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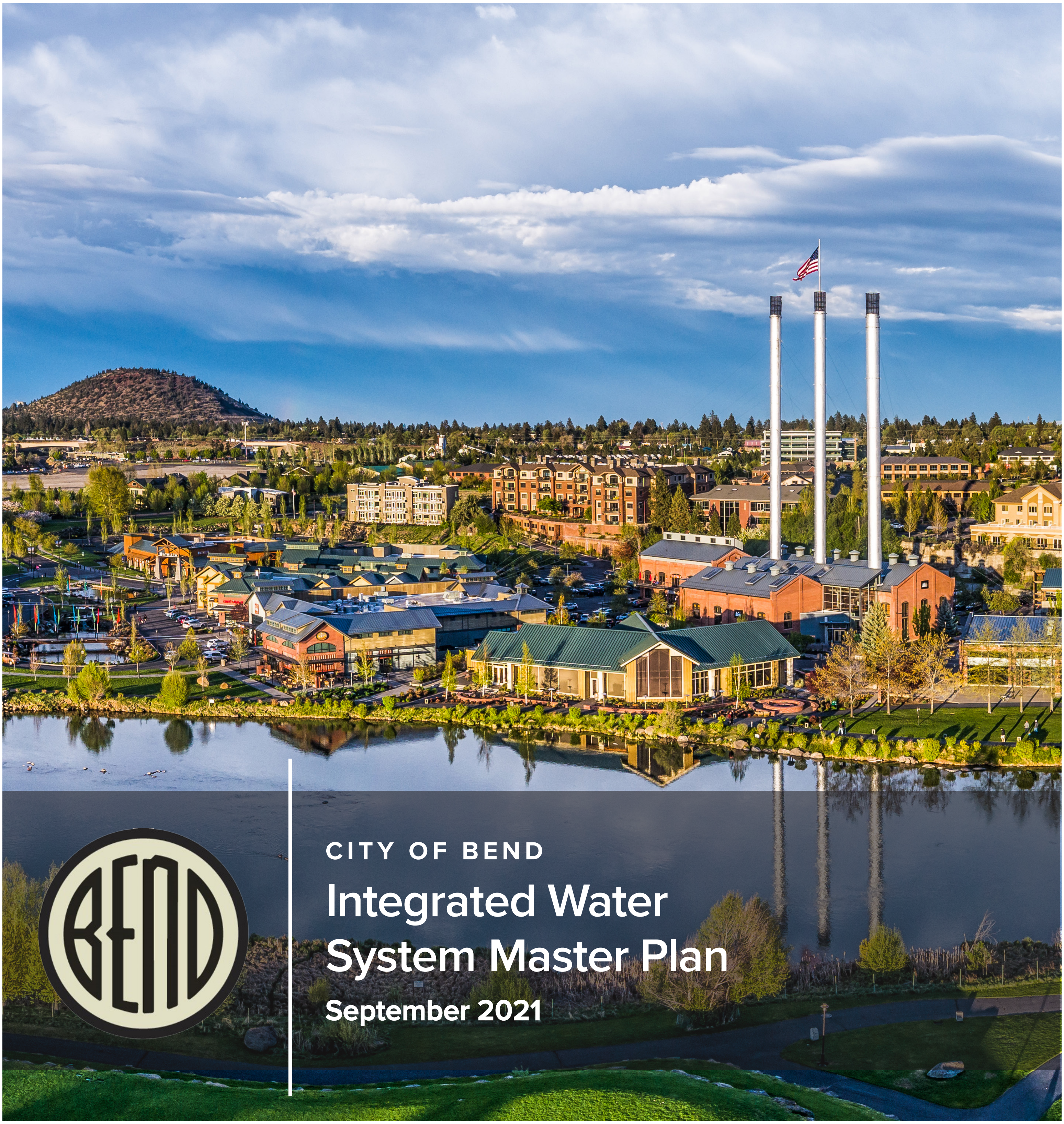

CITY OF BEND

Integrated Water System Master Plan

September 2021

RESOLUTION NO. 3275

A RESOLUTION ADOPTING THE 2021 INTEGRATED WATER SYSTEM MASTER PLAN

Findings

A. The water system of the City of Bend (City) provides reliable, high quality water and service to customers.

B. The City operates a public drinking water system within the City of Bend, that supplies water to its customers from both surface and ground water sources.

C. The Integrated Water System Master Plan (the iWSMP) evaluates the ability of the City's water system to meet desired Level of Service Standards under existing and future conditions. It is a comprehensive update resulting in a complete Water Master Plan as defined under Chapter 333, Division 61 of the Oregon Administrative Rules (OAR). City engineering and legal staff will be further reviewing the need to submit the updated iWSMP to OHA for approval in compliance with OAR 333-061-0060, and will do so as required.

D. The last water master planning effort at the City was conducted in 2007 (the Water System Master Plan Update, Final report), and the Water System Master Plan Update Optimization Study in 2011, and yielded a 10-year capital implementation plan to the year 2020. This updated iWSMP is intended to build upon previous master plans, incorporate the latest changes to growth and maintenance needs of the system, and continue to build upon the successful completion of prior Capital projects.

E. The system is robust; having both surface and groundwater supply sources provides a system that is resilient, reliable and supplies high-quality drinking water. Adding pretreatment to the surface water supply will increase its resilience and reliability.

F. The City's water system includes existing extensive infrastructure that requires significant investment to address deferred maintenance in facilities and pipe to extend its useful life.

G. The City's water needs are projected to continue increasing, requiring investments in new pipe, storage, and wells.

H. Optimization hydraulic modeling was used to test millions of solutions to improve system performance for lower cost.

I. Reductions in water use from increased conservation measures could decrease the required investment in new infrastructure.

J. To implement the $391 million (2020 dollars) in improvements, the iWSMP includes a 30-year financial plan that identifies a need to use existing reserves, raise customer water rates, and issue new bonds.

K. The implementation of the iWSMP moving forward should be informed by the current system conditions and include detailed project designs, refinements to costs and budget, and regular updates to system data.

L. In May 2021, the City Council held an informational work session where City staff provided a water system overview, water conservation efforts to date, a summary of the engineering, technical, and modeling work that went into developing the iWSMP, and preliminary outreach results.

M. Council gave direction to Staff to create an online Open House with a short survey for community members to share their thoughts on the iWSMP. Council further directed that further discussions related to water conservation efforts should continue separately through the end of the year with the Environment & Climate Committee (ECC).

N. With this direction, the City of Bend hosted an online Open House for the iWSMP from June 28 through August 6, 2021. The Open House included a 5-minute community survey to gather feedback on priority values for water system and water conservation planning. Two hundred twenty survey responses were collected.

O. Based on results of the community outreach efforts, the City found a high level of interest from the public in exploring opportunities for additional conservation efforts. Therefore, over the next several months, City staff will be engaging with the ECC and interested public to explore additional conservation possibilities, and will bring options back to the City Council based on the ECC recommendations.

Based on these findings,

THE CITY COUNCIL OF THE CITY OF BEND RESOLVES AS FOLLOWS:

1. The 2021 Integrated Water System Master Plan is adopted.
2. By this adoption, Council authorizes any minor, clarifying or needed changes/amendments to the iWSMP as a result of review, if needed, of the iWSMP by the Oregon Health Authority, without further Council approval.
3. The resolution takes effect immediately upon adoption.

Adopted by City Council on October 6, 2021

YES: Mayor Sally Russell
Mayor Pro Tem Gena Goodman-Campbell
Councilor Barb Campbell
Councilor Melanie Kebler
Councilor Anthony Broadman
Councilor Megan Perkins
Councilor Rita Schenkelberg

NO:

Sally Russell

Sally Russell, Mayor

ATTEST:

____
Robyn Christie, City Recorder

APPROVED AS TO FORM:

____
Mary Winters, City Attorney

Integrated Water System Master Plan

City of Bend

September 2021

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Acknowledgements

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Acronyms & Abbreviations

A	
AACE	American Association of Cost Engineers
ADD	average day demand
AMI	automated metering infrastructure
Avion	Avion Water Company
AWIA	America's Water Infrastructure Act
AWWA	American Waterworks Association
B	
BMW	Bend Municipal Watershed
C	
CCL	Contaminant Candidate List
CCR	Consumer Confidence Report
cfs	cubic feet per second
CI	Cast Iron
CIP	Capital Improvement Plan
City	City of Bend
CT	Contact Time
CWSRF	Clean Water State Revolving Fund
D	
DBPR	Disinfection Byproduct Rule
D/DBP	Disinfectant/Disinfection Byproduct
DI	Ductile Iron
DSS Model	Decision Support System Model
DWS	Drinking Water Services
E	
EMP	Employee
ENR CCI	Engineering News Record Construction Cost Index
EPA	U.S. Environmental Protection Agency
EPS	Extended Period Simulation
ERU	Equivalent Residential Unit
EUAC	Equivalent Uniform Annual Cost
F	
FCLV	flow control and level valve
FCV	flow control valve
fps	feet per second
FY	Fiscal Year
G	
GIS	geographic information system

gpcpd	gallons per capita per day
gpm	gallons per minute
GWUDI	groundwater under the direct influence of surface water
H	
HAA5	Five Haloacetic Acids
HGL	hydraulic grade line
hp	horsepower
HU	Housing Unit
I	
IOC	inorganic contaminants
iWSMP	Integrated Water System Master Plan
L	
LCR	Lead and Copper Rule
LF	linear feet
LOS	Level of Service
LRAA	Locational Running Annual Averages
M	
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MDD	maximum day demand
mg/L	milligrams per liter
MG	million gallons
mgd	million gallons per day
MRDL	maximum residual disinfectant levels
MRDLG	maximum residual disinfectant level goals
µg/L	microgram per liter
N	
NPDWR	National Primary Drinking Water Regulations
NSDWR	National Secondary Drinking Water Regulations
O	
O&M	Operations and Maintenance
OAR	Oregon Administrative Rules
OHA	Oregon Health Authority
P	
pCi/L	picoCuries per liter
PER	Preliminary Engineering Report
pH	hydrogen potential
PHD	peak hour demand
PRC	Portland State University Population Research Center
PRV	pressure reducing valve
psi	pounds per square inch
PSV	pressure sustaining valve
PVC	polyvinyl chloride

R	
Roats	Roats Water System
RR	Radionuclides Rule
RTCR	Revised Total Coliform Rule
S	
SCADA	supervisory control and data acquisition
SDWA	Safe Drinking Water Act
Siting Study	Outback Siting Study
SMCL	secondary maximum contaminant level
SOC	synthetic organic contaminants
Stage 1 DBPR	Stage 1 Disinfectants/Disinfection Byproducts Rule
Stage 2 DBPR	Stage 2 Disinfectants/Disinfection Byproduct Rule
SWTR	Surface Water Treatment Rule
T	
TC	total coliform
TCR	Total Coliform Rule
TOC	total organic carbon
TTHM	Total Trihalomethanes
U	
UCMR	Unregulated Contaminant Monitoring Rule
UGB	Urban Growth Boundary
USFS	United States Forest Service
V	
VOC	volatile organic contaminants
W	
WDS	Water Distribution System
WFF	Water Filtration Facility
WIFIA	Water Infrastructure Funding Innovation Act
WMCP	Water Management and Conservation Plan

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6. Capital Improvement Plan

7. Financial Plan

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Executive Summary

CITY OF BEND

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Executive Summary

INTRODUCTION

The City of Bend (City) is located east of the Cascade Mountains in Central Oregon with a population of approximately 90,000 people. This Integrated Water System Master Plan (iWSMP) documents key water system information and provides analysis and recommendations to inform infrastructure investments and system operations to continue providing high quality water to existing and future customers.

Considerations for How This Plan Should Be Used

This iWSMP serves as a guiding document for the City's water system improvements. Use of this iWSMP should be supplemented with:

- Annual reviews to prioritize and budget needed improvement projects.
- Regular updates to the water geographic information system data, corresponding hydraulic model, and system mapping to reflect ongoing water system improvements and expansion.
- Detailed engineering of conceptual projects recommendations. (The location, size and timing of projects may change as additional site-specific details and potential alternatives are investigated and analyzed in the preliminary engineering phase of project design.)
- Updates and refinements to cost estimates during preliminary engineering and final project designs.

