both regional and sub-regional facilities, as defined in the wholesale water contracts and shown in Figure 4-1.

4.1 ACCOMPLISHMENTS SINCE 2013 WSP

Since completion of the *2013 Water System Plan*, SPU has implemented the number of improvements to the water transmission system to improve reliability:

- Tolt Slide Monitoring and Management:
    - Acquired fee ownership of the land uphill from the active slide area to assure reliable re-vegetation and future logging (2013).
    - Removed an ineffectual large rock buttress to reduce unnecessary weight on most instable portion of slope (2014).
    - Constructed series of five large engineered log jams at the toe of the unstable slope to protect it from further erosion by the North Fork Tolt River (2015).
    - Cut out a buckled welded joint on Tolt Pipeline No. 2 (TPL2) and replaced it with a welded butt strap (2015).
    - Reset the position of the double ball expansion coupling which had reached maximum available deflection (2017).

- Cathodic Protection Program:
    - Bar Wrapped Pipe (BWP). Completed a pilot project that found actual costs of impressed current cathodic protection on BWP would be much higher than expected, and installed a passive cathodic protection system on a steel slope section.

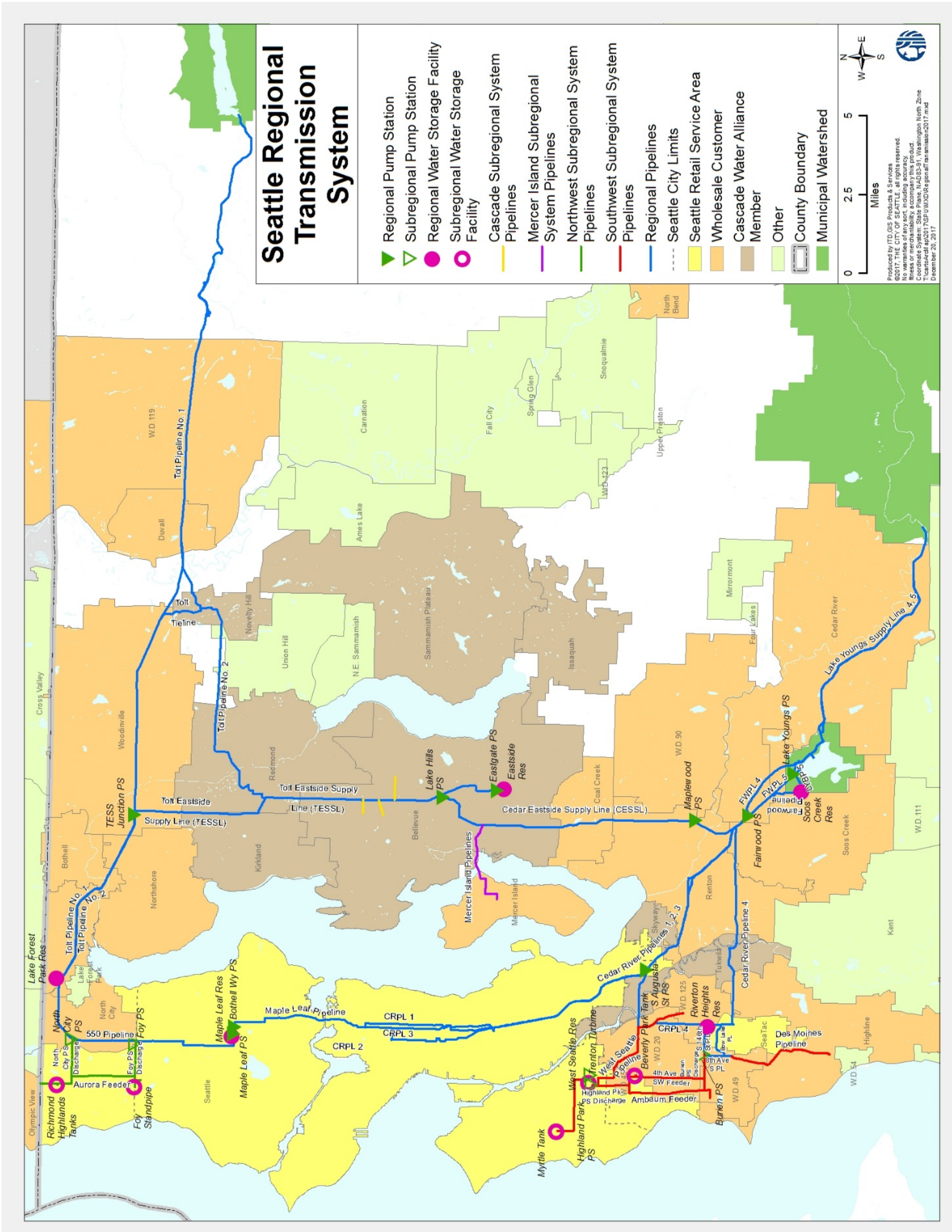

Figure 4-1. Seattle Regional Transmission System

  - Older Steel Pipelines. Replaced and expanded several depleted cathodic protection systems on older steel pipelines.

- Video Inspections: Acquired the necessary equipment and developed in-house expertise in remote controlled video camera internal inspections of water transmission pipelines.

- Wholesale Customer Meters:
  - Added two new wholesale services as requested by its whole sale customers primarily to improve retail service reliability within the wholesale customers' service areas.
  - Replaced several Rockwell turbine meters due to anticipated federal regulations banning re-installation of leaded brass components in contact with drinking water.

- Automation:
  - Added automated operation option for a remote-controlled ball valve controlling flow from CRPL1 into the Volunteer 430 Zone and into the south end of the 430 Pipeline, which improves system control to the Volunteer 430 Zone when the 430 Pipeline is out of service.
  - Installed remote control via SCADA on a diesel engine driven pump providing emergency backup to the Richmond Highlands 590 Zone to allow planned decommissioning of the small Richmond Highlands Tank and Foy Standpipe (possible future).

- Tanks and Standpipes:
  - Removed from service the small Myrtle Tank (#1).
  - Completed exterior recoating of Foy Standpipe.

4.2 SERVICE LEVEL PERFORMANCE

SPU has developed service levels that deal with the water service SPU provides to its wholesale customers. From a wholesale customer's perspective, the quality of water service can be measured by the amount of water flow provided, the pressure of that water, and the duration of any water system outages. Many of the drinking water quality service levels, as stated in the Water Quality and Treatment chapter, also apply to the transmission system. Table 4-1 summarizes SPU's service levels concerning service provision to wholesale customers.

Table 4-1. SPU's Service Levels for Managing Transmission System Assets

Service Level Objective	Service Level Target
Provide agreed-upon service to wholesale customers.	• Meet wholesale contract requirements for pressure and flow. • Limit each unplanned outage in the transmission system to be within the maximum outage duration set for each pipe segment (24, 48 or 72 hours).

These service level targets have been met since 2006. SPU's wholesale contracts require SPU to provide a minimum pressure and maximum flow rate at each wholesale service connection, with contingencies for emergency or unusual conditions. There have been no contractual compliance issues in recent years. Additionally, there have been no unplanned outages of the transmission pipelines that have exceeded SPU's service level for maximum outage durations.

4.3 EXISTING SYSTEM AND PRACTICES

SPU's regional and sub-regional water transmission systems include 193 miles of pipeline, 7 covered reservoirs, 14 pump stations, 7 elevated tanks and standpipes, and 131 wholesale customer taps with meters.

SPU's transmission system consists of the facilities that convey bulk water to wholesale customers throughout the regional service area, as well as to SPU's own retail service area distribution system. SPU's transmission system facilities include the large-diameter transmission pipelines, storage facilities, pump stations, wholesale customer meters, and other appurtenances that are used in conveying water from SPU supply sources to its wholesale customers and the SPU retail service area.

4.3.1 Existing Infrastructure

The regional and sub-regional water transmission systems include approximately 193 miles of pipeline, seven covered reservoirs, 14 pump stations, and seven elevated tanks and standpipes. Taps off of the major supply transmission pipelines from the Cedar and Tolt sources deliver water to 131 wholesale customer master meters and intertie locations. Wholesale customers operate their own distribution systems serving their own retail customers. Brief descriptions of the elements that comprise transmission system infrastructure are presented below, along with assessments of the condition of related assets. Inventories of the primary transmission system facilities are provided in the appendices.

4.3.1.1 Pipelines

SPU's transmission system contains approximately 193 miles of large-diameter pipelines. These pipelines convey untreated water from the supply sources to the treatment facilities and treated water from the treatment facilities to the wholesale and retail service areas. Figure 4-2 depicts the length of transmission pipelines by pipe barrel material installed by decade. The bulk of these pipelines are made of steel and bar wrapped pipe, with a small portion consisting of ductile or cast iron and concrete. As shown in Figure 4-3, these pipes vary in size from 20 to 96 inches in diameter, with some connections and bypasses being smaller.

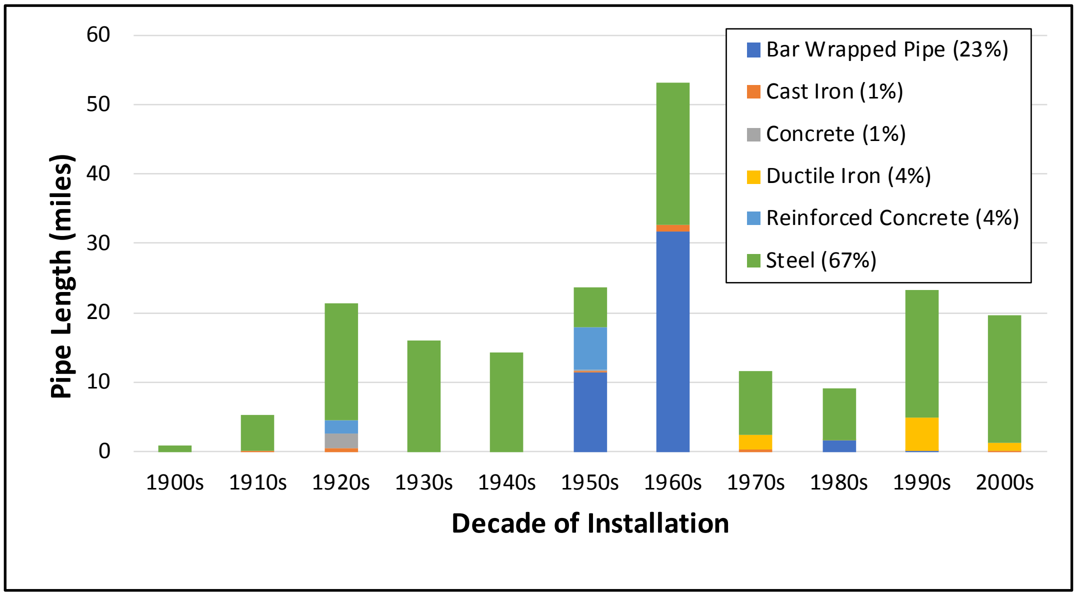

Figure 4-2. Type of Material and Decade of Installation for Transmission Pipes

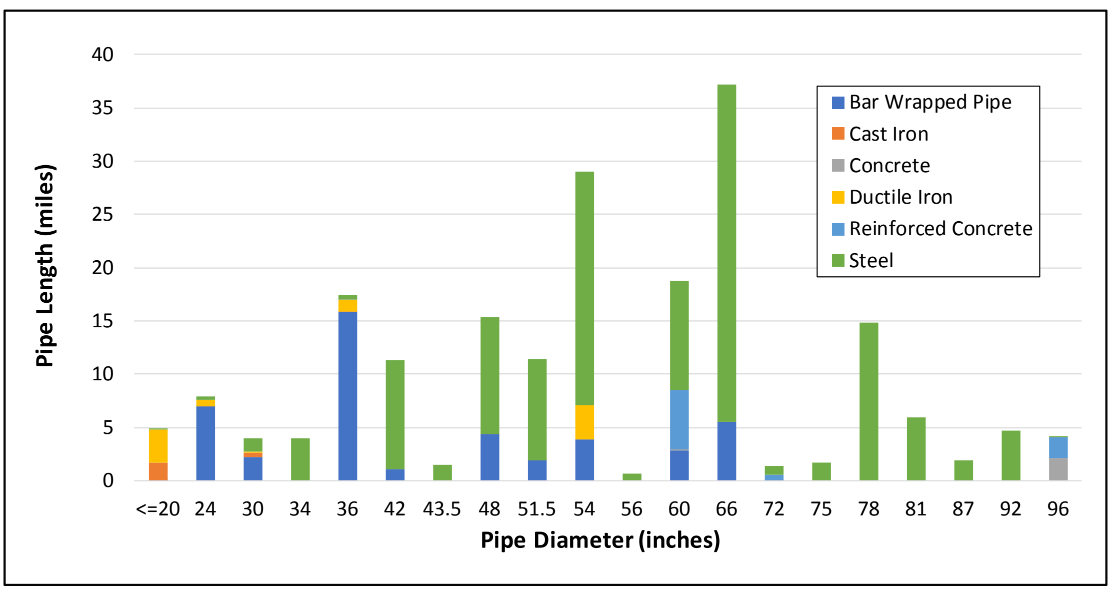

Figure 4-3. Breakdown of Transmission Pipeline Material by Size

SPU relies on the leakage history and visual inspections of its transmission pipes to provide an indication of condition. Leaks are identified by SPU crews that drive along the alignments of the transmission pipes weekly to look for water ponding on the surface. Leaks on transmission pipelines are rare, less than 0.016 leaks per 100 miles in recent decades, as in Figure 4-4, below.

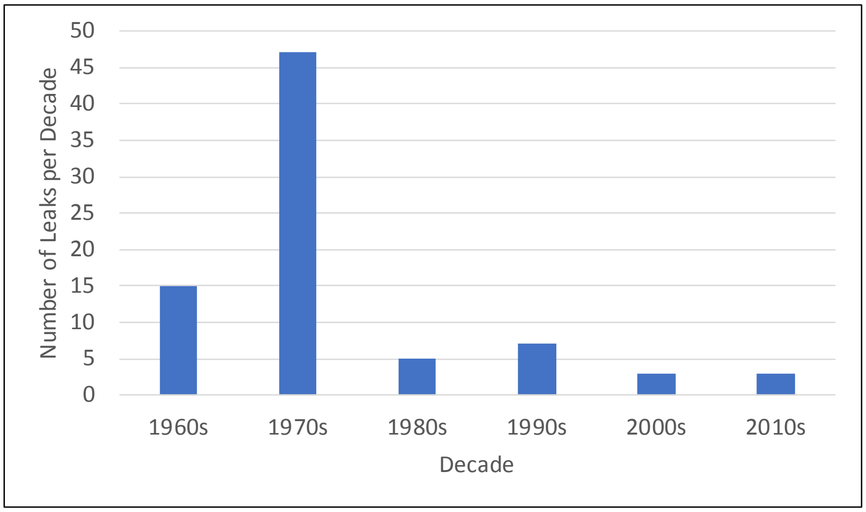

Figure 4-4. Number of Transmission Pipeline Leaks per 100 miles by Decade

Appurtenances related to the transmission pipelines are described below.

Line Valves. Line valves are typically 24-inch and larger, and are used to isolate a pipeline segment between two of them when the need arises. This could occur on a planned or emergency basis. There are about 150 line valves along SPU's transmission pipelines, and it is important that they operate properly when needed. Otherwise the length of pipeline to be out of service increases with each line valve failure.

Air Valve Assemblies (AVAs). There are about 340 AVAs along SPU's transmission pipelines. AVAs are typically installed at local high points and during normal operation let off-gassed air out of the water flow. During pipeline filling AVAs let the air displaced by the incoming water out, while during pipeline draining they let air in to prevent vacuum conditions. Many AVAs include more than one individual air valve.

Blowoffs (BOs). There are about 240 BOs along SPU's transmission pipelines. BOs are typically installed at local low points, and during normal pipeline operation serve no purpose. BOs allow the pipeline to be drained when necessary for inspection or repairs. SPU flushes and exercises each BO once a year to assure that the outlet valve off the pipeline remains operational.

4.3.1.2 Storage

> ***How long does it take the water to get to my house?***
>
> *It typically takes about two weeks for the water to get from the treatment plants to your faucet.*

SPU owns, operates, and maintains 15 storage facilities in its transmission system. All store treated water. An assessment of the condition of these facilities is described below.

Reservoirs. With completion of the Maple Leaf and West Seattle reservoir burying projects in 2010, all seven of SPU's treated transmission system reservoirs are covered. Except for Lake Forest Park Reservoir, these reservoirs are pre-stressed or reinforced concrete tanks. Lake Forest Park Reservoir was constructed in 1961-62, and its structure consists of a hypalon-lined, reinforced concrete slab with a floating cover that was added in 2002.

The condition of the reservoirs is typically assessed by inspecting the structures, the embankment stability, the valves and piping, and any internal lining, and measuring the leakage rate from the reservoirs. When evaluating leakage rates, SPU looks for increasing trends and anomalies that could indicate deteriorating conditions at the reservoir. SPU performs routine structural inspections of the tanks during cleaning activities to assess their condition and ensure that they meet regulatory requirements. Minor and major deficiencies are addressed through capital programs when they are identified.

Periodic inspections reveal that the storage reservoirs are in good condition. The leakage rates from Soos North and Soos South Reservoirs are low, 0.11 gallons per minute per million gallons (gpm/MG) and 0.04 gpm/MG, respectively, when tested in 2006-2007. Riverton Heights and Lake Forest Park Reservoirs had negligible leakage when last tested in 2016 and 2017, respectively. Eastside Reservoir has not been tested for leakage since completion of the sealant project, and West Seattle Reservoir has not been tested since it was replaced and seismically upgraded.

Standpipes and Elevated Tanks. The SPU water transmission system includes four elevated tanks, one standpipe, and two control works surge tanks to provide drinking water storage. The elevated tanks and standpipes were constructed between 1925 and 1959. They range in capacity from 0.3 to 2 MG. Myrtle #1 Tank was removed from service in 2012 and Richmond Highlands #1 Tank is planned to be removed from service for decommissioning as well. Foy Standpipe was evaluated for decommissioning, but near-term plans are for the tank to remain in service.

Tanks, including standpipes, are expected to have a service life of approximately 100 years with regular maintenance. SPU inspects the tanks visually to evaluate their condition and appearance. Structural inspections are conducted when tanks are drained for cleaning. Exterior sanitary inspections are conducted quarterly. The condition of the tanks is evaluated for the condition of interior and exterior coatings, as well as its valves and pipes. The condition of each tank varies, depending on its year of construction and the year the last interior and exterior coatings were applied.

SPU has an on-going tank and standpipe recoating program. The program involves safety modifications at tank sites, minor structural repairs, and interior and exterior surface preparation and coating following a regular maintenance cycle. Tank painting generally follows an approximate 25- to 30-year cycle. The timing will vary with need as shown by inspections and economic analysis. Myrtle Tank #2 was recoated in 2010, Richmond Highlands Tank #2 in 2012, and Foy Standpipe exterior in 2017. Beverly Park Tank is scheduled for recoating in 2019-20.

4.3.1.3 Pump Stations

SPU operates 15 transmission system pump stations. These pump stations are inspected regularly and equipment is repaired or replaced as needed. The condition of SPU's pump stations varies depending on the age and condition of their components, their usage, past maintenance or rehabilitation activities, and other factors. SPU is implementing a Reliability Centered Maintenance (RCM) program for its pump stations, which is described more fully in Section 4.3.3.3. Additionally, SPU intends to continue condition assessment work on its pump stations. This condition assessment, in conjunction with findings from SPU's RCM program, will be used to update SPU's pump station asset management plan.

4.3.2 Operations

Since completion of the Cedar Water Treatment Facility in 2004, water from the Cedar source is pumped from Lake Youngs into the treatment facility and flows through the treatment processes by gravity to the clearwells. From the clearwells, flow to Control Works is through two finished water pipelines (FWP) and flow control facilities (FCF). FWP No. 4 and FCF No. 4 deliver water directly to Control Works through the former Lake Youngs Bypass

No. 4 pipeline. FWP No. 5 and FCF No. 5 deliver water to the Lake Youngs tunnel through the former Lake Youngs Bypass No. 5 pipeline. From the Control Works, water flows to the four Cedar River Pipelines (CRPLs) for transport to wholesale customers generally east and south of Lake Washington, and to SPU's retail service area. A maximum of 200 mgd of treated water can be transmitted from the Cedar Water Treatment Facility clearwells through the Cedar River pipelines, but flow is constrained by the Cedar Water Treatment Facility treatment capacity of 180 mgd.

For the Tolt source, raw water is delivered from the South Fork Tolt Reservoir to the Regulating Basin either through the original South Fork Tolt Pipeline or through the Seattle City Light penstock pipeline installed in 1995. From the Regulating Basin, which serves as a break in the hydraulic grade line and as regulating storage for hydropower production, the raw water moves through a screenhouse and then into Tolt Pipelines Nos. 1 and 2 to the inlet of the Tolt Water Treatment Facility.

Treated water from the clearwells of the Tolt Water Treatment Facility flows west in the original and, in some places, replaced Tolt Pipeline No. 1 (TPL1) to the Duvall area where TPL1 bifurcates into TPL1 and Tolt Pipeline No. 2 (TPL2). TPL2 follows a separate southwesterly alignment and connects to the Tolt Eastside Supply Line in Kirkland. TPL1 runs west and connects to the north end of the Tolt Eastside Supply Line (TESSL) in Woodinville. West from the Woodinville area TPL1 and TPL2 follow the same original right-of-way to Lake Forest Park Reservoir. TPL2 is in active mode along this stretch whereas TPL1 is in standby mode at lower pressure. TPL1 is kept fresh by maintaining a low level continuous discharge directly into Lake Forest Park Reservoir whereas the main supply to the reservoir comes from TPL2. The Tolt transmission facilities are capable of hydraulically delivering 135 mgd through the treatment facility and downstream transmission pipelines; the treatment capacity is 120 mgd.

4.3.3 System Analysis

Comparison of forecasted demands and treatment and transmission capacity indicates that SPU has excess system capacity well into the future. As noted above, the treatment and transmission system capacity is constrained by the capacity of the treatment facilities. The total treatment capacity of the Cedar and Tolt systems is 300 mgd. Also, Seattle's wells could provide up to approximately 10 mgd. As noted in Chapter 2, peak day demands are forecasted to reach 273.5 mgd in 2039, well below the total system capacity.

In addition, SPU has performed extensive hydraulic modeling analysis, and has implemented capital improvements to reduce the likelihood of water service interruption in case of unplanned source outage. As a result, the SPU system is expected to be able to meet indoor and off-peak season water use of the entire service area, most likely including the wholesale customer demand, for at least seven days with only one of its two main sources available. In case of an unexpected source outage during higher demand periods, SPU plans to reduce water demand to indoor levels through aggressive public messaging in the media. More information on system performance under these scenarios is provided in the appendix on System Storage and Reliability Standard contained in the *2013 Water System Plan*. Such responses to emergency outages are covered in the updated Water Shortage Contingency Plan.

4.3.4 Maintenance

Proper maintenance of SPU's transmission system components ensures that SPU will be able to deliver reliable water service, reduce the risk of unexpected failures, and provide safe drinking water to its wholesale and retail customers.

SPU has prepared an asset management plan (AMP) for its transmission system. The AMP covers transmission pipelines and appurtenances, such as line valves, air valves, blowoffs, and pipeline right-of-way, and outlines maintenance and renewal strategies for each. Transmission pump stations, reservoirs and tanks are not covered in the Transmission System AMP since they share similar characteristics with their respective Distribution counterparts. Consequently, AMPs will be developed to cover all water pump stations, water reservoirs, water tanks and standpipes, etc.

Summaries of the maintenance strategies of the core transmission system components are provided in this section.

4.3.4.1 Pipelines

Maintenance strategies related to the pipelines and related appurtenances are described below.

Pipe barrel. Maintenance activities for the pipe barrel of water transmission pipelines are rather limited as the pipe barrel is typically buried. External inspections are performed only when opportunities present themselves, such as when a pipeline barrel is exposed for other work.

Lockbar pipe is manufactured by connecting two half-circle steel plates with an H-shape bar along each of the two longitudinal edges to form a full-circle pipe section.

In the recent past, internal inspections had been typically performed only when pipes are emptied and out of service for repairs or maintenance. Following that approach SPU inspected a short section of decommissioned pipe made of lockbar barrel, riveted joint pipe. The pipeline had been lined with cement mortar in 1949, and was therefore thought to be in good condition internally. The inspection revealed areas of concentrated corrosion along the lockbar where the cement mortar lining had spalled due to the lockbar itself.

The implication of this unexpected discovery is that corrosion along a longitudinal straight line of the lockbar would eventually create a weakened longitudinal cross section along which catastrophic failure could occur. Lockbar pipeline with corrosion along the lockbar may not fail like a typical steel pipeline with increasing incidence of small leaks. Even if external leaks do occur first, and cause the pipe to be exposed, the leak repair is unlikely to reveal much about potential internal corrosion along the lockbar. Lockbar pipe therefore warrants special attention in the near future to determine the extent of mortar spalling by internal visual inspections, and to repair or rehabilitate affected areas.

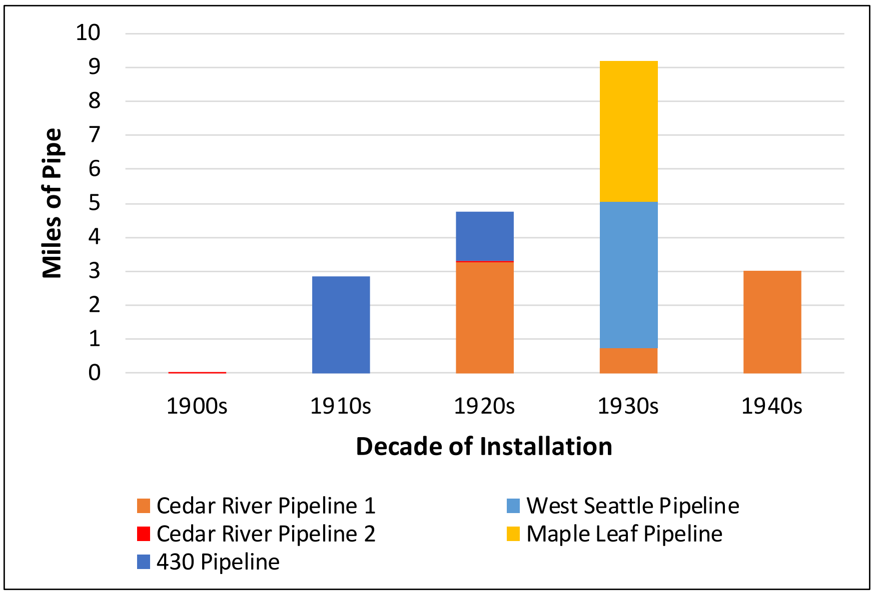

Figure 4-5. Lockbar Pipe by Decade of Installation

To that effect, SPU developed internal video inspection expertise in house, and now plans to perform systematic pro-active internal video inspections. Pipeline segments will be taken out of service and drained solely for the purpose of internal inspection. Internal video inspections of transmission pipelines are projected to be the main maintenance activity related to the pipe barrel for the next 10 years.

Lockbar pipelines will be inspected first, and to date 3.7 miles of 42-inch lockbar pipeline have been covered. The spalling problem was found to be present randomly along 25-30 percent of the length of the pipe barrel. A rehabilitation project is expected to be completed by 2020 for that particular pipeline. SPU operates 19 more miles of lockbar pipelines, and plans to internally inspect all over the next decade.

Line Valves. SPU maintains and exercises each line valve once a year to assure it operates as intended when needed. Deficiencies found are then corrected as soon as practical. The correction of some deficiencies, including replacing failed line valves that can no longer be repaired, requires the pipeline to be empty, which may take several years to procure parts for and schedule.

Air Valve Assemblies (AVAs). SPU maintains and exercises each AVA once a year to assure that it does not leak, and that air is let into the pipeline when necessary.

Blowoffs (BOs). SPU flushes and exercises each BO once a year to assure that the outlet valve off the pipeline remains operational.

4.3.4.2 Reservoirs and Tanks

Storage facility cleaning is performed to remove sediment, debris, and/or microbial growth. Cleaning is done on a scheduled basis or when water quality inside the storage has declined, as evidenced by regular water quality monitoring. The cleaning schedule is explained in the Water Quality and Treatment chapter.

4.3.4.3 Pump Stations

SPU's RCM program focuses on the function, failure mode, and criticality of a component to determine the frequency and type (i.e., preventive, predictive, or corrective) of maintenance to perform. Maintenance activities at water pump stations ensure that the stations continue to operate with minimal loss of function, thereby reducing the likelihood of customer outage, loss of pressure, and potential introduction of pathogens into the distribution systems. SPU performs three types of maintenance activities for its pump stations as described below.

Preventative Maintenance. Preventative maintenance is maintenance which is carried out on a routine basis on elapsed time schedules or equipment run-time hours. Preventative maintenance is designed to eliminate routine failures.

Corrective Maintenance. When preventative maintenance tasks or other data indicate minor equipment malfunctions, corrective maintenance is performed. This type of equipment malfunction does not restrict normal operation of the pump station.

Emergency/Reactive Maintenance. Emergency maintenance is generally carried out when a piece of equipment has failed and the need to restore its performance is critical. The criticality of each pump has been predetermined and incorporated into SPU's computerized work management system to ensure that repair of these facilities receives higher priority than other, non-critical repairs and that critical facilities are quickly put back into service.

4.3.4.4 Wholesale Customer Meters

SPU owns and maintains 131 wholesale water meters at intertie locations with wholesale customer systems that measure usage and provide a basis for billing wholesale customers. Wholesale customer meters are 3 to 24 inches in diameter and are classified as "large meters." SPU's policy is to install, test, and maintain all customer service water meters in such a way as to meet the accuracy standards of the American Water Works Association (AWWA). SPU's meter testing and maintenance practices are described below.

The most significant change to SPU's wholesale meters since the *2013 Water System Plan* has been the replacement of lead containing brass turbine meters made by Sensus/Rockwell. Anticipated, new federal rules would prohibit the re-installation of leaded brass components in contact with drinking water once removed for any reason. SPU used to test these turbine meters by first replacing the measuring element in the field with a measuring element that has been bench tested and known to be accurate. The removed measuring element is then tested on the bench, and repaired as needed. This approach of swapping measuring elements was rendered impossible by the new lead-free brass definition which made the turbine meters untestable as test ports were not available downstream of them. Consequently, they were replaced with new battery powered electronic meters.

Meter Testing. SPU's approach to field testing of wholesale meters varies with the type of the meter. At present, there are two types of meters on SPU's whole sale services: compound/mechanical and electronic. The electronic meters can further be subdivided into alternating current (AC) powered and battery powered, each with a different testing strategy.

SPU tests its compound meters in the field by running the same volume of water through the meter under test and a reference meter tester, and comparing the volumes registered on each. Most compound meters are tested once a year, except the 15 highest use meters which are tested twice a year.

AC powered electronic meters are magnetic flow meters installed in the early 2000s with no test ports downstream; consequently, they cannot be tested against a reference meter. SPU contracts with the manufacturer annually to have the meters checked and certified using electronic diagnostic tools.

Battery powered electronic meters are magnetic flow meters installed recently with test ports downstream. SPU tests them against a reference meter annually regardless of consumption.

Meter Maintenance. SPU performs scheduled maintenance activities on large meters based on a variety of criteria including manufacturer recommendations, AWWA standards and consumption history. Unscheduled maintenance activities are performed in response to billing questions and customer requests. Typically, maintenance is performed at the time of testing.

Meter Replacement. Meter replacement includes pipe work and vault modification necessary to bring meter installations up to current standards for accuracy, safety, and maintenance access, and to ensure that the impacts of supply interruptions due to meter maintenance and testing are maintained at levels that are acceptable to customers. Some upgrades may include relocation of the meter installation. Meter replacements are discussed with the customer prior to scheduling to ensure current and future customer needs are met, as well as to ensure proper meter application and coordination to limit customer impacts. Reasonable efforts are made to coordinate meter upgrade work with local street improvement projects to minimize street cuts.

4.4 Needs, Gaps, and Issues

SPU has identified several needs, gaps, and issues for the transmission system. Needs include mitigating the risk of pipeline failure in the Tolt slide area, extending the life of transmission pipe using cathodic protection, air valve improvements for public health protection, lockbar pipe inspections and rehabilitation, and finishing up a water system seismic vulnerability study that will lead to implementing a more focused seismic capital improvement program to improve system resiliency and performance following a major earthquake. The following subsections summarize these issues and SPU's approach to addressing them.

4.4.1 Tolt Slide Monitoring and Actions

In the mid-2000's, Tolt Pipelines 1 (TPL1) and 2 (TPL2) were found to traverse through an historic landslide complex located between the Regulating Basin and Tolt Water Treatment Facility. The slow-creeping landslide had been dormant, and therefore unknown, since the pipelines were installed in the 1960s and late 1990s. However, the landslide became reactivated in approximately 2000. The slope movement has affected both pipelines: the ground in the vicinity of TPL2 has been moving 1-3 inches per year, and near TPL1 it is about one-half of that rate. Since discovery of the slide, TPL1—the much older of the two pipelines—has been very limitedly used to reduce the risk of new small joint leaks triggered by the ground movement. In addition, SPU initiated an ongoing survey and inclinometer monitoring program to track the slide and pipeline movement.

In 2009, a 48-inch double ball joint expansion sleeve was installed on the newer steel TPL2 to allow the pipeline to better accommodate slope deformation. By 2016 it was determined that the maximum distension of the joint had been reached. In July 2017, the joint was excavated and this expansion sleeve was reset to provide new range of movement for another five to ten years.

Meanwhile SPU has also conducted extensive geotechnical and seismic modeling to better understand the nature of the slide, and to assess the risk of sudden catastrophic large slope movement, especially in an earthquake scenario. The results of that work are encouraging, in that it appears a large sudden movement of the slope is highly unlikely. Ongoing slow creeping movement now appears to be the main concern.

In the context of ongoing detailed geological and groundwater monitoring, SPU is completing an options analysis that is intended to provide strategic direction for managing this problem, including any recommended capital project work.

As noted in section 4.1 earlier, SPU has also invested in projects to protect the toe of the slope from river erosion, and to reduce the weight of material driving the slope movement. It is also of some significance that the forest atop the instability is now becoming more mature following the harvest of the upland areas sustained in the mid-1990's. This should increasingly benefit slope stability through increased evapotranspiration by trees, resulting in fewer contributions to groundwater saturation of the slope.