Components of the Integrated Water System Master Plan:

ES Executive Summary

a. Purpose and scope of the iWSMP
b. Summary of each section and overall recommendations

1 Existing Water System

a. Outline of the existing service area and Urban Growth Boundary
b. Inventory of existing system infrastructure including supply sources, storage reservoirs, booster pump stations, control valves, and pipe network
c. Illustration of the hydraulic and geographic relationship of the system

2 Population and Demand Forecast

a. Historic population and customer data
b. Historic water production and demand data
c. Outline of future growth areas
d. Comparison of future demand projection methodologies
e. Future system-wide and pressure zone demand projections

3 Level of Service and Design Standards

a. Standards to provide reliable, high quality water and contribute to City's mission
b. Criteria to evaluate system water rights, supply, storage, pumping facilities, and piping
c. Guidelines for determining infrastructure life cycles and redundancy

4 System Analysis

a. Overview of system performance under existing and future conditions relative to level of service and design standards
b. Comprehensive analysis of existing system and future needs including:
    iii. Condition and maintenance assessment of existing facilities and pipes
    iv. Capacity analysis of existing water rights, facilities, and pipes to meet existing and future system demands
    v. Criticality assessment of supply, pipes, and valves (to evaluate whether redundant or secondary service infrastructure exists to inform essential or critical rating of system components)
    vi. Optimization of system operations and condition and capacity improvements

5 Water Quality and Regulations

a. Review of the City's compliance with state and federal water quality standards

6 Capital Improvement Plan

a. Project recommendations to address improvement needs identified through system analysis
b. Timing and cost estimates for project implementation

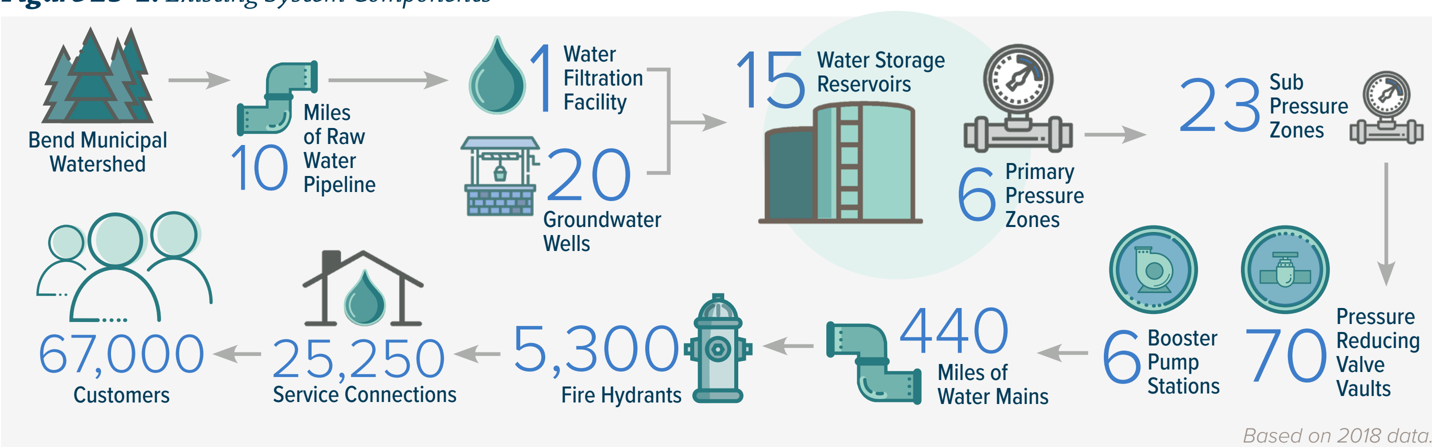
7 Financial Plan

a. Summary of water fund revenue and expenditures
b. Projected needs for rates, reserves, and debt to support proposed capital improvement plan

EXISTING WATER SYSTEM

The City's existing Urban Growth Boundary is served by three primary water suppliers, the City of Bend, Avion Water Company, and Roats Water System. The City also serves water to the Tetherow destination resort, the Westside Transect area including the Tree Farm rural residential development and Awbrey Meadows, which are located outside the UGB. The City has the capability to supply treated water to customers by utilizing groundwater and surface water. The groundwater is supplied by the Deschutes Regional Aquifer and is primarily used to supply peak demands. The City's existing surface water system begins in the Bend Municipal Watershed established by agreement with the USFS in 1926. It includes the Prowell Springs Diversion and a surface water intake facility, a water filtration facility, eight groundwater sites consisting of 20 active wells, 15 finished water storage reservoirs, six booster pump stations, approximately 440 miles of transmission and distribution mains, nearly 10 miles of raw water pipeline, and associated appurtenances including various valves, hydrants, and meters. The system includes six primary pressure zones with an additional 23 subzones.

Figure ES-1. *Existing System Components*



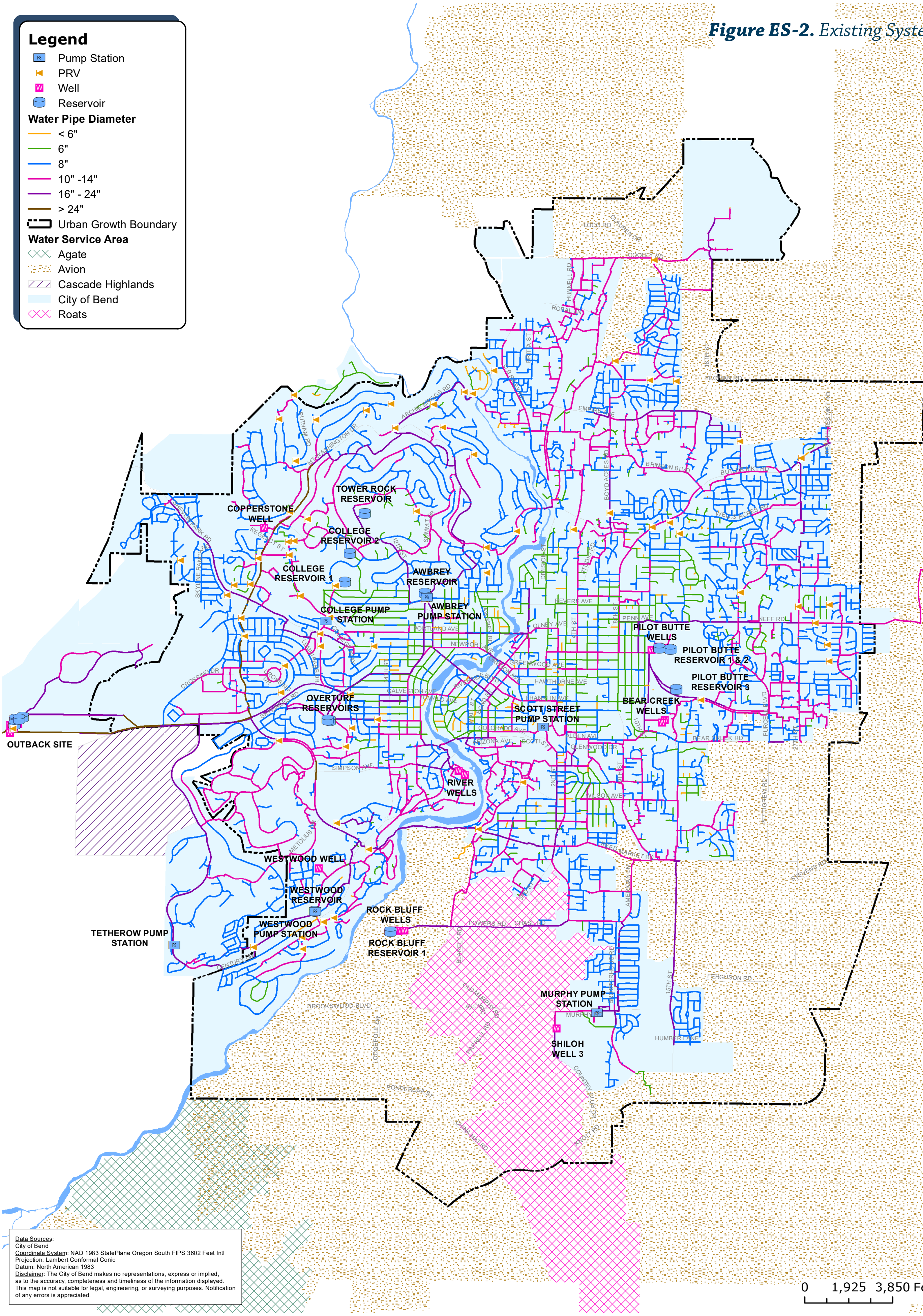
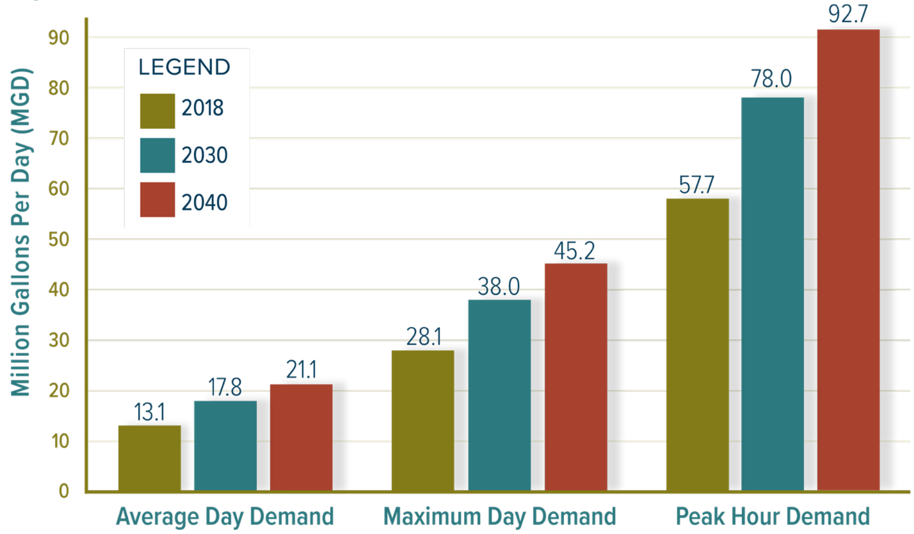


Figure ES-2. *Existing System*

POPULATION AND DEMAND FORECAST

The City's historical customer accounts, service area population, water production, use, and loss were evaluated to determine trends in the system water requirements. The customer base of the service area is estimated at 75% of the City population. The City is regularly improving its data collection and methodologies and as a result the historical data will continue to improve understanding of past and future system requirements. The future and projected number of employees and housing units, previously developed for the City (by Angelo Planning Group during the 2016 Urban Growth Boundary Study) on a parcel basis, was used to project growth in the water service area boundary. Unit demand factors based on 2018 consumption and production data were then applied to the employee and housing unit projections for each timeframe. This growth does not reflect potential declines due to less water use from increased conservation program measures. Projections reflect 20-year increases in average day demand (ADD) from 13.1 to 21.1 million gallons per day, maximum day demand (MDD) from 28.1 to 45.2 million gallons per day and peak hour demand (PHD) from 57.7 to 92.7 million gallons per day. The City currently updates their plan every 10 years which gives the opportunity to track the population and demand trends and update projections. The projected demands for the next 20 years are used to evaluate the hydraulic capacity of the system and identify improvements. The actual timing of any improvements should be based primarily on when the system reaches certain demand thresholds versus specific predetermined timelines.

Figure ES-3. *Demand Projections*



LEVEL OF SERVICE AND DESIGN STANDARDS

The City's Level of Service criteria for the water system aim to provide reliable, high quality water and service that meet regulatory standards and support the City's numerous objectives and considerations. The Level of Service criteria and planning assumptions define the framework for analysis of the system including water rights, supply, storage, pumping facilities, and piping to meet existing and future requirements. The specific criteria are in Table ES-1. Even where specific criteria are not defined, guidelines for determining infrastructure life cycles for maintenance and improvements as well as considering infrastructure redundancy is important in determining system improvements. As individual criteria are used to evaluate the system, consideration is also given more generally to City objectives such as financial and environmental stewardship, compliance with America's Water Infrastructure Act (AWIA), and energy efficiency. Additional consideration is also given to collaboration with the Deschutes National Forest including measurement and other compliance tasks such as maintaining and replacing fish screens, that are required as part of the United States Forest Service (USFS) Special Use Permit.