Cathodic protection is a method used to minimize the rate of electrochemical corrosion of metallic materials, such as pipes, by shifting the corrosion process away from the metal to be protected and onto other more easily corroded "sacrificial" pieces of metal.

4.4.2 Cathodic Protection Program

SPU's transmission system consists primarily of two types of pipe, distinguished by their material and their distinct modes of failure:

- Bar Wrapped pipe can have sudden, unexpected, and sometimes destructive failures.
- Steel and ductile iron pipelines usually develop increasing numbers of leaks that are detectable and repairable well before catastrophic failure.

Failure issues associated with each type of pipeline differ because of their different failure modes and risks. Cathodic protection systems have been shown to extend the life of pipe and reduce the risk of failures for both types of pipes, as described below.

4.4.2.1 CP For Bar Wrapped Pipe

Bar Wrapped Pipe (BWP), also known as C303 Pipe, is manufactured by lining the interior of a thin-walled, steel cylinder with concrete mortar, then wrapping the exterior of the steel cylinder with steel reinforcing bar under slight tension enough to assure the bar is snug against the cylinder. The entire exterior is then coated with concrete mortar to provide additional stiffness and corrosion protection. BWP derives its strength from the combined strength of the steel cylinder and the spiral wound bar. However, should the bar corrode or deteriorate to the point where it can no longer take its design share of the hoop stress, the pipe cylinder can fail, sometimes catastrophically.

SPU's only sudden BWP failure due to pipe deterioration occurred in 1987 on TPL1[1]. The failure caused significant flooding and property damage. Detailed investigations revealed that the failure was caused by a type of corrosion known as hydrogen embrittlement, where chemical reactions with hydrogen ions in the soil cause the steel to turn brittle and lose its strength. The chemical process is irreversible, and the only remedies are to replace the pipe or to use it as a casing and install a new, smaller-diameter, fully competent pipe inside (called slip-lining). Only the

[1] A second catastrophic failure of TPL1 occurred in 1988, however that was triggered by a high-pressure surge caused by human error.

steel that was used for the spiral wrap by one particular pipe manufacturer (United Pipe) was found to be susceptible to hydrogen embrittlement. In SPU's system, all pipe made by United and prone to hydrogen embrittlement has been either replaced or slip-lined with new steel or ductile iron pipe.

Bar Wrapped Pipe is manufactured by lining the interior of a thin-walled, steel cylinder with concrete mortar, then wrapping the exterior of the steel cylinder with steel reinforcing bar.

Investigations in the early 1990s through dig-up inspections of the rest of the BWP pipelines revealed that these lines are still in serviceable condition although some deterioration existed. In an effort to mitigate further deterioration of BWP, SPU piloted a cathodic protection project. Cathodic protection (CP) has the effect of arresting or greatly reducing the rate of metal corrosion in pipelines. The pilot installation proved successful and showed that a single deep cathodic protection well can protect one to three miles of concrete cylinder pipe with fairly even electric potential distribution.

The likelihood of catastrophic failure of BWP varies across pipeline sections. In some places the steel cylinder is thick enough to withstand normal working pressure even if the entire bar corrodes away. In 2012, SPU performed comprehensive analysis of its BWP transmission pipelines to determine the probability and consequence of catastrophic failure in order to best focus its CP installation efforts. It was found that most pipe sections have a steel cylinder factor of safety above 1.2, which would make catastrophic failure unlikely. Only the Tolt Eastside Supply Line was found to have significant segments with a factor of safety below 1.2, however, the bar wrap of these segments is very thick (3/8-inch and greater), making it unlikely for it to completely corrode through given the current age of the pipe (60 years).

Nonetheless, in 2013, SPU initiated a pilot project to install a new impressed current CP system on the highest risk segment of the Tolt Eastside Supply Line (TESSL), risk being the product of probability of failure and consequence of failure. The pilot project stalled over the complexity and much higher costs related to the joint bonding, draining the pipeline for the internal work, and subsequent disinfection prior to return to service. The project was scaled back significantly and its limited success suggests that new CP installations on a larger scale for BWP are not economical at present as the pipe is still relatively new. CP remains a useful tool for managing BWP pipelines under the right circumstances, such as passive CP systems on more deteriorated short sections or individual pipe sticks.

In addition to selective use of CP, SPU plans to reduce of risks of failure in its BWP lines using the following strategies, which were identified in the *2007* and *2013 Water System Plans*, and are still current:

- **Review and update response plans:** In the unlikely event that a failure does occur, plans are in place to respond expeditiously and repair the pipe and place it back on line, as provided in the outage service levels.

- **Stay current on new pipeline inspection technologies:** When high tech tools and methods for non-destructive, no-dig condition assessment for this type of bar wrapped pipe becomes available, SPU would be able to inspect pipe sections. After such inspections, SPU would then apply asset management principles to decide if any should be replaced or protected with CP.

4.4.2.2 CP for Steel and Ductile Iron Pipe

Steel and ductile iron pipelines differ significantly from BWP in that they develop increasing numbers of leaks well before catastrophic failure. In most cases, leaks can be repaired without depressurizing or taking the pipeline out of service. An aging steel pipeline is more likely to present an economic concern due to its increasing repair costs well before its structural strength is imperiled.

When the incidence of leaks on a steel pipeline starts to increase, installing cathodic protection can stop further increases. SPU has used cathodic protection, coupled with internal cement mortar relining, on numerous sections of steel pipelines where either significant leaks have been experienced in the past or may be expected in the future due to corrosive soils.

Cathodic protection is a viable alternative to replacement, and in 2016 SPU developed an economic model to determine when CP is a lower cost alternative to eventual pipeline replacement. The 61 miles of older steel pipelines will continue to be the focus of the expansion of SPU’s cathodic protection program for the next 30-40 years, with a goal of replacing depleted existing systems and adding new systems until full coverage is attained along the 61 miles by 2055. To accomplish this goal, SPU plans to increase annual capital funding for CP.

4.4.3 Lockbar Pipelines Inspection and Rehabilitation

The most significant new issue for the transmission system since the *2013 Water System Plan* is the unexpected discovery of

Lockbar pipe warrants special attention to determine the extent of mortar spalling by internal visual inspections, and to repair or rehabilitate affected areas.

corrosion along the lockbar of lockbar pipelines triggered by cement mortar spalling. Lockbar pipelines described in 4.3.3.1 are now viewed as potentially prone to catastrophic failure, causing SPU to take a proactive approach to their condition assessment and rehabilitation.

SPU has internal video inspection expertise in-house, and plans to perform systematic pro-active internal video inspections as pipeline segments are taken out of service and drained solely for the purpose of internal inspection. Internal video inspections of transmission pipelines are projected to be the transmission system maintenance focus for the next decade.

Following the inspections, each pipeline segment would likely need to be rehabilitated or replaced. At a minimum, the spalled cement mortar areas must be relined to prevent further deterioration.

4.4.4 Seismic Study and Improvements

At the time of writing this plan, SPU is anticipating completion of an update of a 1990 seismic vulnerability assessment that was performed by Cygna Energy Services. This assessment update accounts for changes in the understanding of the seismic hazards that threaten the Puget Sound region. Additionally, the 2017 update assessment emphasized pipeline performance and overall system response.

Findings to-date indicate that although some important “vertical” facilities such as reservoirs, tanks and pump stations are vulnerable, the most significant effect on water system response will be pipeline damage. Damage to transmission and distribution system pipeline damage is expected to severely disrupt system operation and delay system restoration. To mitigate the effects of this pipeline damage, SPU’s strategy will be to employ both short-term measures to manage the current vulnerability of the SPU water system and long-term measures to reduce the vulnerability of the SPU water system. SPU’s mitigation approach will include:

<u>Measures to be implemented over next 5 to 25 years:</u>

- Implementing isolation and control measures to mitigate the effects of pipeline damage on system-wide water pressure.
- Improving earthquake emergency preparedness and response planning to reduce recovery time.
- Implementing seismic upgrades for the most critical reservoirs, tanks, pump stations and support facilities.

- Implementing seismic upgrades for the most critical transmission pipelines through seismically vulnerable areas.

<u>Measures to be implemented over next 5 to 50+ years:</u>

- Upgrading one of the existing Cedar transmission pipelines to make it earthquake-resistant and increase the certainty that a minimal demand could be supplied to SPU's direct service area following a major earthquake.
- Adopting new pipeline design standards that will specify use of earthquake-resistant pipe when pipelines are replaced in permanent ground displacement susceptible areas.
- Continuation of critical facility and transmission pipeline upgrades.

The timing for the longer-term mitigation elements will vary. Facility upgrades and construction of a seismic-resistant Cedar River transmission pipeline would be targeted for completion in 50 years. Because replacement of most distribution pipelines would only occur at the end the pipelines' useful lives, replacement of pipelines in permanent ground displacement susceptible areas would take approximately 100 years.

4.4.5 Other Upgrades and Improvements

Other transmission system needs include ongoing upgrades and improvements to air valve assemblies and pump stations.

4.4.5.1 Air Valve Assemblies Upgrades

Approximately 70% of SPU's transmission pipelines air valve assemblies (AVAs) do not meet two requirements that were not in effect when they were built. One requirement is for the air admitting orifice of the air valves to be tight-lined above ground to avoid potential cross connection. Older AVA designs place the air valves in a below grade vault, usually without drain. If the vault were to flood with ground water and/or surface runoff, and the air valve were to open due to lower pressures in the pipeline, then the potentially contaminated water in the vault would enter the pipeline. The second requirement is for a minimum of 24-inch access hole into any confined space, including underground vaults with AVAs.

SPU has an on-going capital improvement program to gradually bring its AVAs to current standards. Several AVAs are completely overhauled each year to address all mechanical, sanitary, and safety concerns. This includes replacing the air valves themselves if obsolete, tight-lining the air side of the air valves to an above-ground location to eliminate cross connection potential, replacing the vault lid to improve access, and in some cases rebuilding the entire vault when necessary.

4.4.5.2 Pump Station Improvements

Through the normal maintenance and inspection program of pump stations, SPU staff has identified deficiencies at several transmission pump stations that will be corrected through ongoing maintenance and capital improvement programs. The highest criticality stations with the highest priority deficiencies are:

- Burien Pump Station: Contactors are obsolete; transformer is aging and is obsolete; diesel pump needs shielding (noise containment and protection from elements) or replacement with generator; and discharge valves.
- Maple Leaf Gate House/Pump Station: Piping is experiencing some significant corrosion.
- Augusta Gate House/Pump Station: Piping is badly corroded.
- Trenton Turbines: Turbines require rehabilitation.
- TESS Junction: Evaluate replacement of electric pump starter.
- Lake Youngs: Two aging PLC’s.
- Eastgate Pump Station: Piping is significantly corroded.

4.5 IMPLEMENTATION/ACTION PLAN

As described earlier, the primary issues facing the transmission system for the next decade include mitigating pipeline risks in the Tolt slide area, extending the life of existing pipelines through continued deployment of cost-effective cathodic protection systems, inspecting and then rehabilitating the lockbar pipelines, and improving the seismic resilience of our water system and its pipelines. To address those and other issues discussed in this chapter, SPU has identified the following major implementation and action plan items:

- Mitigate the risk of pipe failure in the Tolt slide area through continued slope monitoring, geotechnical data collection, periodic internal inspections, and biannual leak testing, and by implementing additional capital improvements and pipeline stress relief measures when appropriate.
- Continue to implement cost-effective cathodic protection projects for older steel transmission pipelines to protect them

from corrosion and extend their service lives well into the future.

- Perform internal video inspection of all lockbar pipelines, and develop a specific plan for their rehabilitation, slip-lining, or replacement, depending on pipeline condition, capacity, and seismic considerations.
- Based on the water system seismic vulnerability study, improve the overall water system's performance following a major earthquake.
- Upgrade air valve assemblies to current standards, and correct deficiencies found at pump stations.
- Continue to operate the regional water system and manage outage durations for transmission pipelines to meet service level targets.
- Remove Richmond Highlands #1 Tank from service for decommissioning.

CHAPTER 5

WATER DISTRIBUTION SYSTEM

This chapter focuses on the SPU water distribution system, the business area that involves delivery of water for retail use and for fire flow. SPU's water distribution system consists of water mains, distribution storage facilities and pump stations, and related appurtenances such as valves, hydrants, service connections, and retail billing meters. The distribution system includes assets in the retail service area shown in Figure 2-1, excluding the regional and sub-regional assets in the retail service area shown in Figure 4-1. The supervisory control and data acquisition (SCADA) system used to monitor and control the water system is also discussed in this chapter. Proper management of the distribution system ensures that SPU meets its service levels for retail customers.

5.1 ACCOMPLISHMENTS SINCE 2013 WSP

Since completion of the *2013 Water System Plan*, SPU has implemented the following improvements to the water distribution system:

- Transportation-Related Projects: Completed improvements to the water system driven by transportation projects, including the locations:
  - 23rd Ave S from East John Street to South Jackson Street, an SDOT Bridging The Gap opportunity project that involved retiring the 6 and 8 inch diameter water mains on 23rd Ave S from East John Street to South Jackson Street and replacing them with a 12 inch water main, as well as replacing the perpendicular water mains and valves in intersections that serve the cross streets (2016).
  - Aurora Ave N from N 185th to N 192nd Avenues, associated with the City of Shoreline's Aurora Ave North Project (2014).
  - Mercer and Valley Streets, as well as north-south crossings at 9th, Westlake, Terry, Boren and Fairview Avenues, associated with the SDOT Mercer East Transportation Improvements Project (2013).
  - Areas associated with the SDOT First Hill Streetcar Project (2014).

  - N/NW 85th Street between 15th Ave NW and I-5 in conjunction with SDOT's Bridging the Gap project on those streets (2014).
  - Areas associated with the SDOT Airport Way S ARGO bridge project (2013).
  - Areas associated with the SR-99 Holgate to King Project.
  - S Holgate St as part of an SDOT pedestrian project.
  - Yesler Way as part of an SDOT bridge replacement project.
- Pressure Sensors: Installed new real-time pressure sensors integrated with SPU's SCADA system at three locations to replace those in fire stations that were sold by the Seattle Fire Department and to add monitoring capabilities in certain pressure zones (2013-2014).
- Water Main Replacements: Replaced about 850 feet of 6-inch Kalamein pipe on 1st Ave N between Denny Way and Thomas Street that were experiencing high leakage rates (2013).
- Fire Flow Improvements: Installed new infrastructure to improve fire flows in single-family residential areas in Arbor Heights (2012), 44th Ave SW and SW Cambridge Street (2015).
- Plastic Pipe Pilot: Replaced about one mile of primarily 8 and 12-inch cast iron pipe in corrosive soils near Seward Park with PVC pipe as a pilot to inform SPU of performance and suitability of this pipe material.
- Backbone Pipeline System Seismic Upgrades: Replaced a section of cast iron lead joint pipe in South Spokane Street between 8th Ave S and 9th Ave S (underneath the I-5 Interchange) with new 30-inch welded steel pipe, along with accompanying valve / vault seismic upgrades (2017).
- New Taps: Installed over 5,700 new customer taps from 2013 through 2017.
- Service Renewals: Renewed or replaced over 3,300 services, primarily those made of plastic tubing, from 2013 through 2017.

5.2 SERVICE LEVEL PERFORMANCE

SPU developed service levels to manage its water distribution system assets and describe what retail customers can expect of SPU in terms of water pressure and problem response. Also, a

service level was developed to limit the amount of water lost to leakage. Many of the drinking water quality service levels, as stated in Chapter 3, also apply to the distribution system.
Table 5-1, below, summarizes the distribution system service level objectives and targets used by SPU to manage its distribution system assets. SPU has been consistently meeting these service level targets.

Table 5-1. SPU's Service Levels for Managing Distribution System Assets

Service Level Objective	Service Level Target
Provide adequate pressure for drinking water supplies.	• New or expanded parts of the distribution system designed to deliver peak hour demand at a minimum of 30 pounds per square inch (psi) at the meter. • No retail customers with less than 20 psi during normal operations.
Respond quickly and effectively to water distribution system problems.	• 90 percent of distribution system problems (emergency situations such as a pipe break; potential contamination of water supply; hydrant damage) responded to within 1 hour.
Meet water use efficiency goals to ensure wise use and demonstrate good stewardship of limited resource.	• Distribution system leakage losses of no more than 10 percent of total supplied, as defined by Washington Department of Health guidelines.

Distribution system leakage (DSL) has been reported to WDOH since 2006, as required by the 2003 Municipal Water Law (WAC 246-290-820). By definition, DSL is the difference between the total amount of water produced and the amount authorized for consumption. DSL includes water lost from pipe and service line breaks, as well as from storage facilities. It also includes metering inaccuracies and unauthorized uses. Due to the location of SPU's meters, losses in the transmission system are included in the reported DSL figures.

SPU's estimate of authorized consumption consists of water sold to retail and wholesale customers based on metering data, and estimates of water used to drain and clean treated water storage reservoirs and, in past years, in overflowing of open reservoirs for water quality management. Water supplied to Volunteer Reservoir to make-up for evaporation and leakage losses have been included as an authorized use since that reservoir has been removed from service. Small amounts of water used for authorized purposes such as firefighting, hydrant testing, water main flushing, sample stand usage, and permitted hydrant usage (e.g., for building construction) have not been included in the estimate of authorized consumption because it would be costly to meter the use, compute an estimate, or determine the amount used in a calendar year. Exclusion of these authorized uses increases the amount of reported distribution system leakage. As shown in Figure 5-1, SPU's DSL has varied from 4.9 to 6.8 percent over the past 6 years, with the last three years averaging 5.4 percent. Since 2006, the 3-year rolling average has remained below the WDOH standard of 10 percent.