Table ES-1 Level of Service Summary

ATTRIBUTE	EVALUATION CRITERIA	VALUE
Water Supply	Firm Supply Capacity	Greater than MDD assuming storage is adequate for equalization and fire suppression
	Emergency Power	At least two independent sources if adequate standby storage is not available
Storage	Total Storage Capacity	Sum of dead, equalization, fire, operational, and standby
	Dead Storage	Storage that is unavailable for use or that can provide only substandard quality, flows and pressures
	Equalization Storage	Difference of PHD and max supply capacity for 150 min
	Fire Suppression Storage	Largest fire flow in a zone for duration of that flow
	Operational Storage	The volume of water before sources turn on to prevent excess pump operation or cycling
	Standby Storage	48 hours of ADD minus firm supply capacity with backup power, with a minimum of 200 gallons per ERU
Pump Stations	Minimum No. of Pumps	2
	Firm capacity pumping to storage	ADD
	Total capacity when pumping to storage	MDD
	Firm capacity pumping to system (no storage)	MDD plus fire flow or PHD, whichever is greater
	Emergency Power	At least two independent sources adequate to serve ADD plus largest fire flow (where standby power and fire suppression storage are not adequate/available)
Service Pressure	Minimum during MDD plus fire flow	20 psi
	Minimum during PHD	30 psi
	Standard Range	40-100 psi
	Maximum	120 psi[1]
Distribution Piping[2]	Maximum Velocity for ADD or MDD	5 feet per second
	Maximum Velocity for PHD	8 feet per second
	Maximum Velocity during Fire Flow	12 feet per second
	Minimum Future Pipe Diameter	8-inch
Fire Suppression	Minimum Fire Flow Requirements[3]	Residential: 1,500 gpm for 2 hours Commercial/Public: 2,500 gpm for 3 hours Central Business District: 3,500 gpm for 5 hours

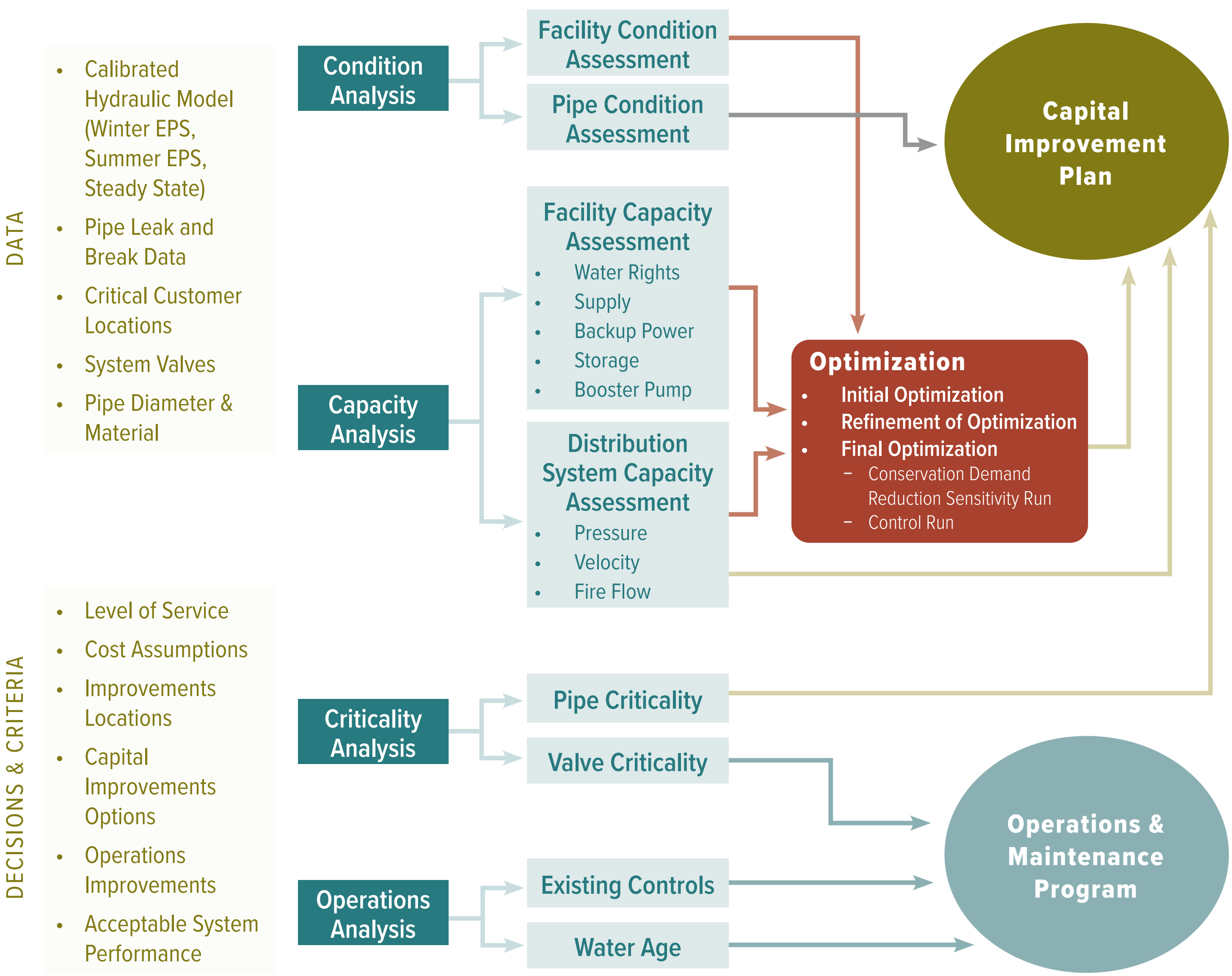
Notes:

1. For pressures greater than 80 psi, installation of individual pressure reducing valves is recommended for compliance with plumbing code.
2. Velocity criteria are primarily for designing pipe improvements and these criteria alone will not typically result in recommendations for existing system improvements.
3. For all fire flow evaluations, it is assumed that flow for only one fire at a time must be available.

SYSTEM ANALYSIS

The comprehensive system analysis of the City's water system included assessments of current infrastructure conditions, existing and future system capacity, asset criticality, and existing operations. Extensive hydraulic modeling and optimization were utilized, in addition to standard qualitative and quantitative assessments of the system. Overall, the City has a robust system that provides many ways to convey water. In addition, the value of having both surface and groundwater sources cannot be overstated from a resiliency standpoint. However, significant investment is needed to address deferred maintenance on the existing pipe and facilities to provide adequate fire flow and increase redundancy to continue service in the event of a critical asset failure.

Figure ES-4. *Comprehensive System Analysis Components*



STORAGE

Does storage volume cover operational, emergency, fire, & peak demands? Where is additional storage most needed?

WATER RIGHTS

Is the water rights portfolio & the reliably available water adequate?

SUPPLY

Where can existing surface water & groundwater supply serve & when does the system start to run short on supply?

PUMPING CAPACITY

For zones served by pump stations, is the station capacity adequate to meet typical & peak demand conditions?

BACKUP POWER

If power goes down, is there adequate backup power and emergency storage to meet minimum system needs?

DISTRIBUTION SYSTEM

Is the network sized to meet velocity & pressure level of service criteria? Where do pipes need to be replaced & new pipe added?

Condition Analysis Summary

The condition analysis focused on the existing system infrastructure to identify what improvements are required at each facility to extend its useful life and comply with current standards as well as develop a long-term pipe replacement program. Condition analysis and improvements are important to ensure investment in the existing infrastructure to maintain its performance and extend its useful life. The City system has over 440 miles of pipe, 20 active wells, six booster pump stations, and 15 storage facilities, in addition to the Water Filtration Facility and dozens of control valve vaults. These assets range in age, but the oldest facilities are approaching 100 years. The City conducts regular and proactive maintenance of the system. However, as the infrastructure ages and safety, structural, and security standards change over time, the maintenance required to repair and replace the existing infrastructure increases. Additionally, as the pipe network ages the City will need to increase the replacement rate and target undersized and substandard pipe to avoid pipe failures and maintain consistent service.

Capacity Analysis Summary

The capacity analysis identifies how much additional supply, storage volume, or pipe upsizing is required to meet Level of Service criteria for existing and future demand conditions. In addition to maintaining the existing pipe and facilities, the system also requires investment in new and upsized pipe to address existing fire flow, velocity, and pressure deficiencies, as well as future improvements to provide capacity for growth. No new well or storage facilities are needed to meet existing system capacity requirements, however, by the 10-year horizon, additional well supply with backup power and storage will be needed. Additional new wells and storage are required to meet 20-year projected demands. Facilities are needed to meet demand thresholds and if demands are lower than those projected (i.e., due to reductions from the conservation program) the number of new facilities will be reduced. The City has adequate water rights to meet 20-year demand projections but will need existing groundwater rights to be available at all facilities across the system to have operational flexibility and optimally utilize its wells.

Criticality Analysis Summary

The criticality analysis is focused on identifying critical infrastructure without redundancy or secondary service options that could significantly disrupt system operations and impact a substantial amount of demand or customers if it were out of service. The criticality analysis focused on determining which assets would have a significant impact or consequence if they were unavailable to serve the system due to failure, reduced capacity, or other unanticipated issues. Most areas of the system have redundancy, where two or more system elements (i.e., looped pipe, multiple PRV vaults, etc.) can provide water to the area and could continue to serve customers for a period if one component of the system was offline. So, although every asset in the system adds value and is important for long-term system performance, identifying the areas without multiple service options is critical to build a more resilient system that can maintain service in the event part of the system was offline.

The Water Filtration Facility capacity is critical to providing reliable supply to the system and the construction of a pretreatment facility is recommended in the near-term as a solution to provide resilience for a wildfire or other water quality event that might cause high total dissolved solids and/or sediment loads that without pretreatment could reduce or nearly eliminate the capacity of the Water Filtration Facility. Pipe improvements are recommended to address areas where single pipe breaks could result in a significant disruption to service, including the Awbrey and Outback transmission mains. Valve criticality can be used to inform ongoing maintenance programs to target locations to exercise existing valves and add new valves to the system to reduce how large an area must be isolated from service during maintenance.

Optimization Analysis Summary

The optimization analysis uses advanced hydraulic modeling techniques to evaluate and determine optimal improvements and modifications to the system to balance the cost of improvements with the improvements to Level of Service. The optimization included extensive setup of improvement alternatives, ranges of operational decisions, and establishing costs for system improvements and hydraulic penalties. The analysis included numerous refinements, resulting in millions of combinations of improvement options. The optimization process reduced the many inputs and iterations to a single recommended solution to meet 2040 projected demands. This solution includes over twenty miles of pipe projects, seven new wells, six new pressure reducing valves, and 14 million gallons of new storage. In addition, four existing storage reservoirs, one well, and one pump stations can be considered for decommissioning or used in standby or backup status with reduced investment in deferred and ongoing maintenance. As the City continues to expand its Conservation Program it should continually assess the impact on demands and the potential reduction in required facility improvements. In addition to the existing conservation programs, newly proposed conservation measures in the draft WMCP could eliminate the need for three of the new wells and 4 million gallons of the additional storage.

Operations Analysis Summary

The operations analysis indicates that the City is doing a good job of leveraging its existing facility operations to maximize surface water use and meet hydraulic requirements. Water age will continue to be an issue in portions of the system during low demand conditions and will improve as demand increases due to growth but can also be improved through operational modifications during low demand periods to circulate water in different ways throughout the system. Operational modifications to address water age should be balanced with increased energy costs due to pumping and reduced water cycling and operations costs associated with making operational changes, as well as any water quality concerns associated with reversing flow in pipes.

WATER QUALITY AND REGULATIONS

By State law (OAR 333-061-0036), the City is required to maintain an ongoing water quality testing and monitoring program. This program is administered by Oregon Health Authority and is comprised of monitoring the water supply for specified chemical and physical contaminants. Oregon Health Authority requires that the source water supply be monitored for the primary and secondary contaminants. Primary contaminant levels are not to be exceeded for health reasons, while secondary contaminants should not be exceeded to improve water color, taste, and odor.

The City is required to monitor inorganic compounds, volatile organic compounds, synthetic organic compounds, and radiological constituents. Distribution system water quality testing requirements include monitoring of many types of components including bacteriological, inorganic chemical, physical, disinfection by-products and disinfection residual, radionuclides, organic chemicals, and any other chemicals for which the state board of health determines maximum contaminant levels.

The City water system is of high quality in meeting or exceeding all water quality regulations. The most immediate change in the City's water quality sampling could be reaching the threshold of 70,000 people served, which will trigger an increase from 70 to 80 required total coliform samples per month.

CAPITAL IMPROVEMENT PLAN

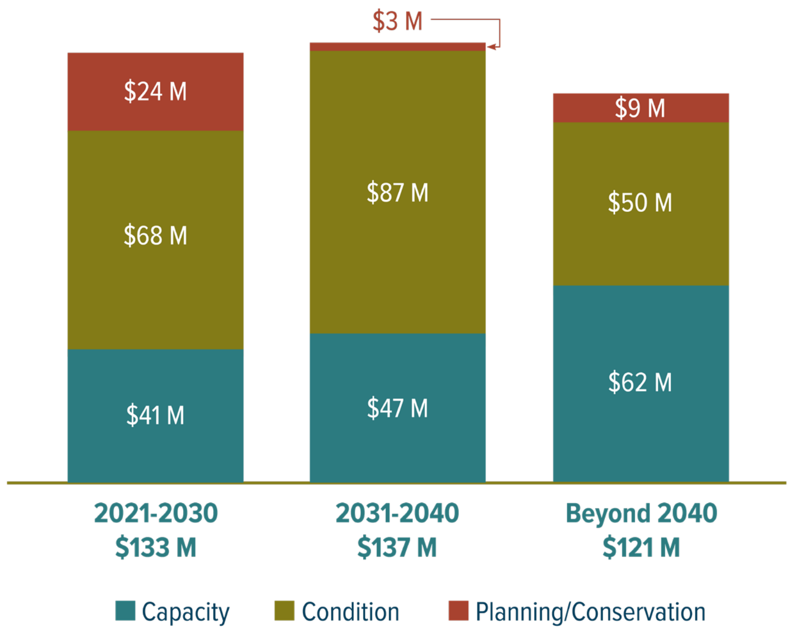
The Capital Improvement Plan identifies projects to address existing system condition and hydraulic capacity deficiencies and serve future growth. It includes recommendations to provide capacity through the 20-year growth projections, which are based on historic demands. However, the improvement timeline extends beyond 20 years due to constraints in funding and staff resource availability to implement the plan. Recommended projects are divided across three timeframes, those within the 10-year, 20-year, and beyond 20-year horizon.

Some of the projects, such as new supply and storage may need to be accelerated to meet demands and other improvements deferred to keep within budget. Or projects may be delayed if demands are lower than projected, for example due to the continuing trend of decreasing per capita demands, or increased conservation program efforts. Projects should be evaluated annually through City reviews of growth in water demand, available budget, and where development is occurring.

The projects prioritized over the next 10 years are intended to address facility condition and piping condition and capacity deficiencies. There are several condition and maintenance projects at current facilities that include the Awbrey Pump Station, Outback Reservoir 1, Awbrey Reservoir, Outback Wells 1 and 2, and the River Wells. Included in facility condition projects is the decommissioning of the Outback Contact Time Basin. The intent is that the contact time requirements can be met by Outback Reservoir 1 or the Outback Facility Plan will identify another configuration to meet contact time. Additionally, interior coating is slated for the Rock Bluff Reservoir and Outback Reservoir 2.

Also included in the 10-year horizon are some major piping projects including a new 30-inch Awbrey transmission main, and upsizing portions of piping along Newport Avenue. Many smaller pipe projects to address fire flow deficiencies and a yearly pipe replacement program are planned. Planning projects include updates to this Integrated Water System Master Plan and the Water Management and Conservation Plan, and an Outback Facility Plan along with additional improvements at Outback including pretreatment that would allow the City to continue operating in the event of a wildfire or other water quality event, incorporation of required federal security recommendations, and land acquisition for the recommended facilities. Future planning projects could include an analysis and possible implementation of hydropower generation that would work in conjunction with pretreatment. Implementation of the expanded conservation program and Standards and Specifications document are planned for the 2021-2030 timeframe as well.

Figure ES-5. *Capital Improvement Plan Cost by Timeframe (in 2020 Dollars)*



Projects focus on replacing and installing new pipe to address distribution system deficiencies and work towards a greater annual pipe replacement rate to attain a program more consistent with expected pipe replacement life cycles. Considerable investment in existing infrastructure will be required at most existing facilities to address deferred maintenance and extend useful life. New facilities will serve growth and be required as demands increase. The total Capital Improvement Plan cost is approximately $391 million (in 2020 dollars), with $133 million scheduled for 2021-2030, $137 million in years 2031-2040 and $121 million beyond 2040.

FINANCIAL PLAN

The financial plan was prepared by FCS Group to determine the funding requirements to provide water service to the City customers and demonstrate the financial plan to fund ongoing system operations and the escalated costs of the recommended Capital Improvement Plan. The financial analysis demonstrates the ability of the water utility to maintain sufficient funds to construct, operate, and manage the system on a continuing basis based on a 30-year implementation timeframe of the CIP.

The water utility is responsible for funding all of its costs and the primary funding source is derived from ongoing monthly charges for service (or user rates), with additional revenues coming from system development charges and other miscellaneous revenue. The City controls the level of user charges and, subject to the City Council, can adjust user charges as needed to meet financial objectives.

The proposed financial forecast will support $164 million (escalated) of capital expenditures within the 10-year planning period and $581 million (escalated) to fund the full Capital Improvement Plan within a 30-year period. The financial forecast indicates that the utility is currently covering all financial obligations under existing rates, however, to fund the Capital Improvement Plan, rates will need to increase annually. The financial plan proposes the following rate increases and debt issuances during the FY 2021 through FY 2030 period to satisfy the identified future obligations of the utility. Although the financial plan is completed for a 30-year time horizon, the rate strategy focuses on the shorter-term planning period of FY 2021 through FY 2030.

FY 2021 - FY 2030 Proposed Annual Rate Increases:

- 3.0 percent in FY 2022 – FY 2023
- 4.0 percent from FY 2024 – FY 2026
- 4.5 percent from FY 2027– FY 2030

FY 2021 - FY 2030 Proposed New Revenue Bond Insurance:

- $23.9M in FY 2026
- $33.9M in FY 2029
- Annual new debt service payments are forecast to increase from $2.0 million with the first issuance to $4.7 million by the second new debt issuance. Including this new debt, total debt service will increase from $5.6 million in FY 2021 to $8.9 million by FY 2030.

Table ES-2 shows a summary of the projected Undesignated Operating Reserve and residual Capital Reserve ending balances through FY 2030 based on the rate forecasts. The operating fund is maintained at a minimum of three months of O&M expenses, and the capital reserve balance fluctuates depending on the level of CIP funded; however, it never falls below the capital contingency target of $5.0 million.

Table ES-2 Ending Reserve Balance Summary ($ in millions)

ENDING RESERVE BALANCES	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027	FY 2028	FY 2029	FY 2030
Undesignated Operating	$3.2	$3.6	$3.7	$4.2	$4.2	$4.6	$4.7	$4.9	$5.2	$5.2
Capital	$57.3	$53.2	$47.8	$37.1	$14.7	$20.5	$16.1	$15.3	$39.7	$25.5
Total	**$60.5**	**$56.8**	**$51.5**	**$41.3**	**$18.9**	**$25.1**	**$20.8**	**$20.2**	**$44.9**	**$30.7**

The analysis performed assumes revenue growth and expense inflationary factors. If the forecasting factors change significantly, the existing rate strategy may need to be updated and revised. The City will continue to annually review and update the key underlying assumptions and revisit the proposed rates to ensure that adequate revenues are collected to support the Capital Improvement Plan and meet the City's total financial obligations.

SUMMARY

This iWSMP constituted a significant investment of time and resources for City staff and includes a comprehensive analysis of the water system integrated to incorporate growth, Level of Service, capacity, conservation, planning, and other considerations for the existing and future system needs. It is the City's first Integrated Water System Master Plan to include a full condition assessment of the existing facilities and pipe replacement program. It utilized advanced optimization modeling and the Capital Improvement Plan and Financial Plan are intended to improve the system over the next 30 years at a sustainable pace that addresses ongoing maintenance and growth requirements. The Integrated Water System Master Plan provides a valuable resource for how to continue providing quality water to the system's customers.

As a result of this Integrated Water System Master Plan, the following recommendations are made:

- Continue to operate and improve the system to provide reliable, high quality water to customers.
- Make significant investments to maintain existing facilities and add pretreatment to the surface water supply.
- Develop a formal replacement program and continue to accelerate replacement rates.
- Construct new supply, storage, and pipe as the system approaches identified demand thresholds.
- Update planning regularly including an Outback Facility Plan, the Integrated Water System Master Plan and the Water Management and Conservation Plan.
- Implement additional conservation measures.
- Evaluate and update the Financial Plan annually.

Section **1**

Section 1

Existing Water System

1.1 Introduction

The City of Bend (City) is located east of the Cascade Mountains in Central Oregon with a population of approximately 90,000 people. The climate is considered high desert typically known for mild winters and warm, dry summers. The City's water supply, transmission and distribution system is responsible for the delivery of treated water to approximately 25,500 service connections to residential, commercial, and industrial customers. The City's existing Urban Growth Boundary (UGB) is served by three primary water suppliers, the City, Avion Water Company (Avion), and Roats Water System (Roats). Both Avion and Roats are rate and service regulated utilities under the Oregon Public Utility Commission. The City also serves water to the Tetherow destination resort, the Westside Transect area including the Tree Farm rural residential development and Awbrey Meadows, which are located outside the UGB. The study area for this master plan includes the area within the UGB served by the City and the three areas served outside the UGB. This report excludes the water infrastructure at the City Airport which is owned and operated by the City outside of the UGB and not connected to the City system.

The City has the capability to supply treated water to customers by utilizing groundwater and surface water. The groundwater is supplied by the Deschutes Regional Aquifer and is primarily used to supply peak demands. The City's existing surface water system begins in the Bend Municipal Watershed (BMW) established by agreement with the United States Forest Service (USFS) in 1926. It includes the Prowell Springs Diversion and a surface water intake facility. Surface water is the primary source year-round. Both sources are known to have excellent water quality. The City's existing water system consists of a surface water intake facility, a water filtration facility, 8 groundwater facilities consisting of 20 active wells, 15 finished water storage reservoirs, 6 active booster pump stations, approximately 440 miles of transmission and distribution mains, nearly 10 miles of raw water pipeline, and associated appurtenances including various valves, hydrants, and meters. The system includes six primary pressure zones with an additional twenty-three subzones.

The current UGB, City and private utility service areas, and existing City water system are in **Figure 1-1**.

1.2 Inventory of Existing Infrastructure

This section provides a description and inventory of the City's existing raw and treated water system facilities.

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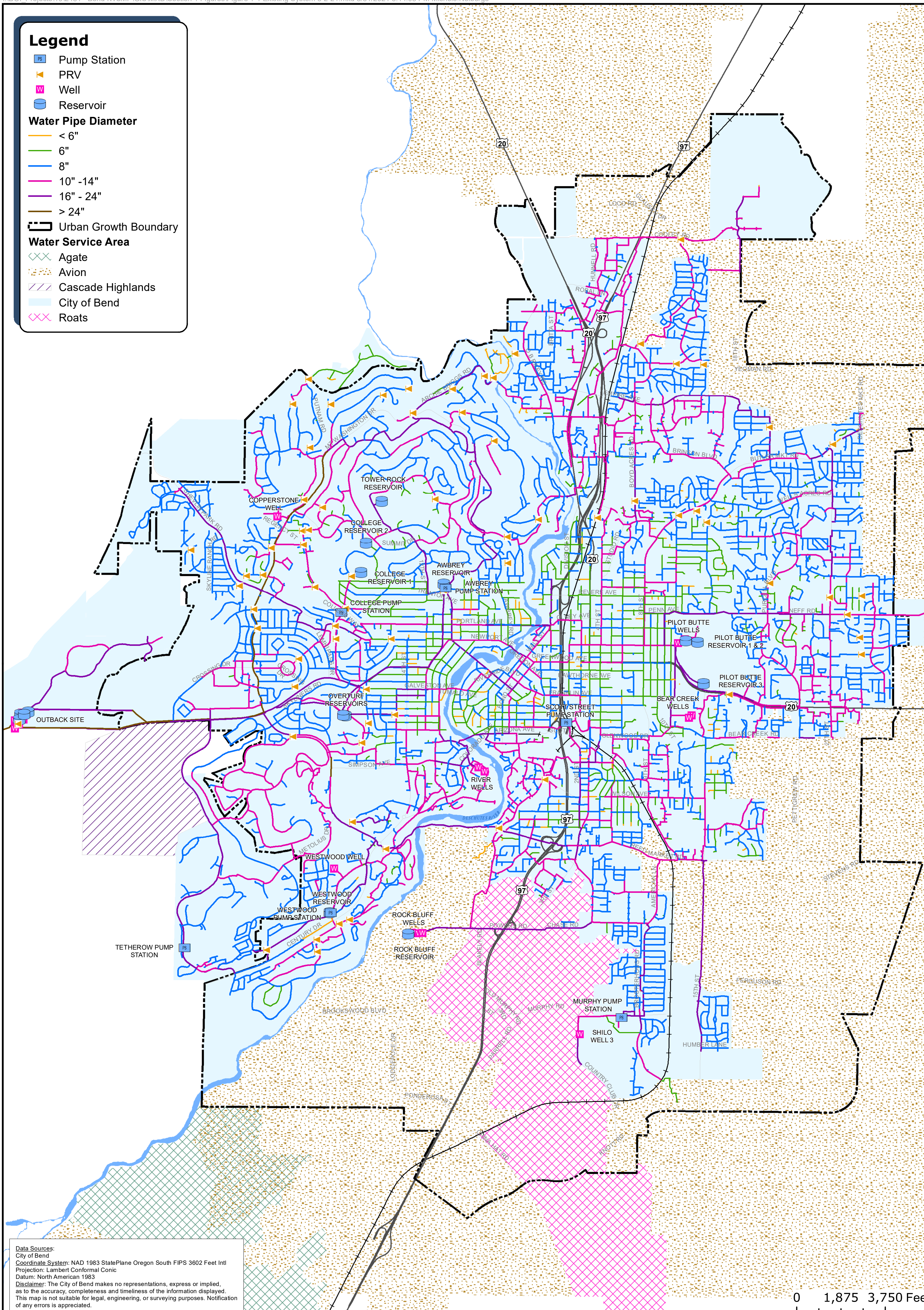

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BEND

City of Bend Integrated Water System Master Plan

Figure 1-1 Existing System

September 2021

19-2484

1.2.1 Sources

The City currently has dual supply sources from a combination of surface water and groundwater to supply customers within its service area, each with associated water rights, infrastructure, and capacity. The City's Water Filtration Facility (WFF) is located west of the City at a location identified as the Outback Site. The site also has seven active groundwater wells. Other groundwater sources are located throughout the service area.

1.2.1.1 Water Rights

The City holds numerous surface water and groundwater rights which are in **Table 1-1**. The City holds 36.1 cubic feet per second (cfs), equivalent to 23.3 million gallons per day (mgd) of surface water rights and 68.2 cfs (44.1 mgd) in groundwater rights. The availability and restrictions on these rights is included in the discussion of each supply source.