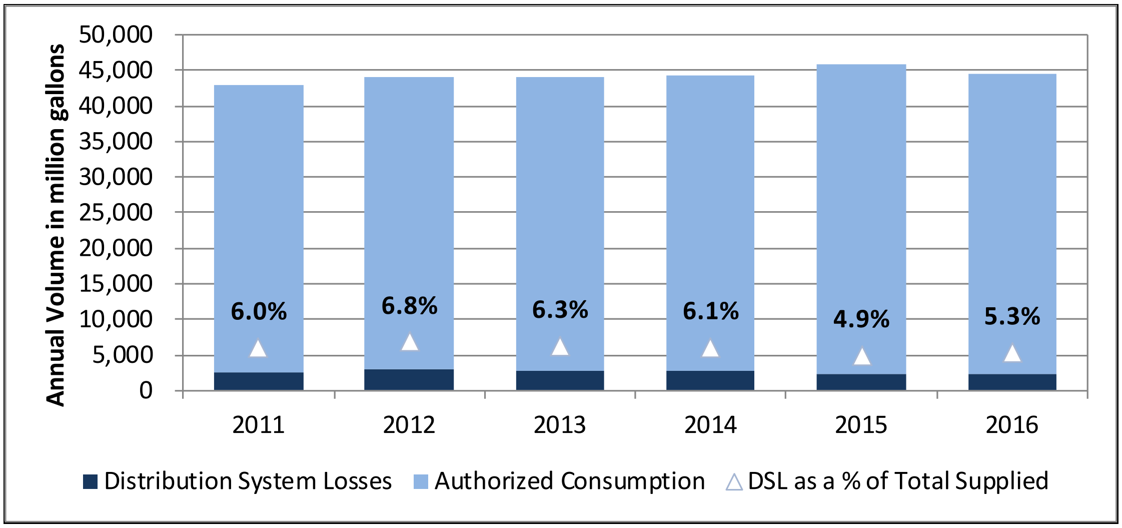

Figure 5-1. Distribution System Leakage

5.3 Existing System and Practices

SPU's distribution system contains more than 1,630 miles of water mains, 6 covered reservoirs, 16 pump stations, 6 elevated tanks and standpipes, 17,000 valves, and 19,000 fire hydrants, as well as more than 191,000 retail service connections.

The water distribution system consists of the facilities that deliver treated water to SPU's retail water customers. Distribution system facilities include water mains, storage facilities, pump stations, retail customer meters, and other appurtenances. The water distribution system contains more than 1,630 miles of water mains, most of them 6 to 12 inches in diameter. Seattle's water distribution system also includes two open reservoirs that have been disconnected from the drinking water system, six covered reservoirs, 16 pump stations, and six elevated tanks and standpipes. In addition, SPU's distribution system has approximately 17,000 valves, 19,000 fire hydrants and 191,000 service lines and meters serving individual residential and non-residential properties.

Due to the hilly terrain, the distribution system is divided into 19 primary pressure zones and 26 sub-zones that are supplied by the primary zones. Pressures within these zones can vary from 25 psi to more than 100 psi (static pressure) depending on topography and how the water is delivered to the pressure zone. Approximately 65 percent of the service area, based total annual volume used, is served by gravity, with the remainder requiring pumping. The boundaries of these pressure zones were established when the system was first developed but are subject to change as the system is further developed.

The following sections provide a description of the major classes of distribution system assets and a brief summary of their condition. The distribution system facilities O&M practices are also described, with attention given to changes in these practices or facilities since the *2013 Water System Plan*.

5.3.1 Existing Infrastructure

A description of the major components of SPU's water distribution system, a summary of their condition, and SPU's replacement/ renewal strategy is summarized below. A detailed inventory of the major asset classes is provided as an appendix.

5.3.1.1 Water Mains

SPU owns a network of more than 1,630 miles of water mains within its retail service area. Since the *2013 Water System Plan*, many water main improvement projects have been completed, with a number completed in conjunction with re-development and other agency projects, such as transportation projects within the city limits of Seattle and Shoreline. However, the overall configuration of the distribution system remains unchanged since 2013.

The condition of SPU's water mains varies based on a number of factors including age, material, size, date of installation, and site-specific conditions such as soil type and corrosivity. The year of installation for water mains by decade and material type of distribution is shown in Figure 5-2. The oldest water main was installed over 125 years ago, and the average age of the is 71 years, reflecting an installation year of 1946 and the end of World War II. The oldest pipe in the system is unlined cast iron pipe, followed by lined cast iron pipe. Since the 1970s, ductile iron pipe has been installed in almost all instances.

Currently, cast iron pipe is the most common type of pipe material used in SPU's distribution system. Approximately 80 percent of the pipes are cast iron, with roughly one-half of that unlined and one-half lined. Ductile iron pipe, the current standard and most common pipe material installed since the 1970s, is the third largest material type, at 14 percent. Galvanized iron and galvanized steel each make up about 2 percent of the system. Steel pipe (wrapped, riveted, welded, lockbar) makes up about 2 percent of the system.

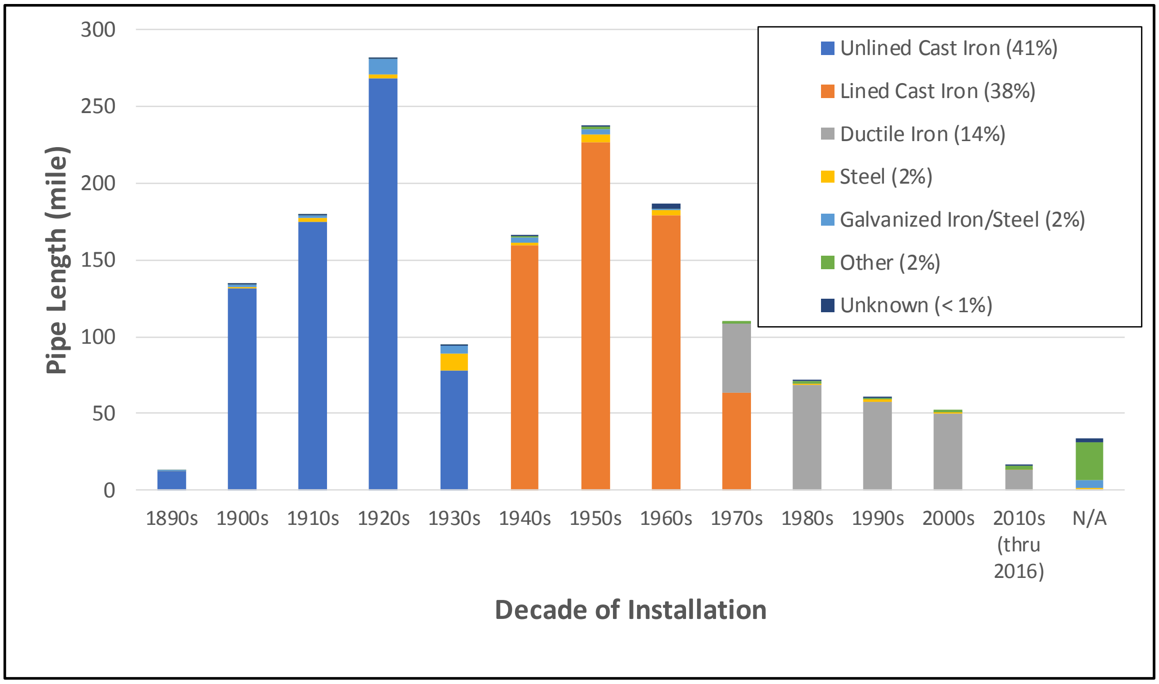

Figure 5-2. Type of Material and Decade of Installation for Water Mains

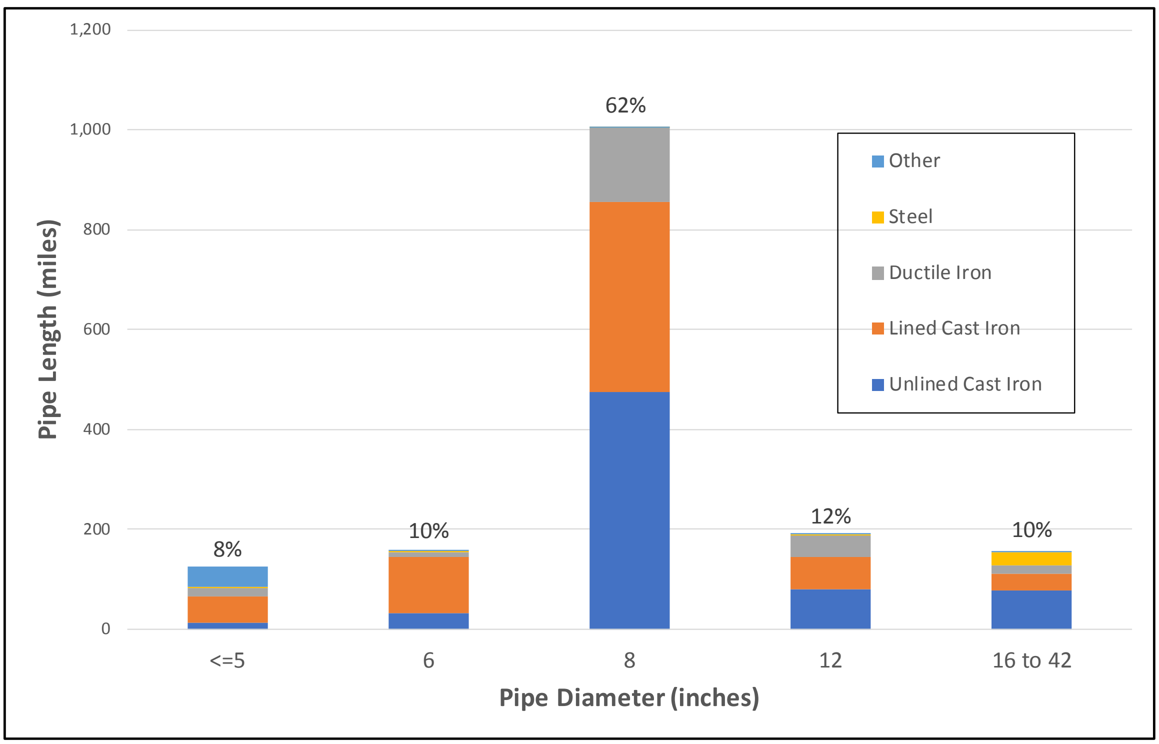

Figure 5-3. Pipe Diameter and Material Types for Water Mains

The remaining pipe is made of other materials, including concrete cylinder, polyvinylchloride (plastic) and copper. There is no asbestos pipe in the system according to SPU's records.

Figure 5-3 provides a breakdown of material types by pipe size. As indicated by the figure, the majority of pipe, or approximately 62 percent, is 8 inches in diameter.

SPU does not have specific condition assessment information for most of the distribution system water mains. Without specific condition assessment data, the condition of the water mains is based on the pipe material, soil type, age and number and types of leaks and breaks. Based on data from 2000 through 2016, the rate of water main leaks and breaks remains low, averaging 9 reported leaks or breaks per 100 miles per year in the distribution system. This is less than the rate experienced by most other major water utilities in the United States[1].

Not all leaks or breaks require water service delivery outages. However, if a repair does require an outage, it is considered unplanned. Distribution system improvement projects can also lead to planned or scheduled outages. Approximately one-half of all outage events were unplanned, and one-half were planned. In 2016, fewer than 1 percent of all customers experienced water service delivery outages of more than 4 hours per year from all planned or unplanned events.

5.3.1.2 Distribution System Water Storage Facilities

SPU's distribution system includes six in-city reservoirs and six elevated tanks and standpipes to provide operating and standby storage capacity to its retail customers. The amount of storage is provided in the appendices.

Distribution System Reservoirs. SPU currently operates and maintains six active reservoirs in the distribution system. Lincoln, Myrtle and Beacon Reservoirs have been recently replaced with below grade reinforced concrete tanks. Two additional open reservoirs, Volunteer and Roosevelt, have been taken out of service, as noted in Chapter 3, and the outlets have been disconnected from the distribution system. However, the inlets are still connected, and at Volunteer, where water is still impounded, the reservoir level is kept below the inlet elevation to establish an air gap. These reservoirs may be used for emergency non-potable

[1] Neil S. Grigg, 2007, *Main Break Prediction, Prevention, and Control*. Report 91165. AwwaRF and AWWA.

storage for post-earthquake or other emergency response, and/or eventually returned to service as covered reservoirs if future water system needs require it.

Condition assessment of in-town reservoirs follows the same procedure as described for the water transmission system reservoirs. Based on inspections, the structures are in good condition. When tested in 2009 and 2016, the leakage rate at Magnolia Reservoir was negligible. The leakage rates from Bitter Lake and View Ridge Reservoirs were low and estimated to be 1.09 and 3.8 gpm/MG, respectively, when tested in 2016. Beacon, Lincoln and Myrtle Reservoirs have not been tested since they were replaced.

Distribution System Elevated Tanks and Standpipes. In addition to its in-town reservoirs, the SPU water distribution system includes one elevated tank and five standpipes. The elevated tanks and standpipes were constructed between 1907 and 2008. They range in capacity from 0.9 mg to 1.9 mg. Barton Standpipe was decommissioned in 2012 after its bypass was completed. SPU is planning recoating projects for Volunteer Standpipe, and Trenton North and South Standpipes.

Distribution system tanks and standpipes are inspected and maintained in the same manner as transmission system tanks, as described in Chapter 4.

5.3.1.3 Distribution System Pump Stations

SPU operates 16 distribution system pump stations with a total of 36 individual pump units. These pump stations are inspected regularly to ensure that they continue to function properly, and equipment is repaired or replaced as needed. Distribution system pump stations are maintained in the same manner as transmission system pump stations, as described in Chapter 4.

5.3.1.4 Distribution System Appurtenances

The SPU water distribution system includes a number of smaller appurtenances, such as valves, hydrants, service lines, and meters. The paragraphs below summarize SPU's inventory and replacement approach for each class of appurtenance.

Distribution System Valves. SPU's water distribution system includes more than 17,000 valves. Most valves are line valves which function to reconfigure the flow of water through the distribution system as needed, while other valves regulate pressure and flow, provide for bypassing of facilities, or allow air to escape the system.

Distribution appurtenances include various parts, features and elements that are incidental, integral, or subordinate to the system, such as valves and hydrants.

SPU asset management approach focuses attention on assessing the condition of critical valves and conducting preventative maintenance or corrective repairs, based on condition. Approximately 1,000 critical line valves, about 6% of the total inventory, have been identified in the distribution system. For non-critical valves (valves that isolate flow on non-critical water mains), repairs are initiated as needed when defects are noted during valve operation. Since a failure of a non-critical valve would be mitigated by operating an adjacent valve, the consequence of its failure is relatively minimal.

Valve replacement is initiated when the repair or resolution of a defective condition is impossible or would cost more than valve replacement. Valve replacement also occurs when distribution mains are replaced or relocated. In 2018, 145 valve repairs were completed, which is in line with historical averages.

The valve chamber replacement program will continue through the next several years. This program replaces existing chamber lids and access maintenance holes with larger diameter lids and new access ladders. This program will provide SPU maintenance staff with safer valve chamber access and meet industry safety standards. In 2018, no valve chamber replacements were performed, due to lack of staff resources. SPU is currently undergoing a resource analysis to assess future staffing needs.

Distribution System Hydrants. SPU maintains 18,664 fire hydrants. Annual condition assessment of fire hydrants is performed by various fire service agencies operating in Seattle's retail service area[1]. Damage to fire hydrants is also commonly reported between routine condition assessment cycles.

SPU resolves problems observed and reported by the fire service agency and the public. Problems are categorized into two levels. First, problems that make a hydrant unusable or unsafe to use are given the highest priority to repair or replace. Second, problems such as minor leaks that do not affect a hydrant's availability for firefighting and main flushing are given a low priority for repair or replacement. SPU's hydrant replacement strategy for obsolete

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[1] Fire departments with jurisdiction in Seattle's retail service area include the Seattle Fire Department, Shoreline Fire Department, Northshore Fire Department, North Highline Fire District, Burien / Normandy Park Fire Department, and King County Fire District 20.

hydrants is to replace these hydrants in areas when other water system projects are being constructed and where excavation costs are low and future costs are likely to be much higher. Other than these "opportunity projects," SPU replaces hydrants that are found to be inoperable and repairs are not possible or exceed the cost of replacement. New hydrants may also be installed as part of new development.

Distribution System Service Connections. SPU has more than 191,000 retail service connections, an increase of more than 5,200 services since 2013, mainly for new residential customers. The number of new service installations has increased at an accelerated rate since 2013 largely due to substantial new residential development projects throughout the City. Most of the services (86 percent) are for residential customers, almost 12 percent are for commercial customers, and the remaining 2 percent are for fire service. The majority of service connections, 58 percent, are ¾-inch diameter pipes. Currently 78 percent of service lines are copper, and 13 percent are plastic. The remaining 8 percent are made of other materials.

Service lines made of plastic or galvanized steel are more susceptible to failure and are now no longer used. Prior to 1947, all of the service lines were made of galvanized steel, and these have been primarily replaced with copper. Between 1968 and 1984, SPU installed or replaced approximately 40,000 small services (3/4-inch to 2-inch) with plastic tubing.