Table 1-1 | Water Rights

Source Type	Certificate or Permit	Priority Date	Authorized Rate (cfs)	Maximum Daily Volume (mgd)
Groundwater	Cert. 85414	9/7/1900	10	6.46
	Cert. 94100	11/8/1968	7.75	5.01
	Cert. 68702	10/13/1971	0.9	0.58
	Cert. 85415	10/13/1971	2.7	1.74
	Cert. 85412	10/13/1971	7.57	4.89
	Cert. 85413	10/13/1971	4.87	3.15
	Cert. 85411	12/22/1978	1.51	0.97
	Cert. 85559	6/30/1989	4.16	2.69
	Cert. 87416	5/1/1991	0.94	0.61
	Permit G-11379	6/30/1989	3.84	1.54
	Permit G-18123	8/27/1992	12	7.76
	Permit G-18124	8/27/1992	12	7.76
Surface Water	85526	Unrestricted	6.0	11.76[1]
	31411	8/5/1900 9/1900 6/1/1907	2.0 4.5 0.02	
	31665	9/1900 4/28/1905 6/1/1907	1.31 0.19 1.10	
	B-112	9/1900 6/1/1907 10/29/1913	1.62 0.39 Varies by time of year (2.43-5.99)	
	85713	12/12/1983	12.2	
	S-49823	12/12/1983	2.8	

Note:
1. The City's surface water diversion is currently limited to a maximum of 18.2 cfs (11.76 mgd) by Special Use Permit BEN1178 issued by the United States Forest Service.

1.2.1.2 Surface Water Supply

A 1926 agreement between the USFS and the City created the BMW, and subsequent USFS plans recognize and designate municipal use as the highest and best use of the watershed. The combined flows of natural springs (the Prowell Springs Diversion) and Bridge Creek in the BMW are diverted approximately 11.5 miles west of the City limits at the Heidi Lansdowne Intake Facility located on Bridge Creek near the confluence with Tumalo Creek. The BMW lies within the Deschutes National Forest, which is managed by the USFS. In addition, the USFS has issued several special use permits to the City that require significant environmental analysis and provide clear communication channels between signatories, control human activity, and protect water quality through regulations, restrictions, and ongoing monitoring. Raw water is routed from the Heidi Lansdowne Intake Facility on Bridge Creek to the City's Outback Site through approximately 9.5 miles of 30- and 36-inch transmission pipeline constructed in 2014 and 2015.

While the maximum rate of the City's combined surface water rights is 36.1 cfs, due to seasonal limitations, sharing of priority dates with other water users on Tumalo Creek, and seasonal low flows, the reliable rate of the City's water rights is significantly lower than 36.1 cfs. Furthermore, under the terms of the City's Special Use Permit authorizing operation of the surface water system on USFS lands, the City's diversion is currently limited to 18.2 cfs (11.76 mgd). **Figure 1-2** shows a layout of the raw surface water supply system.

1.2.1.3 Groundwater Supply

The City currently has eight groundwater production sites that include 20 active wells located throughout the service area and at the Outback Site. **Table 1-2** summarizes the groundwater production facilities, their approximate capacity in gallons per minute (gpm), and the pressure zones that they serve. In 2002, the Oregon Water Resources Commission adopted administrative rules requiring mitigation for the impacts of pumping under new groundwater permits (OAR 690-507). Two of the City's permits for groundwater use (G-18123 and G-18124) require the City to provide groundwater mitigation as part of the Deschutes Basin Groundwater Mitigation Program, and the City has an approved incremental groundwater mitigation plan for each permit.

1.2.2 Treatment

In 2014, the City constructed the WFF located at the Outback Site to filter and disinfect the surface water prior to entry into the distribution system. The WFF has 4 primary membrane filters each with approximately 3,300 gpm capacity for a total capacity of 13,200 gpm and one backwash recovery rack with approximately 1,200 gpm capacity. Normal operations utilize all five filter racks. After filtration, the source water is disinfected using a chlorine solution and flows through the Contact Time (CT) Basin, a baffled reservoir designed to increase contact time and ensure proper mixing with the disinfectant. The groundwater supply is also disinfected using chlorine at each of the eight well field sites.

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City of Bend
Integrated Water System Master Plan

Figure 1-2
Watershed and Raw Water Piping

I:\BOI_Projects\19\2484 - Bend IWSMP\GIS\MXD\Section 1 Figures\Figure 1-2 Watershed and Raw Water Piping.mxd 9/13/2021 2:56:03 PM Michele.Neibergs

Table 1-2 | Existing Groundwater Facilities

Well	Status	Zone Served	Flow Rate[1] (gpm)	Facility Floor Elevation (feet)	Groundwater Surface Elevation (feet)
Bear Creek Well 1	Active	4B	1,050	3,656	3,027
Bear Creek Well 2	Active	4B	1,100	3,656	3,004
Copperstone Well	Active	3	950	3,810	3,300
Outback Well 1	Active	3	800	3,981	3,499
Outback Well 2	Active	3	950	3,981	3,499
Outback Well 3	Active	3	1,050	3,981	3,504
Outback Well 4	Active	3	1,150	3,981	3,503
Outback Well 5	Active	3	1,050	3,981	3,501
Outback Well 6	Active	3	1,100	3,981	3,501
Outback Well 7	Active	3	1,300	3,981	3,497
Pilot Butte Well 1	Active	5	750	3,754	2,969
Pilot Butte Well 2	Inactive	5	-	-	-
Pilot Butte Well 3	Active	5	900	3,781	3,026
Pilot Butte Well 4	Active	5	1,150	3,712	3,014
River Well 1	Active	5	1,800	3,606	3,045
River Well 2	Active	5	1,900	3,607	3,365
Rock Bluff Well 1	Active	4B	750	3,834	3,410
Rock Bluff Well 2	Active	4B	800	3,834	3,438
Rock Bluff Well 3	Active	4B	800	3,830	3,437
Shilo Well 1	Inactive	3	-	-	-
Shilo Well 2	Inactive	3	-	-	-
Shilo Well 3	Active	4B	1,200	3,764	3,422
Westwood Well	Active	4A	700	3,761	3,482

Note:
1. Flow rates were determined from available data sources including typical flow rates in SCADA data, GIS recorded data, model results, and pump curves to the nearest 50 gallons.

1.2.3 Treated Water Storage

The City has a total of 15 storage reservoirs located throughout the distribution system with a total capacity of approximately 30 million gallons (MG). Three of the reservoirs are configured in series at the Outback Site with the CT Basin, Outback 1, and Outback 2 each filling in that order from the WFF so that Outback 2 provides the direct storage to the distribution system. A summary of the existing storage reservoirs is provided in **Table 1-3**.

Table 1–3 | Existing Storage Reservoirs

Reservoir	Reservoir Type	Capacity (MG)	Overflow Height (feet)	Floor Elevation (feet)	Diameter (feet)	Pressure Zone Directly Served
Awbrey	Concrete	5.00	20.5	3,775	206.3	5
College 1	Welded Steel	0.50	23.3	4,096	60.8	2
College 2	Welded Steel	1.00	31.5	4,088	74.1	2
Outback CT Basin	Bolted Steel	1.50	31.0	3,980	91.5	3 (through Outback 2)
Outback 1	Bolted Steel	2.00	35.1	3,976	98.6	3 (through Outback 2)
Outback 2	Welded Steel	3.00	35.4	3,976	120.8	3
Outback 3	Welded Steel	3.63	29.4	3,982	146	3
Overturf East	Riveted Steel	1.45	28.0	3,843	94	4A
Overturf West	Riveted Steel	1.45	28.0	3,843	94	4A
Pilot Butte 1	Welded Steel	1.50	31.5	3,750	89.3	5
Pilot Butte 2	Welded Steel	1.00	39.5	3,840	65.2	4B
Pilot Butte 3	Concrete	5.00	24.3	3,757	188	5
Rock Bluff 1	Welded Steel	1.54	39.0	3,840	82	4B
Tower Rock	Welded Steel	1.00	31.0	4,213	74	1
Westwood	Welded Steel	0.50	31.5	3,845	53.3	4

1.2.4 Booster Pump Stations

The City's distribution system currently has six active booster pump stations. The pump stations' main functionality is to boost water from the lower pressure zones to the higher zones. The stations have varied means of operational controls (i.e., reservoir levels, discharge pressures, manual operation, etc.). **Table 1-4** provides a detailed list of the existing booster pump stations including their approximate flow rates, motor horsepower and the suction and discharge pressure zones.

Table 1-4 | Existing Booster Pump Stations

Station	Elevation (feet)	Pump	VFD	Motor Horsepower (hp)	Zone From-To	Flow Rate[1] (gpm)
Awbrey	3,778	Pump 1	No	200	5 to 1	1,200
		Pump 2	No	350	5 to 1	1,200
		Pump 3	No	350	5 to 1	1,200
College	3,723	Pump 1	No	50	3 to 2	1,100
		Pump 2	No	50	3 to 2	1,100
Murphy Road	3,746	Pump 1	Yes	25	4B to 3D	300
		Pump 2	Yes	25	4B to 3D	300
		Pump 3	Yes	25	4B to 3D	300
		Pump 4	Yes	25	4B to 3D	300
		Pump 5	Yes	25	4B to 3D	300
Scott Street	3,649	Pump 1	No	50	5 to 4B	1,000
		Pump 2	No	50	5 to 4B	1,000
		Pump 3	No	50	5 to 4B	1,000
Tetherow	3,877	Jockey	Yes	7.5	3 to 2A	120
		Pump 1	Yes	15	3 to 2A	300
		Pump 2	Yes	60	3 to 2A	700
		Pump 3	Yes	60	3 to 2A	700
		Pump 4	Yes	60	3 to 2A	700
		Pump 5	Yes	60	3 to 2A	700
		Pump 6	Yes	60	3 to 2A	700
Westwood	3,836	Pump 1	No	20	4A to 3C	275
		Pump 2	No	40	4A to 3C	550
		Pump 3	No	75	4A to 3C	900
		Pump 4	No	40	4A to 3C	550

Note:
1. Flow rates were determined from available data sources including typical flow rates in SCADA data, GIS recorded data, model results, and pump curves.

1.2.5 Control Valves

Control valves play an important role in the movement of water through the City's distribution system. Many pressure reducing valves (PRVs) within the system supply the subzones. The City standard is to provide a pressure reducing station that includes both a small (bypass) valve that supplies flow under typical flows and a larger (main) valve that provides flow under emergency conditions such as fire flows. The bypass valve will have a higher pressure setting than the main valve, which may be set 3 to 10 pounds per square inch (psi) lower. In most cases each pressure zone will be served by at least two PRV stations, though in the case of some smaller zones, a single station provides supply.

In addition, there are several important control valves that influence the transmission of water across primary zones in the system. These include flow control and level valves (FCLV) into Awbrey and Overturf Reservoirs (AWBREY_FCV and WAPRV086A), the Athletic Club PRV (WAPRV038B) that conveys water from Zone 3 to 4B, and the flow control valve from Zone 4B to Zone 5 (HWY20_FLOW) referred to as the "Highway 20 Valve." The FCLV at Outback into the CT Basin (CTBASIN_CONTROLVALVE) controls flow from the WFF and then a FCV (WAPRV074A) controls the supply of surface water into the system out of the Outback 2 Reservoir. The PRV (WAPRV075A) at Outback Reservoir 3 currently serves to supplement surface water supply from the Outback Wells as needed based on pressures in Zone 3. The settings of each of these valves can be remotely adjusted through Supervisory Control and Data Acquisition (SCADA) by operations staff as needed and are changed throughout the year to adjust to demand conditions or supply and operations preferences. Although the setting on these valves is adjusted seasonally based on demand, a representative range of setpoints are shown in **Table 1-5**.