Prior to 2003, SPU's approach to renewal of small water service lines was "fix when fail." The cost of this primarily reactive strategy for some services has been high in both SPU's direct repair cost and social impact costs, such as damage to customer property, roads, and the environment. In 2003, a plastic service renewal pilot program began whereby blocks of plastic services were proactively renewed. In 2005, the programmatic approach was modified from block renewal to critical service renewal whereby plastic pipes with high risk costs were identified and renewed first.

The current water service renewal program consists of both reactive and proactive components and is described more fully in Section 5.3.3.4. Replacement of lead whips is described in Chapter 3.

Distribution System Meters. Each service line is fitted with a water meter used to determine customer consumption and charges. Nearly 92 percent of SPU meters are small (3/4-inch and 1-inch).

SPU has installed approximately 3,000 automated meter reading (AMR) radios on difficult-to-read meters. This form of AMR allows these meters to be read safely and efficiently in walk-by or drive-by mode. Examples of where AMR is cost-effective and used at SPU include:

- Meters that are a safety hazard and/or require costly setup to read visually, mostly due to being located in an area with traffic hazards.
- Clusters of meters located in larger vaults with heavier lids, which pose an injury risk to meter readers when repeated frequently.
- Meters located in parking areas that are unreadable when a vehicle is parked over them, leading to frequent estimated bills.
- Meters that tend to get buried and/or overgrown and require frequent clearing.
- "Deduct" meters owned by the customer and located on private property in hard to access locations, leading to lengthy time required to get a reading.

5.3.2 Operations

SPU's water distribution system is primarily served by gravity, but pumps are used to serve some pressure zones. To control flow and storage levels, SPU water system operators at the Operations Control Center operate pump stations, valves and other water system components using the remote control capability of the SCADA system or by directing crews to locally operate field equipment. The current SCADA system, which was installed in 2006, provides real-time data regarding pressure, flow, storage facility water level, and pump/valve status to system operators. Archived SCADA data are also useful for hydraulic network modeling, system planning, and engineering design.

In addition to the control room at the Operations Control Center, SPU has a backup control room at the SPU North Operations Center. The backup control room has been improved to substantially reduce start up time to begin system monitoring and control from that location.

Additional information on system operations, particularly the Operations Planning and Scheduling function, is provided in the appendix for Water System Management and Operator Certification.

5.3.3 System Analysis

SPU expects excess system capacity well into the future. The following sections summarize the capacity analysis for the distribution system, including treated water storage and pumping capacity. Additionally, a summary is provided for the hydraulic modeling used in pressure and fire flow analysis for the distribution system.

5.3.3.1 Storage Analysis

There are five types of storage volumes that must be accounted for per Washington Administrative Code (WAC) 246-290-235, as described below.

- **Operational Storage** (OS) is the highest elevation storage located from the maximum water elevation down several feet, known as the operating band. For storage facilities supplied by pump stations, the OS volume is associated with pump cycling under normal operating conditions, whereby a pump is turned on at the bottom of the operating band and turned off at the top of the operating band. For storage facilities supplied by gravity through control valves off transmission pipelines, the operating band is necessary to ensure turnover of the stored water to prevent water quality degradation. The OS in SPU's system is significant, approaching 100 MG. For details by storage facility, see the storage allocation table in Appendix D.

- **Equalizing Storage** is the volume of storage needed to supplement supply to customers when the peak hourly demand exceeds the total supply capacity. Based on conservative peaking factors for the regional system, peak hour demands are estimated to be 360 mgd by 2040, which would exceed the treatment and transmission capacity of the Cedar and Tolt systems by 60 mgd. Thus, the amount of equalizing storage needed to provide for system-wide peak hour demands for 2.5 hours is approximately 6 million gallons. This storage is available from existing storage that is not allocated to operational or standby purposes (see storage allocation table in Appendix D). For individual pressure zones in the distribution system that are supplied only by pumping, the installed pumping capacity significantly exceeds peak hour demands in the zone. (See Section 5.3.3.2 Pumping Analysis, below.)

- **Standby Storage** is the volume of stored water available for use during loss of source capacity or power, or similar short-term emergency. SPU considers standby storage to be available to a pressure zone if (a) it is elevated storage providing at least 20 psi by gravity; or (b) it is ground level storage that can be pumped using a pump driven by hydraulic turbine, diesel/gas engine, or electric motor with on-site power generator.

  Analysis of standby storage considered startup times based on availability of remote control, emergency response experience, and/or reasonably conservative staff response times are used in the storage analysis. Also, the analysis includes verification that standby storage immediately available would last sufficiently long to allow longer activation time pumped standby storage sources to be brought online without loss of service.

  Details by zone and by storage facility is provided in the storage allocation table in Appendix D. The analysis uses 200 gallons per Equivalent Residential Units (ERU) minimum for each pressure zone. The number of ERUs per pressure zone was derived from 2009 billed consumption data which, according to the current water demand forecast, is not expected to be reached until 2040. To determine average daily water use per ERU the 2009 annual consumption of all ¾-inch services systemwide was added up and then divided by their number, yielding 145.4 gallons per day per ERU after unit conversion. The average day demand for each pressure zone was determined by adding up the annual consumption of all services in the zone, and the number of ERUs in each pressure zone was determined by dividing the average day demand in the zone by the previously calculated 145.4 gallons per ERU per day. The table shows allocation of standby storage (gravity and/or pumped, per the criteria above) in storage facilities serving each pressure zone. Any remaining standby storage is tagged as “unallocated”, meaning that it is available for other storage purposes as needed, and which amounts to over 128 million gallons.

- **Fire Suppression Storage** is the volume of stored water necessary for fire suppression activities. SPU estimates fire suppression storage to be smaller than the minimum standby storage, and therefore considers it nested with standby storage.

- **Dead Storage** is the volume of stored water not available to all consumers at 20 psi. Storage below 20 psi is identified in the storage allocation table and amounts to only 6 million gallons. For details by storage facility, see the storage allocation table in Appendix D.

5.3.3.2 Pumping Analysis

SPU's system is primarily supplied by gravity, however, there are a few higher elevation pressure zones that must be supplied by pumping. Analysis provided in the appendices shows that for all of these pressure zones there is pumping capacity in excess of peak hourly demands, even if the largest pump in each pump station supplying a given pressure zone is out of service at the same time. Small zones supplied by booster pump stations intended to boost minimum pressure well above the allowed minimum of 30 psi are not included.

5.3.3.3 Hydraulic Analysis

SPU has developed a set of hydraulic network models of its water distribution system to analyze system performance. These models are used to:

- Model available fire flow in support of design of water system improvements or additions.
- Identify and prioritize fire flow improvements under certain operating conditions.
- Support operational response and public notification during a system disruption.
- Compare results of hydrant flow tests performed for customers to modeled flow, for model calibration purposes.
- Analyze distribution system performance in a seismic event.
- Identify low pressure areas needing upgrades (completed in 2009).
- Plan and stage unidirectional flushing.
- Provide system performance information to the Washington Surveying and Rating Bureau.
- Analyze water age in distribution system.

Details of these models and recent hydraulic analyses are provided in Appendix D. Based on these analyses, recommendations to improve fire flows were identified and are discussed in Section 5.4.3.1.

5.3.4 Maintenance

Proper maintenance of distribution system components ensures that SPU will be able to deliver reliable water service by reducing the risk of unexpected failures. Summaries of maintenance activities for the distribution system are provided below.

5.3.4.1 Water Mains

The most significant maintenance for water mains is leak assessment and control and water main repairs. The 2000 through 2016 water main break/leak data indicate that approximately 103 to 168 water main failures (leaks and breaks) occur each year, with an average of 135. This excludes leaks on other appurtenances, such as water services and water mains, that result from damage attributed to third parties. Approximately one-third of the failures, however, are joint leaks which often do not require a complete water main shutdown. Also, repair of leaks from corrosion-related pinholes do not usually require complete shutdowns. Small water main leaks can be repaired “live” by throttling adjacent valves and temporarily reducing the feed to the water main segment being repaired. Only larger breaks typically involve a complete water main shutdown. When this is the case, routine shutdown practices are used. These include controlled release of water, vacuum relief at higher portions of the affected pipe segment, and maintaining positive pressure at the repair site until the broken pipe is exposed and decontaminated.

Reports of potential water main leakage require immediate response. Prompt investigation and preemptive valve operation can prevent distribution system pressure loss when apparently minor leakage progresses to a more serious main break. SPU has implemented a Field Operations Mapping System with automatic vehicle location capabilities to quickly dispatch the nearest equipped crew/vehicle to address a problem. Improvements to SPU’s work order management process have also been implemented. SPU distribution staff has been consistently meeting the service level target for problem response (90 percent problems responded to within one hour).

Other water main maintenance practices include water main flushing. Additional information on water main flushing is provided in Chapter 3.

5.3.4.2 Reservoirs and Tanks

Storage facility cleaning is also performed to remove sediment, debris, and/or microbial growth as described in Chapter 3.

5.3.4.3 Water Pump Stations

Pump stations in the distribution system are maintained in the same manner as described for the transmission system pump stations in Chapter 4. The asset management approach used by SPU to optimize pump station inspection and repair is Reliability Centered Maintenance (see Section 4.3.3.3).

5.3.4.4 Water Appurtenances

SPU also performs maintenance activities for its valves, hydrants, service lines, and meters to ensure their continuing operation. A brief description of each follows.

Valves. Between 2006 and 2016, SPU responded to an average of 118 valve-related problems per year, or approximately 1 percent of all valves. Most valve problems can be categorized as leaks, casting failures, mechanical inoperability, and valves being buried by new pavement. Deterioration of interior packing, broken and bent stems, and construction projects are usually the causes of valve problems.

Due to a shift in priorities, the routine operation work of exercising critical valves is performed less frequently than in the past (prior to 2003). There have been no demonstrated negative impacts from this reduction in routine exercising. However, drinking water utilities throughout the country and the industry as a whole have largely demonstrated that valve failure probability increases substantially over time if routine exercising is neglected. SPU intends to resume and accelerate critical valve preventative maintenance as resources become available. SPU is undergoing a workload and resource analysis that will help define future staffing needs.

As part of the Shutdown Block Analysis described in the *2013 Water System Plan*, a GIS layer has been developed to help identify the need for new isolation valves, or relocation of existing isolation valves. Cost-effective system improvements can then be implemented as opportunities arise (e.g. third-party projects or asset failure).

A Valve Asset Management Plan was developed in 2015, which included an update to valve maintenance, replacement, and renewal strategies. The AMP documented a substantially improved criteria for identifying critical valves whereby criticality criteria is based on more comprehensive water system impacts. These criteria were expanded beyond the typical criticality designation derived from adjacent (connected) water pipe diameter. Another notable advancement in SPU's valve management was the plan for reimplementing a valve inspection and exercising program, which will reduce overall maintenance and capital costs and provide a more reliable and effective means of controlling the water distribution system.

Hydrants. Each fire service agency inspects hydrants located within its service area, generally on an annual basis. Defects are reported to SPU for repair. In 2016, SPU responded to approximately 1,500 work orders to address fire hydrant defects.

SPU updated the Hydrant AMP and associated maintenance strategy in 2017. The AMP also included a strategy and timeline for completing a substantial backlog of unresolved hydrant maintenance work orders. This strategy adds a task to all hydrant maintenance work orders to paint hydrants when needed and during amendable weather conditions. An optimal hydrant painting program driven by an 8-year painting rotation will begin when funding and crew resources become available at a future date.

Service Connections. Maintenance related to service connections includes leak investigations, minor repairs on service lines, and replacement of broken valves, rods, or fittings. SPU's water service renewal program consists of both reactive and proactive components:

- **Reactive renewals** include asset failure renewals due to emergency or non-emergency breaks, leaks, or mechanical failures (shutoff valve or meter failures), typically reported by customers. Reactive renewals called "demand renewals" are also identified by SPU staff when other projects trigger the need for a service connection replacement, such as during water main relocation/replacement, service upsizing/downsizing, or "companion" renewals (substandard service pipes located in the same trench as another excavated water asset, which would likely fail during backfill and compaction).

- **Proactive renewals** include opportunity renewals and critical renewals. Opportunity renewals are performed when other projects, typically transportation-related projects, are restoring street pavement at no cost to SPU, which can be as much as 40 percent of the total cost to replace service connections. Critical renewals target small services where the remaining life is projected to be short and the consequences of a break would likely be significantly higher than typical. For example, a "critical" site may be in a steep slope or landslide area, or in high volume traffic roads offering few options for detouring traffic.

In addition, SPU has observed through practice that proactive service retirement is often not cost effective, and, therefore, most service retirements are carried out reactively, except for opportunity renewals. Inactive service pipes are typically retired when leaks develop, new services replace the obsolete service, or the unused service is in conflict with or is abandoned with new right-of-way improvements or water main work.

SPU intends to analyze the need for future proactive service renewals in light of the removal of lead whips, as described in Chapter 3. A workload and resourcing analysis is underway.

Meters. SPU's retail water meters ensure proper billing for water use as well as for wastewater services. Meter problems may be identified at the time of meter reading, such as when broken meter dials are found, or by the billing system, such as when consumption is much higher or lower than what is expected for a customer based on historical information. Metering issues may also be discovered when customers inquire about unusually high bills. Such issues may lead to testing, repair or replacement of a meter depending on its size and customer class.

SPU has a meter testing and maintenance program for its large meters, which represent less than three percent of all retail meters. SPU's goal is to maintain accuracy of large meters to between 97 and 103 percent as per the guidelines of the American Water Works Association. A large meter with an accuracy falling outside that range is either repaired to restore its performance or replaced. In 2009 and 2010, SPU replaced approximately 125 large retail meters per year. The pace of the replacement program has since slowed since the older large meters with consumption sufficient to justify a proactive replacement have already been replaced. At present the large meter exchange program is largely reactive, replacing obsolete meters when they fail. For retail services this typically does not result in revenue loss as they have a well-established water use pattern that can be used reliably to estimate consumption for the billing period(s) when the meter was not functioning.

In the 2008-2012 period SPU piloted the use of electronic large meters, and found them superior to their mechanical counterparts in terms of low flow accuracy, reliability, and level of O&M. Electronic meters do not benefit from periodic testing as they have no moving parts to degrade their accuracy, which lowers routine maintenance costs. On the other hand, they are battery powered, with estimated battery life of 12-15 years at most.

In 2012 SPU standardized on ultrasonic large meters, and has since then been using them for all new retail services, as well as for failed existing meters in need of replacement. The brand and model currently in use by SPU may not provide for a battery replacement while the meter is installed in the field; at present meters with drained batteries must be removed and shipped back to the manufacturer for battery replacement, which causes significant SPU labor costs, as well as some customer impact. SPU is experimenting with developing in-house expertise to replace depleted batteries while the meter is installed on the service.

However, if that approach does not work out as hoped, it is expected that in 2023-2025 period a new meter replacement workload will gradually arise to replace large meters with drained batteries. While by then most of the legacy/obsolete mechanical meters would have been replaced, this new workload could keep the overall meter replacement program at a level close to current.

SPU does not typically perform maintenance activities for small meters since repairing small meters is not cost-effective and it is generally less expensive to replace a small meter than repair it. SPU reactively replaces less than one percent of its small meters per year when they fail or when a service is renewed for other reasons. SPU continues to use multi-jet mechanical meters for its small meter needs, and has found them very reliable, durable, and with little or no accuracy degradation over the life of the meter.

As noted in Section 5.3.1.4, existing meters may be retrofitted, or new meters may be equipped, with radio units for AMR to allow walk-by meter reading as needed. AMR system maintenance involves replacing failed radios or encoded registers as needed.

SPU has generally not adopted AMR nor advanced metering infrastructure (AMI). The reason is cost-effectiveness: one significant factor is that the added cost over time of changing the battery and radio on an AMR meter outweighs the savings associated with fewer labor hours for meter readers. An added factor is that the batteries on AMR radios have not lasted nearly as long as manufacturers have claimed.

AMR is currently used by SPU when a meter is difficult to access, involves safety concerns such as being located in a busy street, or can be made somewhat more cost-effective based on locations of meters in a logical grouping.

AMI is a significant increase in cost from AMR, so it is even less cost-effective.

SPU is following industry trends to assess the latest developments in technology and cost. As trends change, SPU will re-evaluate its strategy around AMR and AMI. Currently, SPU is discussing the implementation of AMI by Seattle City Light (SCL) to learn more about SCL's experience and lessons learned.

5.3.4.5 Record Keeping and Reporting

SPU has a number of tools to track and report on water distribution assets. SPU uses its MAXIMO work management system to capture asset failure and maintenance history. SPU also uses a geographic information system (GIS) to record and display locations of physical assets and problems. This tool is also used to review shutdown blocks, gridding and hydrant spacing, identify critical assets and develop asset management strategies.

5.3.5 Asset Management Planning

As noted Chapter 2, important asset management planning documents that SPU uses include asset management plans (AMPs). The Distribution System business area is the most asset-intensive of the business areas for the drinking water system. SPU has prepared a number of AMPs for major classes of distribution system infrastructure components, including the following:

- Water Distribution Pipes (2018)
- Water Pump Stations (2006), with Reliability Centered Maintenance recommendations implemented in 2011
- Water Valves (2015)
- Water Distribution Hydrants (2017)

- Water Distribution Service Pipes (2004)
- Water Distribution Meters (2004)

Updates to the Water Distribution Hydrants AMP and Pipes AMP were recently completed, and the Meters AMP will be updated next.