Table 1-5 | System Valves

Valve	Valve Type	Elevation (feet)	Diameter (inches)	From Zone	To Zone	Setting (gpm or psi)
CTBASIN_CONTROL VALVE	FCV	3,979	12	Raw Water	Outback	8,169
WAPRV025A	PRV	4,069	2	1	2	16
WAPRV025B	PRV	4,069	8	1	2	14
WAPRV026A	PRV	4,050	2	1	2	24
WAPRV026B	PRV	4,050	6	1	2	22
WAPRV002A	PRV	3,750	2	2	3	90
WAPRV002B	PRV	3,750	8	2	3	95
WAPRV020A	PRV	3,788	3	1	3	77
WAPRV020B	PRV	3,788	10	1	3	72
WAPRV032A	PRV	3,885	2	2	3	37
WAPRV032B	PRV	3,885	6	2	3	32
WAPRV045A	PRV	3,835	10	2	3	59
WAPRV074A	FCV	3,976	24	Outback	3	8,900
WAPRV075A	PRV	3,980	24	Outback	3	7
AWBREY_FCV	FCV	3,783	12	3	5	4,500
HWY20_FLOW	FCV	3,675	12	4B	5	850
WAPRV015A	PRV	3,666	2	4B	5	47
WAPRV015B	PRV	3,666	8	4B	5	43
WAPRV024A	PRV	3,639	2	4A	5	62
WAPRV024B	PRV	3,639	6	4A	5	57
WAPRV036A	PRV	3,641	6	4A	5	58
WAPRV036B	PRV	3,641	16	4A	5	53
WAPRV037A	PRV	3,641	2	4A	5	44
WAPRV037B	PRV	3,641	6	4A	5	39
WAPRV039A	PRV	3,654	6	4B	5	52

Valve	Valve Type	Elevation (feet)	Diameter (inches)	From Zone	To Zone	Setting (gpm or psi)
WAPRV039B	PRV	3,654	10	4B	5	48
WAPRV057A	PRV	3,642	3	4B	5	58
WAPRV057B	PRV	3,642	10	4B	5	54
WAPRV005A	PRV	3,543	4	5	6	63
WAPRV005B	PRV	3,543	8	5	6	59
WAPRV007A	PRV	3,553	4	5	6	58
WAPRV007B	PRV	3,553	12	5	6	54
WAPRV008A	PRV	3,542	2	5	6	63
WAPRV008B	PRV	3,542	6	5	6	59
WAPRV009A	PRV	3,570	4	5	6	51
WAPRV009B	PRV	3,570	14	5	6	47
WAPRV011A	PRV	3,572	12	5	6	50
WAPRV012A	PRV	3,530	2	5	6	69
WAPRV012B	PRV	3,530	8	5	6	65
WAPRV013A	PRV	3,574	2	5	6	49
WAPRV013B	PRV	3,574	12	5	6	45
WAPRV018A	PRV	3,609	3	4A	6	34
WAPRV018B	PRV	3,609	8	4A	6	30
WAPRV041A	PRV	3,580	6	5D	6	47
WAPRV041B	PRV	3,580	12	5D	6	43
TETHEROW_PS_PSV	PSV	3,877	12	3	2A	86
WAPRV031A	PRV	3,831	2	2	3A	47
WAPRV031B	PRV	3,831	6	2	3A	42
WAPRV049A	PRV	3,817	10	2	3A	45
WAPRV049B	PRV	3,817	10	2	3A	45
WAPRV003A	PRV	3,838	2	2	3B	75
WAPRV003B	PRV	3,838	8	2	3B	73
WAPRV073A	PRV	3,865	2	2A	3C	65
WAPRV073B	PRV	3,865	8	2A	3C	60
WAPRV019A	PRV	3,728	2	3	4A	57
WAPRV019B	PRV	3,728	8	3	4A	52
WAPRV022A	PRV	3,808	2	3	4A	13
WAPRV022B	PRV	3,808	10	3	4A	8
WAPRV035A	PRV	3,760	2	3	4A	30
WAPRV035B	PRV	3,760	6	3	4A	25
WAPRV043A	PRV	3,758	2	3	4A	43
WAPRV043B	PRV	3,758	6	3	4A	39
WAPRV047A	PRV	3,726	3	3	4A	60
WAPRV047B	PRV	3,726	12	3	4A	55
WAPRV050A	PRV	3,761	3	3	4A	43
WAPRV050B	PRV	3,761	8	3	4A	38
WAPRV052A	PRV	3,730	3	3	4A	58

Valve	Valve Type	Elevation (feet)	Diameter (inches)	From Zone	To Zone	Setting (gpm or psi)
WAPRV052B	PRV	3,730	8	3	4A	53
WAPRV053A	PRV	3,743	3	3	4A	53
WAPRV053B	PRV	3,743	8	3	4A	47
WAPRV056A	PRV	3,667	3	3	4A	83
WAPRV056B	PRV	3,667	8	3	4A	78
WAPRV065A	PRV	3,730	6	3	4A	56
WAPRV065B	PRV	3,730	10	3	4A	54
WAPRV076A	PRV	3,735	6	3	4A	56
WAPRV076B	PRV	3,735	10	3	4A	51
WAPRV082A	PRV	3,750	3	3	4A	49
WAPRV082B	PRV	3,750	8	3	4A	44
WAPRV086A	FCV	3,844	6	Outback	4A	750
WAPRV086B	FCV	3,844	12	Outback	4A	1,500
WESTWOODPS_PSV	PSV	3,836	12	3C	4A	68
MURPHY_PRV	PSV	3,749	12	3D	4B	116
WAPRV038A	PRV	3,712	4	3	4B	71
WAPRV038B	PRV	3,712	12	3	4B	68
WAPRV059A	PRV	3,758	2	3	4C	53
WAPRV059B	PRV	3,758	6	3	4C	50
WAPRV084A	PRV	3,804	2	3	4C	42
WAPRV084B	PRV	3,805	6	3	4C	37
WAPRV046A	PRV	3,820	3	3	4D	61
WAPRV046B	PRV	3,820	8	3	4D	58
WAPRV001A	PRV	3,739	2	3	4E	52
WAPRV001B	PRV	3,739	8	3	4E	48
WAPRV067A	PRV	3,744	3	3	4E	49
WAPRV067B	PRV	3,744	8	3	4E	47
WAPRV044A	PRV	3,764	3	3	4F	47
WAPRV044B	PRV	3,764	10	3	4F	43
WAPRV027A	PRV	3,798	2	3C	4H	53
WAPRV028A	PRV	3,769	4	3C	4H	60
WAPRV029A	PRV	3,774	6	3C	4H	61
WAPRV064A	PRV	3,760	2	3C	4I	53
WAPRV064B	PRV	3,760	8	3C	4I	48
WAPRV021A	PRV	3,753	2	3	4K	68
WAPRV021B	PRV	3,753	8	3	4K	63
WAPRV023A	PRV	3,751	2	4D	5A	62
WAPRV062A	PRV	3,751	6	4D	5A	64
WAPRV030A	PRV	3,643	2	4E	5B	35
WAPRV030B	PRV	3,643	6	4E	5B	30
WAPRV034A	PRV	3,612	2	4E	5B	48
WAPRV034B	PRV	3,612	8	4E	5B	43

Valve	Valve Type	Elevation (feet)	Diameter (inches)	From Zone	To Zone	Setting (gpm or psi)
WAPRV077A	PRV	3,651	3	4E	5C	53
WAPRV077B	PRV	3,651	8	4E	5C	48
WAPRV078A	PRV	3,644	3	4E	5C	56
WAPRV078B	PRV	3,644	8	4E	5C	51
WAPRV040A	PRV	3,623	4	4F	5D	62
WAPRV040B	PRV	3,623	12	4F	5D	57
WAPRV040C	PRV	3,623	2	4F	5D	52
WAPRV014A	PRV	3,592	2	5	6A	57
WAPRV014B	PRV	3,592	12	5	6A	52
WAPRV016A	PRV	3,568	2	5	6A	67
WAPRV016B	PRV	3,568	6	5	6A	62
WAPRV017A	PRV	3,590	2	5	6A	57
WAPRV017B	PRV	3,590	6	5	6A	52
WAPRV048A	PRV	3,596	2	5	6A	55
WAPRV048B	PRV	3,596	6	5	6A	50
WAPRV033A	PRV	3,470	2	5B	6B	66
WAPRV033B	PRV	3,470	6	5B	6B	61
WAPRV004A	PRV	3,486	3	6	7A	59
WAPRV004B	PRV	3,486	10	6	7A	54
WAPRV054A	PRV	3,483	3	6	7A	60
WAPRV054B	PRV	3,483	8	6	7A	55
WAPRV061A	PRV	3,460	3	6	7A	70
WAPRV061B	PRV	3,460	8	6	7A	66
WAPRV080A	PRV	3,482	3	6	7A	61
WAPRV080B	PRV	3,482	8	6	7A	57
WAPRV006A	PRV	3,481	2	6	7B	62
WAPRV006B	PRV	3,481	6	6	7B	57
WAPRV058A	PRV	3,486	2	6	7C	57
WAPRV058B	PRV	3,486	6	6	7C	52
WAPRV066A	PRV	3,501	2	6	7D	47
WAPRV066B	PRV	3,501	6	6	7D	42
WAPRV079A	PRV	3,493	2	6	7D	56
WAPRV079B	PRV	3,493	6	6	7D	51

1.2.6 Pressure Zones

The City's distribution system currently operates with six primary (defined as those with storage facilities) pressure zones with numerous subzones served through PRVs or booster pump stations. Pressure zone boundaries are generally defined to maintain a desired range of service pressures based on ground topography and designated by overflow elevations of storage reservoirs or the discharge hydraulic grades of PRVs or booster pump facilities serving the area. **Table 1-6** provides details pertaining to the primary pressure zones with more extensive discussion for each zone provided below. Each pressure zone with the infrastructure it contains, and the system hydraulic grade line (HGL) configuration is illustrated in **Figure 1-3**. Additionally, **Figure 1-4** displays the pressure zone boundaries and pipe network by primary pressure zone.

Table 1–6 | Existing Primary Pressure Zones

Pressure Zone	Approximate Existing Service Elevation Range (feet)	Storage Reservoir Serving Zone	Controlling Overflow Elevation (feet)
1	3,967-4,167	Tower	4,244
2	3,828-4,017	College 1 and 2	4,120
3	3,675-3,969	Outback 2 & 3	4,011
4A	3,638-3,768	Overturf East & West, Westwood	3,872
4B	3,609-3,779	Rock Bluff & Pilot Butte 2	3,880
5	3,534-3,696	Awbrey & Pilot Butte 1 and 3	3,796

1.2.6.1 Pressure Zone 1

Pressure Zone 1 ranges in service elevation from approximately 3,967 to 4,167 feet. The HGL of the zone is set by the Tower Rock Reservoir. Tower Rock Reservoir has an overflow elevation of 4,244 feet and water supply is provided by the Awbrey Booster Pump Station. Several of the customers located in this service area at higher elevations have installed individual booster pump stations to increase in-home pressures to an adequate level.

1.2.6.2 Pressure Zone 2

Pressure Zone 2 ranges in service elevations from 3,828 to 4,017 feet. Supply into Zone 2 is from the College Booster Pump Station that pumps from Pressure Zone 3 and from several PRV connections from Pressure Zone 1. The HGL of the zone is established by College Reservoirs 1 and 2, with overflows at 4,120 feet.

1.2.6.3 Pressure Zone 3

Pressure Zone 3 serves customers with ground elevations roughly between 3,675 and 3,969 feet. The high elevation customers are primarily near the Outback Site and have service line booster pumps to increase pressures. The minimum HGL, set at the Outback 3 Reservoir from the Outback Site is limited by the suction pressures required on these service line boosters. Supply is provided primarily from the Outback 2 Reservoir through a flow control valve regulating surface water into the system and from the Outback 3 Reservoir through a PRV from the groundwater sources at Outback. Additional supply is provided from the Copperstone well located within Zone 3.