5.4 Needs, Gaps, and Issues

The primary needs, gaps, and issues facing SPU's distribution system in the coming years are related to distribution system assessment and planning, seismic improvements aimed at improving system resiliency and performance following a major earthquake, and other projects including fire flow, pump station upgrades, and opportunities presented by third-party projects related to transportation and redevelopment. The following subsections summarize these needs and SPU's approach to addressing them.

5.4.1 Distribution System Assessment and Planning

In recent years, SPU developed asset management plans, conducted water main condition assessments, and completed shutdown block analyses, which have resulted in a number of findings and strategies for the distribution system.

5.4.1.1 Water Distribution Pipes Asset Management Plan

A Water Distribution Pipe AMP was recently completed to refine SPU's water main rehabilitation and renewal strategies. The AMP includes the development of a risk profile using software that analyzes data contained in SPU's GIS to quantify specific risks, assesses how specific risks compound for each water main, and ranks all water mains based on total risk score. Risk is the product of likelihood of failure and consequence of failure. This ranking is then used to develop programs for water main rehabilitation, renewal, inspection and condition assessment. Risk based decision making is a water utility industry standard for asset management.

Rehabilitation and renewal strategies are investments used to reduce cost and risk and enhance benefits by selectively refurbishing or replacing existing assets. These strategies are generally capital projects: pipe lining, adding cathodic protection, or replacing the water main with a new pipe either in the same location or in another alignment.

Implementation of these rehabilitation and renewal strategies will require greater investments by SPU than what has been spent in the past. Use of the new risk model allows SPU to better focus these investments on high risk water main assets.

5.4.1.2 Water Main Condition Assessment

Parts of SPU's water distribution system, in particular many of its pipes, have been in place for more than a century. Although the existing system is in good condition, as evidenced by its low leakage and failure rates, SPU has limited information about the condition of water mains. High risk pipes, which meet threshold criteria will undergo water main condition assessment, if feasible. The threshold criteria is under development.

SPU plans to increase water main inspection programs as resources become available to better monitor and assess water main conditions. SPU is conducting a workload and resource analysis to develop future staffing plans.

Inspection methods under evaluation include:

- More focused visual inspection programs for high risk water mains that are physically accessible and for which a visual inspection is feasible (e.g. water mains attached to bridges and roadways or located in utilidors).
- More frequent water main condition data collection when SPU crews dig up and expose water mains in the distribution system while completing other work.
- More proactive leak detection, using acoustic leak detection equipment and technologies described below, to monitor water mains with high risk.

As noted in the *2013 Water System Plan*, SPU conducted in 2007 a leakage test of Cedar River Pipeline 2 from Volunteer Reservoir to Maple Leaf Reservoir (also known as the 430 Pipeline) using Pure Technologies SmartBall technology to assess its condition. This initial phase of a leak detection pilot was successful. In 2015 and 2016, SPU conducted two field demonstration projects using Pipeline Inspection and Condition Analysis Corporation's (PICA) "SeeSnake", a remote-field electromagnetic technology to scan pipe wall thickness of cast iron pipelines in corrosive soils. The 2015 and 2016 field demonstration projects were successful.

These technologies as well as other technologies are under consideration as pilot programs to ascertain the condition of water mains by assessing for leaks and/or remaining pipe wall thickness.

If water mains are found to be in need of repair, they will be repaired or given a high priority for capital investment to rehabilitate or replace prior to pipe failure. This evaluation will be based on asset management principles.

5.4.1.3 Shutdown Block Analysis

As described in the *2013 Water System Plan*, SPU has completed a shutdown block analysis in which each pipe segment in the retail service area was evaluated to determine the service delivery impact if that pipe segment is taken out of service. In this context, service delivery impacts are based on the number of customers and the number of hydrants.

Pipe segments associated with High Impact Shutdown Blocks (HISB) are identified on a GIS layer, as are the associated outage areas. The HISB GIS layer is used during the planning phase of water main replacement projects, redevelopment and third-party projects to reduce the size of these potentially large outage areas. Mitigation measures typically involve additional gridding of distribution mains and installation of additional line valves at existing grid junctions. The HISB GIS layer also informs the crews who plan and execute shutdowns for routine and emergency work, which prevents inadvertent initiation of an unusually large service outage.

The analysis of high-impact shutdown blocks has also resulted in changes to SPU's Design Standards and Guidelines to place greater emphasis on outage management in water main design and valve placement.

5.4.2 Seismic Study and Improvements

SPU's seismic study was described in Chapter 4 – Water Transmission System. Many of the seismic improvements that are being considered are for distribution facilities. Improvements to distribution system facilities include isolation systems that could be used to prevent heavily damaged areas from draining less damaged areas, upgrading the most critical reservoirs and pump stations, and using earthquake resistant pipe when pipelines are replaced in areas subject to permanent ground displacement. Soil liquefaction in the Duwamish Valley poses one of the key seismic vulnerabilities for SPU's distribution water mains. Landslide areas present another vulnerability.

Replacement of distribution water mains in soil liquefaction and landslide-prone areas with seismically resistant pipe can be cost-effective when the water main needs to be replaced for other reasons, such as the end of useful life or when third-party projects require relocation of the water main. For example, previous seismic upgrades in the Duwamish River Valley area occurred when SPU took advantage of opportunities created by Seattle Department of Transportation (SDOT) projects. SPU plans to continue to take advantage of opportunities to accomplish replacements of older water main with new earthquake resistant pipe in seismically vulnerable areas as they present themselves.

5.4.3 Other Distribution System Upgrades

SPU has a large capital program for distribution system improvements. This program is used to identify, prioritize and fund seismic upgrades and fire flow and pressure improvements. The program may also consider cleaning and lining as an option for making system improvements in areas with unlined cast iron pipes. These aspects of the distribution system improvement program are described in the following subsections.

5.4.3.1 Fire Flow Improvements

Although the majority of the SPU's hydrants are able to deliver more than adequate flows to combat fires, there are areas inside and outside of the City of Seattle where SPU's water system has hydrants that cannot deliver fire flows to existing buildings under current codes required for new buildings. This can be caused by a combination of factors including pipes with small diameters or areas with low water pressure due to older design standards, or pipes whose interiors have been reduced by deposits. There are also areas that were originally built to now obsolete fire codes.

In 2011-2012, SPU conducted a system-wide hydraulic network modeling analysis to determine available fire flow under average day demand conditions. Based on this analysis, SPU constructed fire flow improvement projects at nine locations from 2012 through 2016: Arbor Heights, 24th Ave S, 50th Ave SW, Blue Ridge, Capitol Hill, Madison Park, North Admiral, SW Cambridge St, and Burien Shorewood. These improvements consisted of over 5,000 linear feet (LF) of water main replacements, over 4,000 LF of water main cleaning and lining, and several new pressure-reducing valve stations.

SPU's distribution system contains approximately 700 miles of unlined cast iron pipes. As these pipes age, many exhibit varying degrees of tuberculation that increases the pipe wall roughness inside of the pipe, thereby increasing resistance to water flow which reduces pipe flow capacity, lowers the pressure of water delivered to customers, impacts fire flow capabilities, increases pumping costs, and can causes water quality problems. In its options analysis to address fire flow in the distribution system, SPU will continue to consider the use of cleaning and lining as an alternative to replacement of deteriorated unlined, cast iron pipe.

In 2017, SPU conducted an updated fire flow hydraulic modeling analysis under maximum day demand conditions, as described in more detail in Appendix D. This analysis identified nine areas not meeting fire flow performance targets, with six of the deficiency areas caused by undersized/unlined water mains and three deficiency areas caused by high points in the system that restricted the available fire flow at 20 psi residual pressure. Those areas and options for solutions to the fire flow deficiencies are summarized in Table 5-2. SPU's distribution system is upgraded to current fire flow standards as needed for development/redevelopment and as other system improvements are made (see section 5.4.4).

Table 5-2. Fire Flow Deficiency Areas Identified in 2017 Fire Flow Analysis

Area Name	Fire Flow Targets Not Met	Number of Parcels Not Meeting Target	Reasons for Fire Flow Deficiencies	Possible Fire Flow Solutions
Shoreline – Innis Arden	Single Family	6	Undersized water mains	Upsize water mains
Blue Ridge	Single Family	75	Undersized & unlined water mains	Upsize and/or clean and line water mains
Montlake	Single Family	20	Undersized & unlined water mains	Upsize and/or clean and line water mains
North Capitol Hill	Single Family	106	Undersized & unlined water mains	Upsize and/or extend water mains
Burien – Shorewood	Single Family	8	Undersized water mains	Upsize water mains
Burien - Hurstwood	Single Family	126	Undersized water mains	Upsize and/or extend water mains
Ballard 326	Commercial/ Multi-Family/ Industrial	23[1]	High points restrict flow at 20 psi	Expand adjacent higher-head pressure zone (Maple Leaf 430) to serve affected parcels
Lower Queen Anne 326	Commercial/ Multi-Family/ Industrial	35[1]	High points restrict flow at 20 psi	Expand adjacent higher-head pressure zones (Queen Anne 530, Volunteer 430) to serve affected parcels
Eastlake 326	Commercial/ Multi-Family/ Industrial	0[2]	High points restrict flow at 20 psi	Provide supplemental fire flow from adjacent Volunteer 530 feeder water main.

1. Number of high-elevation parcels dropping below 20 psi during fire flow events elsewhere in the pressure zone.
2. Feeder main not directly serving any parcels.

5.4.3.2 Pump Station Improvements

A number of distribution system pump station deficiencies have also been identified by SPU staff. The highest priority deficiencies at the most critical stations are:

- Spokane Street Pump Station: Structure is failing; floor structural timbers have rotted out in some locations; roof is leaking; electrical equipment is obsolete and/or does not meet code; low voltage panel; medium voltage transformers.
- Broadway Pump Station: Obsolete oil pump contactor.
- West Seattle Pump Station/Gate House: Piping is badly corroded.
- Lincoln Pump Station: Piping in bypass chamber is significantly corroded.
- Volunteer Pump Station: Obsolete contactors.

5.4.4 Third-Party Projects

Other agencies, utilities and private developers construct projects in the retail service area that can impact the distribution system. These third-party projects often necessitate SPU to make system changes that it would not otherwise do, but they can also present opportunities for improving flow capacity, pressure, reliability, and water quality in the distribution system at a reduced cost to SPU ratepayers. The following sections describe the impact on the distribution system from transportation projects and new development.

5.4.4.1 Transportation Projects

Transportation projects are third-party projects that can have a significant impact on the water system because of the need to relocate or protect existing water infrastructure. Also, transportation projects often create opportunities to renew or upgrade water infrastructure assets at a lower cost by taking advantage of the street opening and reducing pavement restoration costs. The impact of transportation projects on the water system continues to grow as the region invests in new transportation infrastructure.

SPU considers whether to relocate or retire water infrastructure for transportation projects when the existing water infrastructure would not be able to remain in its existing location due to grade conflicts, would no longer be accessible for maintenance and repair, would have increased consequences of failure after the transportation improvements have been built, or would have a high probability of failure due to damage during construction that cannot be remedied by protection measures. Water infrastructure may be retired when it is not needed for water delivery to specific water services or fire hydrants, for the delivery of fire flow to the surrounding area, and for delivery of water to surrounding areas such as usually provided by feeder mains. Water main gridding is also considered in water main decisions as a way to mitigate the impacts that dead-ends have on the system, such as to water quality and shutdown block size. Distribution mains that cannot be retired but are smaller or larger than the standard pipe sizes (8-inch for single–family residential areas and 12-inch for industrial and commercial areas) are evaluated for proper sizing prior to relocation. The evaluation usually involves hydraulic modeling of the present-day water system configuration and expected future uses and densities.

If water infrastructure does not need be relocated and is not slated for retirement, SPU may choose to protect it in place or take the opportunity to renew or upgrade it. SPU has developed guidelines for impact and opportunity-driven asset replacements for transportation projects. These guidelines are based on the type and condition of the asset and the type and size of the impact (or opportunity). The water main may be replaced in kind, upsized or downsized depending on current and anticipated capacity requirements.

The extent of transportation improvements in Seattle's retail service area by Sound Transit, Washington State Department of Transportation (WSDOT), Seattle Department of Transportation (SDOT), and the City of Shoreline is expected to remain high at least through the first ten years of the planning period, with the larger projects being as follows:

- SR99 Improvements through downtown Seattle by WSDOT, including new tunnel construction and demolition of the existing Alaskan Way Viaduct.
- Seattle Central Waterfront Redevelopment by SDOT.
- Center City Streetcar by SDOT.
- Sound Transit light rail projects, including the Northgate and East Links and Ballard and West Seattle Link Extensions.
- SR520 highway replacement, and improvements to the I-5/SR520 interchange by WSDOT.

- Approved by voters in November 2015, the 9-year, $930 million Seattle Department of Transportation Levy to Move Seattle provides funding to improve safety, maintain Seattle's streets and bridges, and invest in reliable, affordable travel options. The program is creating very significant impacts to SPU's water infrastructure in the street right-of-way, especially the arterial street resurfacing and reconstruction components. However, it is also presenting some opportunities for SPU to replace aging water main infrastructure.

Because these transportation projects are led by third-parties, the schedule for completion is not within SPU's control and is subject to change.

5.4.4.2 Redevelopment

Redevelopment activities can have a substantial impact on the ability of the existing distribution system to provide sufficient water to customers and for fire flows. Rezoning can also change distribution system requirements, particularly when single-family residential parcels are rezoned to mixed or commercial uses. Most often, extension of the distribution system or improvements to existing water mains in the redeveloped area becomes necessary to provide water service to new dwellings, more densely arranged, on streets previously occupied by low-density housing and larger lots. Frequently, the required water main extensions promote better system gridding, which has the effect of improving fire flows and looping existing dead end mains. Detailed hydraulic models or hydrant flow tests are used in conjunction with fire flow requirements provided by the fire department[1] to identify potential water main improvements when properties are redeveloped, as well as when new development takes place.

New developments must meet the current fire code, and new service connections must be made to suitable water mains. SPU reviews and provides a water availability certificate for each development as part of the local government's building permitting process (see appendices for SPU's policies and procedures for new services). If there is a gap between what the existing system can provide and what the private development needs, the developer will be required to upgrade the existing system to meet

[1] See footnote on page 5-9 for fire departments with jurisdiction in SPU's retail service area. For the City of Seattle, fire flow requirements are defined by the Seattle Fire Code (SMC 22.600). Fire flow standards for unincorporated King County are defined by KCC 17.04 and 17.08.

requirements. Developers are required to pay for connection to the system. New tap installations are directly billed to the customers.

5.5 Implementation/Action Plan

As described in this chapter, the major needs for managing the distribution system to meet service level targets include asset management planning, distribution system assessment and planning, addressing the performance of the water system following a major earthquake, and opportunities presented by third-party projects such as SDOT's Move Seattle program. SPU has identified the following actions to address these needs:

- Manage retail service delivery, problem response and leakage to meet service level targets.
- Improve operational response and customer service by using information from the water main shutdown block analysis in project and emergency shutdown plans.
- Update asset management documents, including the Meters AMP, and implement the strategies identified therein.
- Continue to proactively replace or rehabilitate water mains based on risk profile including leak/break history.
- Resume critical valve preventative maintenance and exercising program (updated via Valve AMP) to ensure adequate and reliable control of the water distribution system grid.
- Based on the water system seismic vulnerability study, improve the overall water system's performance following a major earthquake.
- Continue to work with the Seattle Fire Department and Shoreline Fire Department to improve fire hydrant maintenance and testing practices, better coordinate communication, and prioritize fire flow improvement projects. Engage in similar discussions with other fire districts.
- Include proactive hydrant painting tasks in all hydrant maintenance work orders to paint hydrants when needed and during amendable weather conditions.
- Correct deficiencies found at pump stations.
- Continue working with developers where water main replacements or upgrades in redevelopment areas are required to meet current fire flow requirements and water main standards.

- Address impacts to the water system from transportation projects, particularly Move Seattle levy and Sound Transit projects.

CHAPTER 6

CAPITAL IMPROVEMENT BUDGET

Previous chapters describe SPU's drinking water CIP projects and O&M programs and identified a number of needs, gaps, and issues facing SPU in each of its business areas. This chapter focuses on the budget required to implement capital programs to meet SPU's regulatory and customer service objectives, including addressing the needs and gaps. The first part of the chapter begins by describing SPU's process for developing a capital improvement budget for the water system. Later, the chapter identifies the budget for the 10-year capital improvement program (CIP) and capital facilities plan (CFP) through 2040 for the water line of business, along with potential additions to the CFP.

6.1 Capital Improvement Budgeting

SPU uses an asset management approach in selecting which capital improvement projects go forward. Asset management is a method of meeting established and well-defined service levels at a cost that represents the highest life cycle value to the utility's ratepayers. This may lead to new capital projects or shifts in O&M activities. By adopting an asset management approach, SPU is better able to ensure cost effectiveness in service delivery in the long-run.

Elements of SPU's asset management approach were described in the *2007 Water System Plan.* One key element is development of a business case for each project (formerly known as a Project Development Plan) that includes a clearly defined problem, an analysis of alternative solutions, and a benefit-cost analysis to inform a preferred alternative decision. Business cases for projects or programs that are projected to cost $1,000,000 or more over their life, considering both capital and O&M costs, must be reviewed by SPU's Asset Management Committee (AMC), which is composed of SPU's Executive Team. Water CIP projects that are estimated to cost less than $1,000,000 must be reviewed by the AMC for the water line of business. Such approvals support asset management by making deliberate decisions about projects and programs in a transparent manner, fully informed by financial, environmental, and social impact life-cycle costs and benefits of the business case.

Many of the projects that are included here have not yet gone through a final business case evaluation and review by the AMC.

The project descriptions, scope, budget and timing are based on best current planning.

6.2 Business Area Actions and Costs

Previous chapters of this water system plan identify key actions for each water utility business area over the next 10 years. Those key actions related to capital projects are recapped below for each business area. An overview of the 2019-2028 CIP budget, summarized according to business areas, is presented in Table 6-1. The detailed CIP is provided with the Capital Facilities Plan as an appendix. CIP cost estimates presented in this plan are preliminary and subject to change as the projects are further developed and analyzed. CIP projects are subject to AMC approval and budget adoption by the Seattle City Council.

Table 6-1. Capital Improvement Program Budget 2019-2028 (2018-2023 Adopted CIP, plus 2024-2028 Estimate, in thousands of 2017 dollars)

Business Area	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Water Resources	1,966	2,253	2,816	2,825	3,575	2,584	2,974	11,752	6,117	2,124	38,986
Water Quality and Treatment	5,822	19,028	1,802	6,753	16,901	8,497	821	801	781	6,783	67,988
Transmission	12,176	10,508	11,401	3,880	4,482	4,305	13,686	16,382	17,620	16,688	111,129
Distribution	56,201	48,612	35,341	33,122	35,790	58,654	59,689	58,686	57,316	57,043	500,454
Major Watersheds	14,730	2,239	1,684	1,509	1,629	1,471	889	893	521	1,122	26,688
Other	15,664	14,262	16,002	10,298	9,878	24,144	24,263	20,238	17,555	16,655	168,957
Total	106,558	96,902	69,047	58,387	72,254	99,654	102,321	108,751	99,910	100,416	914,201

6.2.1 Water Resources

Major CIP projects for the Water Resources business area include the following:

- Implementation of the 2019-2028 Water Use Efficiency program for the Saving Water Partnership, which is budgeted at $1.045 million per year[1].
- Continuation of the Seattle-only low-income conservation assistance program at a cost of almost $700K per year.

[1] This is less than what was adopted in November 2018 for the 2018-2023 CIP, but reflects the program funding level for the 2019-2028 WUE Goal described in Chapter 2.

- Completion of Overflow Dike Improvements to raise the crest to elevation 1554 feet. The CIP includes $6.1 million in 2024-2027 for this work.

- Completion of any capital improvements resulting from regular inspections by Ecology and FERC of SPU's dams and related infrastructure, as well as flood passage improvements at Landsburg Diversion Dam on the Cedar River and improvements to the Cascades Dam at Lake Youngs. The current Dam Safety program CIP totals to $15.3 million in 2019-2028.

6.2.2 Water Quality and Treatment

Reservoir improvement projects comprises the bulk of the CIP projects in the near-term for the Water Quality and Treatment business area:

- Replacement of the floating covers at Lake Forest Park and Bitter Lake Reservoirs, which is budgeted at $64 million in the 2019-2024 period.
- Additional budget for seismic and other upgrades at the treated water reservoirs is included beyond 2024.

The CIP also includes approximately $4 million in 2019-2028 for various smaller scale water quality and treatment facility rehabilitation and improvement projects that relate to public health protection and drinking water regulatory compliance.

6.2.3 Transmission

The major CIP projects identified for the transmission system include the following:

- Transmission Pipeline Rehabilitation, including any additional work to mitigate the risk of pipe failure in the Tolt Slide area, is budgeted at over $54.3 million in 2019-2028.
- Implementation of cost-effective cathodic protection for transmission pipelines, which is budgeted for a total of $17.6 million in 2019-2028.
- Seismic improvements to transmission pipelines and facilities are included at almost $32.1 million in 2019-2028.
- Air valve chamber replacements and system dewatering improvements are budgeted at approximately $150K per year.

- Purveyor Meter Replacements are estimated to cost approximately $200K per year through 2020 and $90K thereafter.

6.2.4 Distribution

Capital improvements in the distribution system comprise almost one-half of the total CIP for 2019-2028. Several ongoing improvement programs and other major CIP projects identified for the distribution system include the following:

- Relocation, rehabilitation or replacement of water mains and appurtenances impacted by other projects, primarily transportation-related projects, but also other utility projects. The CIP includes $128.7 million for these types of projects for 2019-2028.
- Water main rehabilitation to address aging infrastructure needs is budgeted at more than $143 million for 2019-2028, with significant increases beginning in 2024, from less than $4 million per year to approximately $25 million per year.
- Water main extensions and new taps and hydrant installations to new developments comprise almost $85 million in the 2019-2028 CIP.
- Seismic improvements to distribution mains, facilities and other infrastructure are included at approximately $59 million in 2019-2028.
- Miscellaneous distribution system improvements and modifications, including fire flow improvements, are budgeted at approximately $600K per year.
- Pump station improvements, in the transmission and distribution system, are budgeted at over $5 million in the 2019-2028 CIP.
- Improvements to various storage tanks are budgeted at more than $17 million in the 2019-2028 CIP.
- Replacement of leaking or substandard service connections, including those with lead whips, is budgeted at almost $45 million in the 2019-2028 CIP.
- Upgrades to or replacement of hydrants, valves, chambers and meters, as well as other system modifications, are budgeted at $12 million in the 2019-2028 CIP.

6.2.5 Major Watersheds

Projects in the Major Watersheds business area are not covered in detail in this water system plan, but include the following:

- Improvements to roads and bridges within the watersheds, which is estimated to cost almost $1.9 million in the 2019-2028 CIP.
- Ongoing programs related to the Cedar River Watershed Habitat Conservation Plan, which are budget at $9.5 million in the 2019-2028 CIP.
- Upgrades to or replacement of facilities associated with the Cedar River Sockeye Hatchery (including the broodstock collection weir), and the Landsburg fish ladder, which total to more than $15 million in the 2019-2028 CIP.

6.2.6 Other Water Utility Capital Projects

In addition to the major projects discussed in this water system plan and summarized above, SPU has identified a number of other water system capital projects to be implemented over the next ten years. Projects involving more than one business area yet important for achieving the overall goals of the drinking water utility are also included here. These projects and programs comprise just over 20 percent of the CIP for 2019-2028. The costs for these projects and programs are summarized in Table 6-2.

Table 6-2. Other Capital Projects and 10-Year CIP Costs (2018-2023 CIP, plus 2024-2028 Estimate, in thousands of 2017 dollars)

Capital Project or Program	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Water System Plans	48	0	0	0	0	0	0	155	522	321	1,046
In-Town Facilities	5,856	4,599	4,890	1,667	830	9,632	10,547	8,288	6,211	5,792	58,311
Regional Facilities	705	2,020	3,986	1,724	1,897	7,361	6,566	4,644	3,672	3,392	35,966
Integrated Control/ Monitoring Program	343	334	326	318	310	310	310	310	310	310	3,184
Security Improvements	1,356	1,207	849	829	1,121	1,121	1,121	1,121	1,121	1,121	10,967
Heavy Equipment Purchases	1,904	1,857	1,907	1,856	1,811	1,811	1,811	1,811	1,811	1,811	18,389
1% for Arts	232	337	201	156	251	251	251	251	251	251	2,433
Technology	5,220	3,907	3,842	3,749	3,657	3,657	3,657	3,657	3,657	3,657	38,661
Total	15,664	14,262	16,002	10,298	9,878	24,144	24,263	20,238	17,555	16,655	168,957

6.3 Long-Range Capital Facilities Plan Budget

In addition to developing the ten-year capital improvement program summarized above, SPU has developed its best estimate of a Capital Facilities Plan (CFP) budget through 2040, given what is known and anticipated at this time, including our understanding of future regulations. The long-range CFP represents a continuation of the programs in the 10-year CIP. Beyond 2028, the range of uncertainty in project costs and timing is greater. While projections are shown through 2040, experience has shown that new requirements emerge and projections change over time. In particular, many programs are shown with uniform expenditures in each future year even though it is likely that the costs will be concentrated into some years as specific projects are identified and scheduled. In particular, this CFP does not address any potential major emergency or disaster which could lead to the need for a new major project. SPU would most likely attempt to smooth out expenditures, but this is not always possible.

The CFP budget estimate is provided as an appendix and summarized in Table 6-3. The CFP totals to almost $2 billion for 2019 through 2040. Almost 60 percent of the current CFP is for improvement to and rehabilitation of the distribution system.

Table 6-3. Capital Facilities Plan Budget through 2040
(2018-2023 CIP, plus 2024-2040 Estimate, in thousands of 2017 dollars)

Business Area	2019-2020	2021-2025	2026-2030	2031-2035	2036-2040	Total
Water Resources	4,219	14,774	22,121	5,170	4,975	51,259
Water Quality and Treatment	24,850	34,773	16,798	13,089	5,481	94,991
Transmission	22,683	37,755	83,674	96,330	85,721	326,162
Distribution	104,813	222,596	291,168	276,187	253,817	1,148,582
Major Watersheds	16,969	7,182	4,498	8,323	7,155	44,127
Other	29,925	84,584	76,034	54,504	50,063	295,111
Total	203,460	401,664	494,294	453,603	407,212	1,960,232

*See Appendix for additional detail.

6.4 Potential Additional CFP Budget Needs

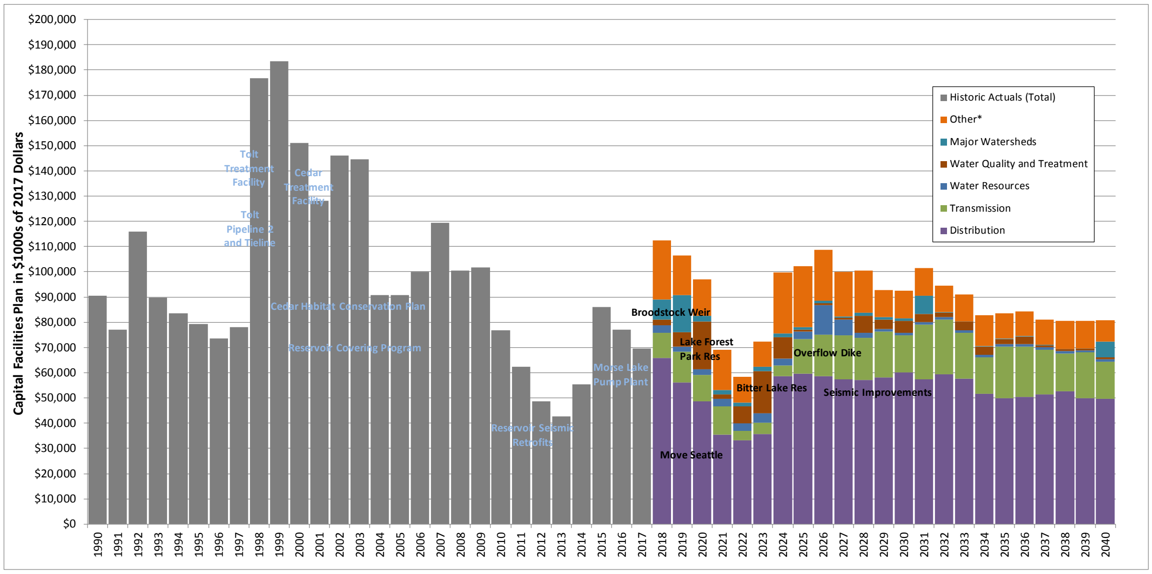
In developing the CFP, SPU identified several capital projects that could also occur but the costs and timing are less certain. It is possible, though, that SPU would reduce or defer other projects to accommodate these additional projects within current budget projections. These additional projects are:

- Extension of the regional water conservation program beyond 2028.

- Additional work in the near-term in the Dam Safety program for Tolt Dam debris boom replacement, spillway repair and dam warning system replacements and upgrades.
- Improvements to meet any requirements associated with the pending water right permits for the Seattle Well Fields.
- Capital budget to implement climate change adaptation options based on further analysis.
- Additional budget for electrical upgrades at Cedar Falls and potentially providing permanent power supply to the Morse Lake Pump Plant to improve reliability.
- Possible upgrades to the Cedar Treatment Facility should additional treatment be required or desired.
- Additional budget for the Water Main Rehabilitation program to address aging infrastructure needs.
- Potential additional land acquisitions in the Kerriston Road area.

6.5 SUMMARY

Figure 6-1 graphically represents SPU’s long-range CFP budget for the water utility, including the potential additional budget needs described above. Capital spending is expected to be highest in the earlier years, and on the order of what was spent in the late 2000s, due to significant expenditures associated with the Move Seattle transportation levy (Distribution). This is followed by increased expenditures for the Broodstock Weir (Major Watersheds) and to replace the floating covers at Lake Forest Park and Bitter Lake Reservoirs (Water Quality and Treatment). Starting in 2024, capital budget estimates increase for watermain rehabilitation in the Distribution system and seismic improvements in the Transmission and Distribution systems. These capital budget needs are subject to change as project timing and costs better understood.



* Other includes Fleets, Facilities, Security, Information Technology, SCADA and other miscellaneous projects.

Figure 6-1. Historic and Proposed Capital Facilities Plan Spending through 2040

SPU's *2013 Water System Plan* included a long-range capital facilities plan for the water utility. Table 6-4 compares the CFP budget for the 2013 plan with the CFP budget presented in Table 6-3 and Figure 6-1.

As Table 6-4 shows, SPU has increased its capital spending projections for the 2018-2040 period relative to that provided in its *2013 Water System Plan* primarily due to increased expenditures for the transmission and distribution system, including those related to transportation projects, water main rehabilitation, additional seismic improvements, cathodic protection and transmission pipeline rehabilitation.

Table 6-4. Comparison of Capital Facilities Plan Budget Estimates from *2013* and *2019 Water System Plans*
(in total millions of dollars for the year range shown)

Water System Plan	2018-2020	2021-2025	2026-2030	2031-2035	2036-2040
2013 (in 2017 $s)	191	301	268	256	255
2019 (in 2017 $s)	316	402	494	454	407
Increase	125	101	226	198	152

Assumes 2.5% inflation

CHAPTER 7

FINANCIAL PROGRAM

This chapter describes the likely methods of financing the estimated cost of operating SPU's water system and investing in the capital projects described in Chapter 6.

7.1 FINANCIAL POLICIES

Financial management of the water system is directed by formal financial policies adopted by the City Council and by informal guidelines that have evolved over time in response to specific issues. These policies and guidelines are used to decide how to finance water system operations and capital projects. They are intended to ensure that the water system finances its costs in such a manner that specific policy goals are achieved. These goals are:

- To ensure the financial integrity of the water utility.
- To moderate rate increases for water system customers over the near and medium term.
- To ensure an equitable allocation of capital costs between current and future ratepayers.

In 2005, the City Council adopted new water system financial policies that reflect changes and additions to the financial policies adopted in 1992. The new financial policies are more appropriate for the current financial environment and capital financing requirements, and also reflect changes made in 2005 to the conditions for activity in the Revenue Stabilization Subfund. The financial policies are as follows:

1. Maintenance of Capital Assets. For the benefit of both current and future ratepayers, the municipal water system intends to maintain its assets in sound working condition. Future revenue requirement analyses will include provision for maintenance and rehabilitation of facilities at a level intended to minimize total cost while continuing to provide reliable, high quality service.

2. Debt Service Coverage. Debt service coverage on first-lien debt should be at least 1.7 times debt service cost in each year on a planning basis.

3. Net Income. Net income should generally be positive.

4. Cash Funding of the Capital Improvement Program. Current revenues should be used to finance no less than 15 percent of the municipal water system's adopted CIP in any year, and not less than 20 percent of the CIP over the period of each rate proposal. Cash in excess of working capital requirements may be used to help fund the CIP.

5. Eligibility for Debt Financing. Unless otherwise authorized by the City Council, the following criteria must be met before project expenditures are eligible for debt financing:

   - Project is included in the CIP.
   - Total project cost exceeds $50,000.
   - Project has expected useful life of more than two years (more than five years for information technology projects).
   - Resulting asset will be owned or controlled by SPU, is part of the regional utility infrastructure, or represents a long-term investment for water conservation.
   - Consistent with generally accepted accounting practices, project costs include those indirect costs, such as administrative overhead and program management, that can be reasonably attributed to the individual CIP project.

Revenue Stabilization Subfund is available to offset shortfalls in metered water sales revenues or to meet financial policies.

6. Revenue Stabilization Subfund. A target balance of $9 million will be maintained in the Revenue Stabilization Subfund, except when withdrawals resulting in balances below this amount are needed to offset shortfalls in metered water sales revenues or to meet financial policy requirements. Funds in excess of the minimum balance may be used to meet operating expenses, pay CIP expenditures, or meet financial policy requirements.

   SPU, when all financial policy targets are exceeded, is required to deposit water sales revenue above planned revenue. SPU may also make discretionary deposits to the Revenue Stabilization Subfund, provided that these discretionary deposits are in excess of the amounts required to meet the financial policy requirements. Should the balance in the Subfund fall below the target balance, SPU must submit within one year a water rate proposal that rebuilds the balance in the Subfund.

7. Cash Target. The target for the year-end operating fund cash balance is one-twelfth of the current year's operating expenditures.

8. Variable Rate Debt. Variable rate debt should not exceed 15 percent of total outstanding debt. Annual principal payments shall be made on variable rate debt in a manner consistent with fixed rate debt.