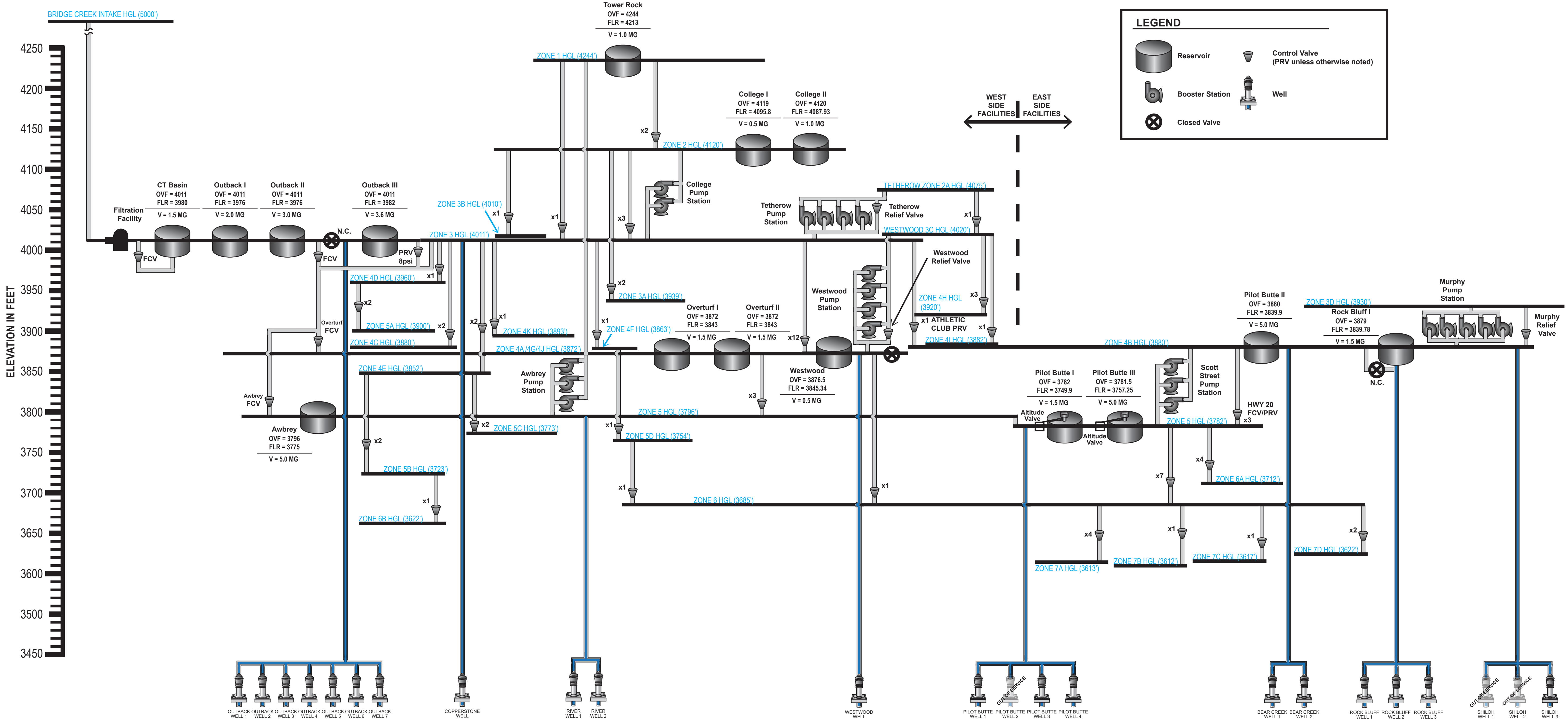

Figure 1-3
Hydraulic Profile

City of Bend
Integrated Water System Master Plan

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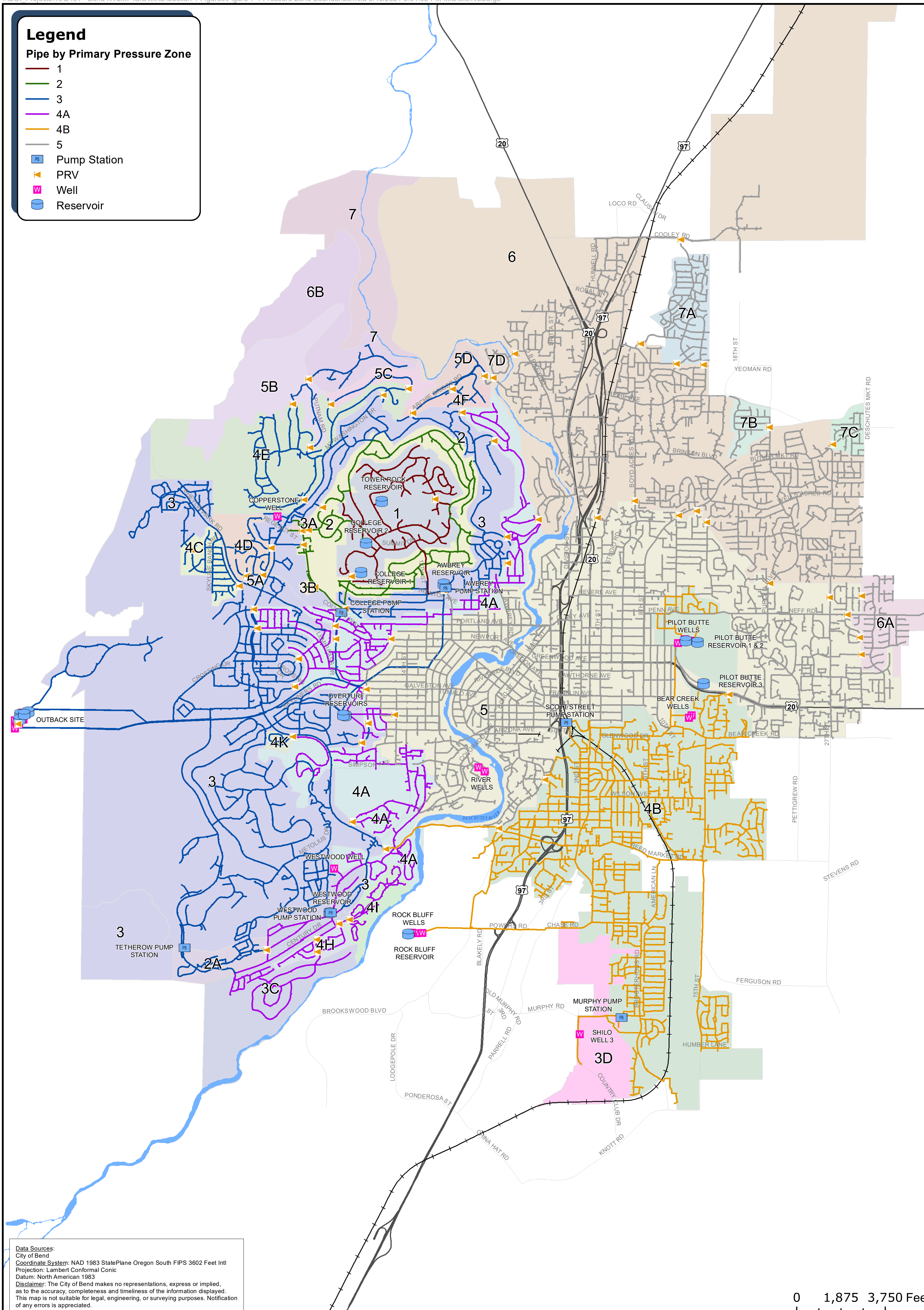
I:\BOI_Projects\19\2484 - Bend IWSMP\GIS\MXD\Section 1 Figures\Figure 1-4 Pressure Zone Boundaries.mxd 9/13/2021 3:01:02 PM Michele.Neibergs



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Integrated Water System Master Plan

Figure 1-4
Pressure Zone Boundaries

September 2021

19-2484

1.2.6.4 Pressure Zone 4A

Pressure Zone 4 is divided by the Deschutes River resulting in the area being comprised of two non-contiguous tracts, Zone 4A and Zone 4B, which operate at different HGLs. The two sections are connected via a 16-inch pipeline under the River, but during normal operations remain hydraulically isolated from each other via a closed valve. The area that lies on the west side of the River, Zone 4A operates at a hydraulic grade of 3,872 feet, set by the overflow elevations at the Overturf Reservoirs. The Westwood Reservoir also serves Zone 4A at a slightly higher HGL but is further away and much smaller than the Overturf Reservoirs so has less influence on the zone pressures. Supply to Zone 4A is primarily from a control valve from Zone 3, however the Westwood Well also provides a small amount of groundwater supply to the Zone. Zone 4A serves customers with ground elevations between roughly 3,638 and 3,768 feet.

1.2.6.5 Pressure Zone 4B

Pressure Zone 4B serves customers with ground elevations ranging from roughly 3,609 to 3,779 feet. The HGL of the Zone is set by the Rock Bluff and Pilot Butte 2 Reservoirs at a hydraulic grade of 3,880 feet. Water supply is provided primarily from the Shilo 3 Well, Rock Bluff and Bear Creek well sites, with a PRV connection from Zone 3 also available. Additionally, although not used during typical operations, supply may also be boosted from Pressure Zone 5 via the Scott Street Pump Station.

1.2.6.6 Pressure Zone 5

Pressure Zone 5 serves the largest number of customers in the system with ground elevations ranging from roughly 3,540 to 3,680 feet. The Zone 5 HGL is set by the Awbrey and Pilot Butte 1 and 3 Reservoirs. Similar to Zone 4A and 4B, Zone 5 serves the west and east sides of the Deschutes River, however, has more pipeline connectivity across the River serving the Zone. The Awbrey Reservoir is on the west side of the River and Pilot Butte 1 and 3 Reservoirs are on the east side. Overflow elevations of the reservoirs are 15 feet different with Awbrey overflow at 3,796 feet and Pilot Butte 1 and 3 at 3,782 and 3,781 feet, respectively. Water supply is provided primarily by the City's surface water supply and groundwater production wells located at the Outback Site through a flow control valve to the Awbrey Reservoir. Supply is also provided by the three Pilot Butte Wells and River Wells 1 and 2. PRV connections with Pressure Zone 4A and 4B provide additional water supply options for the Zone.

1.2.7 Distribution System

The City's distribution system is composed of approximately 440 miles of pipe (excluding 10 miles of raw water pipeline) comprised of multiple pipe materials installed over decades, with more than 98 percent installed since 1950. Most of the pipe is ductile iron (DI), the City's current material standard. There are cast iron (CI), galvanized iron, steel, and polyvinyl chloride (PVC) pipe materials in the system in lesser quantities. Pipeline diameters range from 2 to 36 inches. **Table 1-7** presents a summary of the length of distribution pipe in miles by diameters, approximate age, and material type. The piping summarized includes the distribution network piping that conveys treated water. The 9.5 miles of 30-inch and 36-inch raw water pipe is not included in the distribution pipe table below.

Table 1-7 | Distribution System Pipe (miles)

Installation Age	Material	6-inch and Less	8-inch	10-inch to 14-inch	16-inch to 18-inch	24-inch to 36-inch	Total
Before 1950	CI	2.64	0.90	1.54	0.88	0.00	5.97
	DI	0.66	0.14	0.26	0.26	0.00	1.32
	Other	0.30	0.00	0.35	0.12	0.00	0.77
1950-1959	CI	1.64	0.86	0.14	0.42	0.00	3.06
	DI	0.15	0.17	0.39	1.43	0.00	2.14
	Other	0.39	0.00	0.82	0.82	0.31	2.33
1960-1969	CI	3.46	1.26	1.79	0.00	0.00	6.51
	DI	0.73	0.15	1.09	0.01	0.00	1.97
	Other	0.00	0.00	0.00	0.00	0.00	0.00
1970-1979	CI	5.97	4.40	2.00	0.00	0.00	12.37
	DI	6.63	6.84	5.87	0.00	0.00	19.33
	Other	0.25	0.00	0.00	0.00	0.00	0.25
1980-1989	CI	0.05	0.30	0.00	0.00	0.00	0.35
	DI	2.07	10.47	9.50	1.57	0.00	23.61
	Other	0.21	0.68	0.27	0.11	0.00	1.27
1990-1999	CI	0.12	0.31	0.00	0.00	0.00	0.43
	DI	3.69	58.96	41.46	9.17	2.01	115.29
	Other	0.00	0.21	0.00	0.00	0.00	0.21
2000-2009	CI	0.00	0.13	0.00	0.00	0.00	0.13
	DI	1.18	78.93	18.09	13.07	4.80	116.08
	Other	0.01	0.06	0.00	0.00	0.00	0.07
2010-2019	DI	0.32	22.96	6.88	1.94	1.69	33.79
	Other	0.40	0.00	0.00	0.00	0.14	0.54
Unknown	CI	16.26	9.35	4.45	0.67	0.00	30.73
	DI	13.47	11.42	22.80	7.76	0.65	56.10
	Other	3.21	0.27	0.87	0.23	0.13	4.71
Total		**63.81**	**208.77**	**118.57**	**38.47**	**9.73[1]**	**439.35**

Note:
1. There is an additional 9.5 miles of 30-inch and 36-inch ductile iron raw water pipeline constructed in 2014 not included in this table.

1.3 Summary

The City is located east of the Cascade Mountains in Central Oregon with a population of approximately 90,000. The City's existing Urban Growth Boundary is served by three primary water suppliers, the City of Bend, Avion Water Company, and Roats Water System. The City also serves water to the Tetherow destination resort, the Westside Transect area including the Tree

Farm rural residential development and Awbrey Meadows, which are located outside the UGB. The study area for this master plan includes the area within the UGB served by the City and the three areas served outside the UGB.

The City has the capability to supply treated water to customers by utilizing surface water from the Bend Municipal Watershed and groundwater from the Deschutes Regional Aquifer. Both sources are known to have excellent water quality. Surface water is the primary source year-round while groundwater supply supplements peak season demands. The City's existing water system consists of a surface water intake facility, a water filtration facility, eight groundwater sites consisting of 20 active wells, 15 finished water storage reservoirs, 6 booster pump stations, approximately 440 miles of transmission and distribution mains, nearly 10 miles of raw water pipeline, and associated appurtenances including various valves, hydrants, and meters. The system includes six primary pressure zones with an additional twenty-three subzones.

Section **2**

Section 2

Population and Demand Forecast

2.1 Introduction

This section reviews the City of Bend (City) historical water use and develops growth projections and estimated water demand forecasts for the anticipated 10-year and 20-year planning periods. Employee (EMP) and housing unit (HU) projections across the City's water service area, developed during previous efforts, were used with water demand forecasts to estimate future water demand.

2.2 Historical Data

A summary of the historical and current system conditions is provided including connections and water use, service area population, water loss, and system production.

2.2.1 Service Connections and Water Use

Information on the water service connections by customer class is presented in **Table 2-1**. The City customer base is primarily residential, and the City maintains five customer classifications, with two residential classifications including single family and multifamily. There are also commercial, irrigation-only, and hydrant meter classifications. The City provides potable irrigation during peak season demands in addition to year round domestic demands. Multiple irrigation districts also serve customers within the City service area with non-potable irrigation water. This plan assumes similar irrigation service trends in the future as currently exist with irrigation for some areas served by the City and some areas served by irrigation districts or contracted entities. **Table 2-2** has the total water use billed to each customer class in millions of gallons (MG).