The financial policies help determine how much revenue the utility must collect from its customers each year to meet the cost of operations, maintenance and repair, and capital improvements. Because of this, rate impacts stemming from specific courses of action recommended in this water system plan cannot be determined without also considering what financial policies are to be followed. If an action's rate impacts are unacceptable, the action can be scaled back to reduce costs or alternative financial approaches can be considered to spread costs over a longer period.

7.2 Financial Health

Financially healthy organizations have the flexibility to respond to unexpected circumstances. Such circumstances may include new, unexpected-but-essential tasks or a shortfall in earnings. Flexibility can mean redirecting expenditures, borrowing money to meet an unexpected need, or other approaches.

The use of debt to finance a significant amount of new and replacement infrastructure has kept rates low but increased the amount of revenue used to repay loans.

In the past, the water system financed a significant amount of new and replacement infrastructure through the use of debt. While it helped keep rates low at that time, it has also greatly increased the portion of revenue that is used to pay off the debt. In 1990, 20 cents of every revenue dollar were used to repay loans. In 2016, 33 cents of every revenue dollar were used to repay loans. This means that SPU has less flexibility in how it spends its revenues. Current revenues that are used for new facilities are the most flexible resource for meeting unexpected needs.

The increasing commitment of each revenue dollar to pay off debt makes sources of financial instability riskier because SPU has less flexibility to adjust to revenue shortfalls and unanticipated needs. One cause of revenue fluctuation for SPU is seasonal rates, which are used to discourage water use in the summer when water is most scarce. Variations in summer weather can cause annual water use to vary from an average year by as much as 5 percent. Since this variation happens in the summer, when rates are higher than the winter, summer weather variation can result in annual water sale revenue shortfalls of up to 8 percent. The Revenue Stabilization Subfund can be used to offset revenue shortfalls beyond these levels.

Reducing this weather-related revenue risk could also be accomplished by reducing the difference between winter and summer rates. Higher winter rates or increasing the base service charge would provide more annual revenue and therefore more of a "cushion" against revenue shortfalls. However, changing the seasonal rate structure would reduce incentives to conserve water in the summertime.

There are two key indicators used by the financial community that provide a measure of how well SPU is doing in the areas identified above. The first, debt-service coverage, is an annual measure of the revenue an organization has available to repay debt, divided by debt payments. Debt-service coverage is calculated after operational expenses and some taxes have been paid. While the legal requirement in bond covenants is 1.25, SPU's debt-service coverage policy target is 1.70. The higher target provides SPU flexibility when actual revenues are lower than projected. This flexibility enabled SPU to collect the necessary revenue to stay above the legal requirements, but below the policy target, when demand in the late 2000's and early 2010's was lower than originally projected and variable rate debt was refunded into fixed rate debt when market conditions changed. Since 2013, debt service coverage has not been lower than 1.77, well above the policy target.

SPU's water utility is rated Aa1 by Moody's and AA+ by Standard and Poors.

The second key indicator is the debt-to-assets ratio. The debt-to-assets ratio is the outstanding debt of the utility divided by the sum total of its assets. The debt-to-assets ratio shows how reliant the utility is on debt to finance its infrastructure and how much flexibility is has to respond to unexpected circumstances. SPU's debt-to-assets ratio for the water system is currently higher than comparable utilities and is at a level that could be a concern to the financial community, which could result in higher debt financing costs if investors view SPU as overextended. To counteract this concern, SPU has generally decreased the levels of debt financing and has forecasted continuation of this trend in the near future. As a result, in recent years, SPU has had excellent bond ratings.

While SPU has been generally decreasing the levels of debt financing of the capital improvement program, exceptions occurred in 2008 and 2009 when revenues fell to the point where cash available to fund the capital program was less than 20 percent of total spending, forcing more reliance on debt. Revenue financing of capital projects is expected to remain above 35 percent through 2023, decreasing to around 21 percent from 2024 through 2040. In the near term, the binding financial policy target remains debt service coverage. In order to meet debt service coverage targets, revenue requirements will generate more cash than needed to cover operating expenses and other financial policy targets. The excess cash will be put towards the capital program. By investing more current revenue in infrastructure, SPU will reduce its reliance on debt and thereby reduce its debt-to-assets ratio. The necessity of meeting the debt service coverage targets will drive rate increases in the coming years. Beginning in 2024, the binding financial policy is expected to move back and forth between debt service coverage and cash financing of the capital program.

A summary of SPU's financial results for its water utility over the past six years is shown in Table 7-1.

Table 7-1. Financial Revenues and Expenditures, 2011-2016 (in millions of dollars)

	2011	2012	2013	2014	2015	2016
Revenues						
Water Sales	183	199	217	225	232	233
Other (tap fees, interest income, operational grants, reimbursements, etc.)	19	25	27	26	38	34
Total	202	224	244	251	271	266
Expenditures						
Operations and Maintenance	78	81	89	93	101	103
Taxes	31	34	38	40	42	42
Debt Service	80	78	79	78	79	83
Revenue-Financed Construction	16	26	24	35	53	45
Total	204	219	230	246	275	273
Net of Revenues and Expenditures	(1)	5	15	6	(4)	(6)

7.3 FUNDING SOURCES

The primary source of funding for SPU's water utility is revenues derived from the wholesale and retail sales of treated drinking water.

The primary source of funding for SPU's water utility is revenue derived from wholesale and retail sales of treated drinking water. To finance capital facilities, SPU relies primarily on borrowing. SPU also receives contributions from developers, but that funding source plays a much smaller role in capital financing. The water system has entered a new period of capital expenditures, moving away from large, centralized projects to smaller, decentralized infrastructure improvements.

As stated earlier, debt service coverage is the binding financial policy through 2024, when debt service coverage and cash financing of CIP alternate as the binding policy. In years where debt service is the binding constraint, revenues will be in excess of operating expenses, leaving excess cash to fund the CIP. As a result, from 2018 through 2040, SPU plans to meet or exceed its financial policy of financing 20 percent of its capital facilities plan with revenues. However, because of the large size of the CIP in the next six years, SPU will still rely heavily on borrowing.

7.3.1 Water Rates

In 2016, water sales made up 93 percent of operating revenues. Rates must provide sufficient revenue to operate the water system. Rate-design objectives include:

> ***If we use less water, shouldn't it cost less?***
>
> *Most of the utility's costs are the same whether we sell a lot of water or a little. These fixed costs include debt service (principle and interest paid for past capital projects) and the labor needed to operate the system, treat the water, and respond to problems 24 / 7.*
>
> *When we sell less water, we need to charge more per gallon to be sure that SPU makes enough revenue to operate and maintain the water system while meeting financial policies set by the City Council.*

- Provide financial soundness.
- Advance economic efficiency.
- Promote customer equity.
- Encourage customer conservation.
- Contribute to transparency and customer understanding.
- Reduce impacts on low-income customers.

The affordability of rates to retail customers is also an issue considered by City Council during rate setting.

In most years, City Council has set rates for 3-year periods. Rates were last set in 2017 for 2018-2020. These rate schedules are provided in the appendices.

Rates are set by customer class. The major customer groupings are wholesale and retail. Wholesale rates are set as described in their contracts with SPU. Retail customers are further categorized into residential and general service classes (multi-family housing is considered general service for rate-setting purposes). The rate structure for each of the customer classes includes a fixed monthly charge, which is graduated by the size of the service, and a seasonally-differentiated commodity charge. The combination of fixed and commodity charges can be fine-tuned to meet the rate objectives identified above. For example, the fixed charge can be set to recover costs that are unrelated to the amount of water used, such as billing and meter reading. Similarly, seasonal commodity rates can be set to reflect the cost differentials that exist between winter, when streamflows are high and demand is low, and summer, when streamflows are low and demand is high. Setting rates so that the bills of individual customers reflect the cost of serving them is especially important in achieving customer equity because the most commonly used definition of equity is that bills reflect costs.

To encourage conservation in the summer period, the residential commodity rate is structured with three tiers. The first tier, up to five hundred cubic feet (CCF), is designed as a “lifeline” to meet basic needs. The second tier, from 5 to 18 CCF, is billed at a higher rate than the first. The third tier[1], above 18 CCF, is set at an even higher rate to discourage the use of very large volumes of water, often for irrigation.

System-wide average rates[2] are likely to increase faster than the rate of inflation, particularly in the near-term. A significant portion of current and near-term rates are due to debt service on prior capital investments, such as the Tolt and Cedar Water Treatment Facilities. Going forward, those effects are still felt as future CIP and O&M spending will put pressure on debt service coverage requirements, thereby requiring increasing rates. Additionally, future rate levels depend on revenue requirements as well as the amount of water sold. With demand for water forecasted to generally decline through 2040, there will be no growth in water sales to absorb any increases in revenue requirements.

While the above discussion applies to the system as a whole, there is a categorical difference between the rates paid by wholesale customers and the rates paid by retail service customers. Wholesale customers do not pay for SPU’s distribution system, since they are not served by these facilities. They pay only for their share of water supply, treatment, and transmission. Going forward, the CIP contains fewer regional projects in the areas of supply, treatment, and transmission. The rates charged by SPU’s wholesale customers to *their* customers include the cost of the wholesale customer distribution systems, and would be different than what SPU charges its retail customers.

7.3.2 Debt Financing

From 2018 through 2040, 76 percent of the Capital Facilities Plan (CFP) is expected to be financed with debt, as shown in Figure 7-1, below. Debt is expected to be used to finance 64 percent of CIP through 2023 and 79 percent thereafter. Until 2024, debt service coverage is expected to significantly alter the way capital projects are financed. Because of the large debt incurred since 1999, a larger portion of revenue must go to finance capital facilities to meet bond covenant requirements and financial policy targets. To

[1] The third tier was instituted in 2001 in response to Ordinance 120532, the Initiative 63 Settlement Ordinance.

[2] System-wide average rates are defined as the average rate paid by all customers of the utility. It is computed by taking the total water sales revenue divided by total system water use by all customers.

maintain debt service coverage requirements, revenue is higher than otherwise would be required. The additional revenue will then be utilized to fund the current capital program, reducing debt issuance and future debt service requirements.

Figure 7-1. Past and Planned Debt Financing

7.3.3 Debt-to-Assets Ratio

From the mid-1990's through 2010, SPU borrowed extensively in order to finance the capital program and the building of new assets. This level of borrowing increased the debt-to-asset ratio 40 percent over 15 years, peaking at 75 percent in 2011, as shown in Figure 7-2. Beginning in 2012, SPU has taken advantage of strong bond ratings and favorable interest rates to refinance large portions of historical debt. In three separate re-financings, SPU lowered outstanding debt by $50 million while also lowering debt service payments. These refinancing results, combined with low capital expenditure in the early 2010's, dramatically lowered the debt-to-asset ratio. Increased revenue financing is expected to continue lowering the debt-to-asset ratio through the mid-2030's.

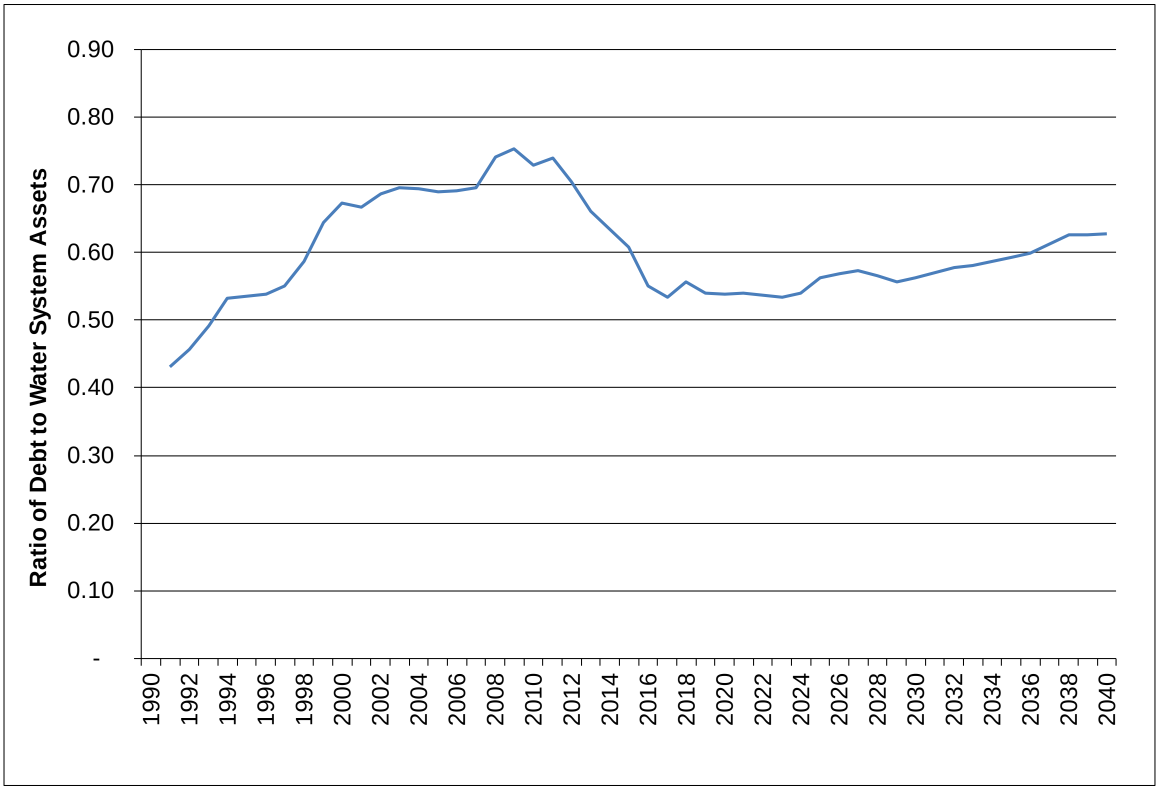


Figure 7-2. Past and Projected Debt-to-Assets Ratio

7.3.4 Alternative Financing Paths

A lower debt-to-assets ratio could be achieved more quickly by higher rate increases in the near-term, coupled with deferral of part of the capital program. This would allow a greater portion of the capital program to be financed out of revenues over time. However, it would also result in higher near-term rates, and deferring projects could prevent the water system from complying with regulatory agreements made with state and federal agencies. The current approach strikes a balance between short-term debt service needs and long-term financing that will provide the utility stability and address important capital needs and operating requirements.

7.4 Financial Model Cash Flow Analysis

The capital improvements summarized in the Part II, Chapter 1, together with projected operating expenses through 2040, were incorporated into the water system's financial model in order to develop a long-term picture of rate requirements and financial performance. The anticipated cash flows and financial performance generated by the financial model are summarized at five-year intervals in Table 7-2. The debt service coverage of 1.7

controls rates through 2032. After 2032, SPU's financial policy target for cash-to-CIP becomes binding for rates.

Table 7-2. Summary of Water System Cash (in millions of dollars)[1]

Revenue/Expenditures[1]	2020	2025	2030	2035	2040
Revenues					
Water Sales	263	312	377	438	549
Other (tap fees, interest income, operational grants, reimbursements, etc.)	30	35	40	44	51
Total Revenues	293	347	416	482	601
Expenditures					
Operations and Maintenance	131	160	195	238	289
Taxes	46	58	73	86	110
Debt Service	90	103	121	131	163
Revenue-Financed Construction	16	17	19	17	18
Total Expenditures	283	339	408	471	580
Net Revenue	10	8	8	11	20
Debt Service Coverage	1.7	1.7	1.7	1.7	1.8
Debt-to-Assets Ratio	54.23%	57.84%	55.63%	60.45%	62.13%
Cash Balance	33	38	43	48	53
Capital Improvement Program	2018-2020	2021-2025	2026-2030	2031-2035	2036-2040
Revenue Financing	99	96	96	96	95
Contributions in Aid of Construction	20	36	40	45	51
Debt Financing	212	338	512	531	538
Total CFP Financing	332	469	648	672	684

[1]Notes and Assumptions:

- Actual dollars spent or received in any given year; revenues and expenditures are inflated to off-set the erosion of purchasing power over time due to inflation.
- Revenues and expenditures do not net zero in this summary because of rounding errors, contributions to cash balances, and lags between when revenues are billed and when they are received.
- Operations and Maintenance assumed to increase by 40 percent from 2018 through 2040 in real terms, or 1.5% compounded annual growth per year. For comparison, from 1990 to 2017, O&M costs have grown at an annual rate of 1.3% in real terms.
- The forecast assumes bond issues every other year at 5.5% interest and 30-year terms.
- The forecast assumes inflation of 2.5% per year.

Cash expenditure remains high throughout the plan. From 2018-2025, cash expenditure is high because capital expense is largely financed by revenue. The largest capital programs include Distribution System Improvements, Transmission Pipeline Upgrades, Water Main Rehabilitation and projects related to transportation improvements. From 2026-2040, revenue expenditure remains level as capital expenditure remains fairly consistent and financial policy dictates minimum spending levels. After 2025, operations and maintenance spending growth is the primary driver of increased spending.

7.5 CONCLUSION

SPU has been making, and continues to make, significant investments to protect public health, comply with federal and state regulations, and replace aging infrastructure. While SPU has invested in major regional facilities in the past decades, the need is now shifting to significant capital investments to rehabilitate and improve the distribution system and to improve performance after an earthquake. Implementation of this water system plan will help to ensure that SPU meets its mission to provide efficient and forward-looking utility services that keep Seattle the best place to live and work for everyone.