Table 2-1 | Service Connections by Customer Class

Customer Class[1]	2016	2017	2018
Single Family	20,649	20,658	21,017
Multi-Family	1,569	1,597	1,631
Commercial	2,124	2,141	2,169
Irrigation-only	359	359	371
Hydrant Meters[2]	61	56	57
Total[3]	**24,762**	**24,811**	**25,245**

Notes:
1. Irrigation is a component of each customer class.
2. Hydrant meters are specific hydrants designated for purposes such as construction, dust control, and other allowed uses. They are used multiple times by different users and are intended to measure hydrant use and prevent unauthorized hydrant use.
3. Number of connections varies throughout the year so the average, maximum, or current number may differ, and the values reported may differ slightly from information reported in other City documents.

Table 2-2 | Use by Customer Class (Million Gallons)

Customer Class	2012	2013	2014	2015	2016	2017	2018
Single Family	2,325	2,484	2,433	2,487	2,461	2,453	2,523
Multi-Family	1,316[1]	1,306[1]	452	475	495	521	531
Commercial	-	-	1,110	1,139	1,146	1,145	1,140
Irrigation-only	267	276	328	295	283	287	318
Hydrant Meters	10	18	31	43	28	35	26
Total	**3,919**	**4,182**	**4,353**	**4,439**	**4,413**	**4,441**	**4,537**

Note:
1. Prior to 2014, the Multi-Family and Commercial Classes were combined.

2.2.2 Service Area Population

The City's existing Urban Growth Boundary (UGB) and service area is served by three primary water suppliers, the City, Avion Water Company, and Roats Water System. The City currently estimates that they serve approximately 75 percent of the population within City limits. **Table 2-3** shows a breakdown of the City of Bend population versus those served by the City water system, with the difference served by private water systems.

Table 2-3 | City Population with City Water Service

	2012	2013	2014	2015	2016	2017	2018
City of Bend Population[1]	77,455	78,280	79,985	81,310	83,500	86,765	89,505
Population with City Water Service	58,703	59,341	59,744	60,673	62,091	64,905	67,187
Percent of City Population with City Water Service	76%	76%	75%	75%	74%	75%	75%

Note:
1. Population based on Portland State University Population Research Center (PRC) estimates

2.2.3 Water Production

Water production measures the total quantity of water drawn from the City's surface and groundwater supply sources. The amount of surface water production and well production varies on both a monthly and yearly basis. The City typically operates the system to utilize surface water supply first and then supplement as needed with groundwater. Water production from 2012 to 2018 is provided in **Table 2-4.** Monthly production by source for 2018 is shown in **Table 2-5** and **Figure 2-1**. The surface water supply infrastructure was undergoing maintenance from April through June of 2018 so was not being utilized as the primary supply source.

Table 2-4 | Production by Source Type (Million Gallons per Year)

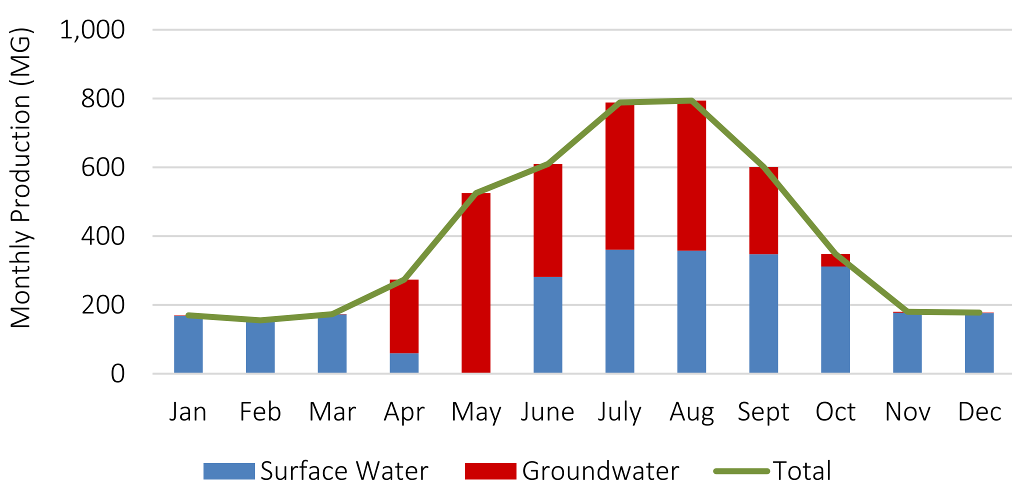
Source	2012	2013	2014	2015	2016	2017	2018
Surface Water	1,863	2,383	2,024	953	1,818	2,988	2,566
Groundwater	1,775	1,723	2,207	3,575	2,704	1,736	2,230
Total	**3,638**	**4,106**	**4,231**	**4,528**	**4,522**	**4,723**	**4,796**

Table 2-5 | 2018 Monthly Production by Source (Million Gallons)

Month	Groundwater	Surface Water	Total
January	1	168	**170**
February	2	154	**155**
March	1	172	**173**
April	214	60[1]	**273**
May	525	0[1]	**525**
June	328	282[1]	**610**
July	428	361	**789**
August	436	358	**794**
September	254	347	**601**
October	36	312	**348**
November	3	177	**180**
December	2	176	**178**
Total	**2,230**	**2,566**	**4,796**

Note:
1.Due to maintenance of the surface water treatment infrastructure from April to June, surface water was not the primary supply source (as it typically is) during these months.

Figure 2-1 | 2018 Monthly Production by Source[1]



Note:
1.Due to maintenance of the surface water treatment infrastructure from April to June, surface water was not the primary supply source (as it typically is) during these months.

Average day demand (ADD) is the annual demand divided by 365 days and is often expressed in units of million gallons per day (MGD). The maximum day demand (MDD) is the largest quantity of water delivered to the system over an actual 24-hour period during the year while peak hour demand (PHD) is equal to the system demand rate during the hour of highest use. **Table 2-6** shows the annual ADD and MDD for the period of 2012 to 2018 along with the peaking factor for each year and the average across the six-year period.

Table 2-6 | Historical Water Production

Year	ADD[1] (MGD)	MDD[1] (MGD)	MDD:ADD[1] Peaking Factor
2012	10.0	24.7	2.5
2013	11.2	21.3	1.9
2014	11.6	24.4	2.1
2015	12.4	26.5	2.1
2016	12.4	25.8	2.1
2017	12.9	28.0	2.2
2018	13.1	28.1	2.1
Average	**11.9**	**25.6**	**2.1**

Note:

1. The system changes over time and the ADD, MDD, and peaking factors reported can vary based on the degree of accuracy and the use of the data and may differ slightly from information reported in other City documents. For example, the City sold the Hole Ten well in 2016 so production values prior to 2016 may or may not include it depending on the reporting intent and use of the data.

2.2.3.1 Peak Hour Demand (PHD)

The City does not have historic PHD data available. However, the relatively recent installation of system-wide automated metering infrastructure (AMI) at all customer meters provides refined water use information including hourly data. This meter data provides information about the allocation of water use across each zone in the system as well as the time variation in water use. The City AMI data was evaluated to determine the demand allocation across each pressure zone and hourly peaking patterns based on six primary pressure zone groupings. Two weeks of AMI data from June 2018 was processed and scaled to match 2018 ADD production and was multiplied by the 2.1 peaking factor to get MDD. The MDD peaking factor was not evaluated zone by zone but could be done for additional future refinement of localized peaking factors. The PHD was calculated based on the AMI data peak hourly ratio for the six zone groups. The PHD to MDD peaking factor is higher in zones with mostly residential customers and highest in residential areas with large lot sizes where irrigation is greater. Zones with more commercial customers have less hourly variation in use, resulting in lower PHD to MDD peaking factors. The results are in **Table 2-7**.

Table 2-7 | 2018 Water Use and Peak Hour Demand (PHD) by Zone

Zone	2018 ADD (gpm)	2018 MDD (gpm)	2018 PHD (gpm)	PHD:MDD Peaking Factor	Service Connections[1]
1	272	582	1,563	2.68	423
2	286	611	1,673	2.74	521
2A	24	51	117	2.30	72
3	1,320	2,822	6,485	2.30	3,198
3A	8	18	49	2.74	20
3B	2	4	10	2.74	2
3C	158	337	775	2.30	388
3D	3	6	13	2.10	3
4A	570	1,220	2,692	2.21	1,738
4B	1,449	3,100	6,499	2.10	4,304
4C	91	194	446	2.30	295
4D	69	148	340	2.30	199
4E	159	341	783	2.30	335
4F	26	55	126	2.30	42
4H	45	97	224	2.30	156
4I	31	66	152	2.30	122
4K	23	50	115	2.30	52
5	2,602	5,565	9,627	1.73	7,162
5A	5	10	22	2.30	14
5B	12	25	57	2.30	24
5C	8	17	38	2.30	27
5D	33	70	161	2.30	54
6	1,528	3,267	6,443	1.97	4,453
6A	114	243	421	1.73	551
6B	27	59	135	2.30	40
7A	153	327	646	1.97	648
7B	58	125	246	1.97	220
7C	45	97	192	1.97	211
7D	6	13	30	2.30	40
System-wide	**9,127 (13.1 MGD)**	**19,519 (28.1 MGD)**	**40,080 (57.7 MGD)**	**2.05**	**25,314**

Note:
1.The number of active service connections in summer 2018. Slight differences in number of customers occur over the course of the year due to new and closed accounts, resulting in the minor difference in system-wide number of connections from Table 2-1.

2.2.4 Water Loss

The difference between the total water produced and metered consumption is called water loss. Since 2013 the City has used the American Water Works Association (AWWA) water audit methodology outlined in the AWWA M36 Manual. The City's water audits for 2013 through 2018 are in **Appendix 2A**. This method provides definitions and classifications for annual water production and consumption used to calculate water loss. The components of the water balance applicable to the City system are shown in **Table 2-8**.

Table 2-8 | Components of the AWWA Water Balance

<table>
<tr><td rowspan="4">System Input Volume
=
Water Supplied
=
Production
=
System Demand</td><td rowspan="2">Authorized Consumption</td><td>Billed Authorized Consumption</td><td>▪ Billed metered consumption
▪ Billed unmetered consumption</td><td>Revenue Water</td></tr>
<tr><td>Unbilled Authorized Consumption</td><td>▪ Unbilled metered consumption
▪ Unbilled unmetered consumption</td><td rowspan="3">Non-Revenue Water</td></tr>
<tr><td rowspan="2">Water Losses</td><td>Apparent Losses</td><td>▪ Customer metering inaccuracies
▪ Unauthorized consumption
▪ Systematic data handling errors</td></tr>
<tr><td>Real Losses</td><td>▪ Leakage on transmission and distribution mains
▪ Leakage and overflows at storage tanks
▪ Leakage on service connections up to a point of customer metering</td></tr>
</table>

AWWA. Manual of Water Supply Practices M36. Water Audits and Loss Control Programs, Fourth Edition, 2016.

Water loss can be the result of real or apparent losses. Apparent losses can be the result of things such as meter inaccuracy, theft, or reporting errors. Real loss is most likely due to system leaks, main breaks, or reservoir overflows. Water for uses such as firefighting, hydrant flushing, and street sweeping is authorized, but can be unbilled so the City attempts to account for this water use where possible. The City's water loss is calculated as the difference between measured production for the surface and groundwater supplies and the accounted for consumption, primarily the quantity of water measured through meters. The City's water loss is generally low as seen in the historical loss for the years 2012 through 2018 is in **Table 2-9**.

Table 2-9 | Water Loss

Year	Production[1] (MG)	Accounted for Water (MG)	Loss (MG)	Loss [2] (%)
2012	4,052	3,919	133	3.3
2013	4,317	4,248	69	1.6
2014	4,461	4,371	90	2.0
2015	4,746	4,455	291	6.1
2016	4,727	4,449	278	5.9
2017	4,746	4,453	294	6.2
2018	4,793	4,549	244	5.1
Average	**4,549**	**4,349**	**200**	**4.2**

Notes:
1. The historical production values used to calculate water loss are from the City's M36 Water Audits and include production from the Hole Ten wells, which were sold to Roats in 2016. The Hole Ten well production is included in the water loss calculations to avoid negative loss values compared to accounted for water but is not included in other production values throughout this section.
2. Third-party verification of the M36 Water Audit process in 2015 improved the City's data handling and reporting practices, which may be responsible for the somewhat higher loss starting in 2015.

2.2.5 Per Capita Demand

One measure of water use is per capita demand, which accounts for all uses, commercial, residential, and water loss for each person served. Because per capita demand includes all these types of use it exceeds the amount of water actually used by a typical individual. Per capita use can illustrate year-to-year trends however does not account for differences in customer mix, climate, rainfall, current economic conditions, or specifics such as hotel occupancy or number of commuters that may have an impact on system demand that does not reflect a direct relationship to population or efficiency of use. **Table 2-10** contains per capita calculations for 2012 to 2018. The estimated population served is based on the Portland State University Population Research Center (PRC) information and estimated percent of the City population with City water service as provided in **Table 2-3**. Per capita demand is measured in gallons per capita per day (gpcpd).

Table 2-10|Per Capita Demand

	2012	2013	2014	2015	2016	2017	2018
Service Area Population	58,703	59,341	59,744	60,673	62,091	64,905	67,187
Water Demand ADD (MGD)	10.0	11.2	11.6	12.4	12.4	12.9	13.1
Per Capita Demand (gpcpd)	170	189	194	204	199	199	195

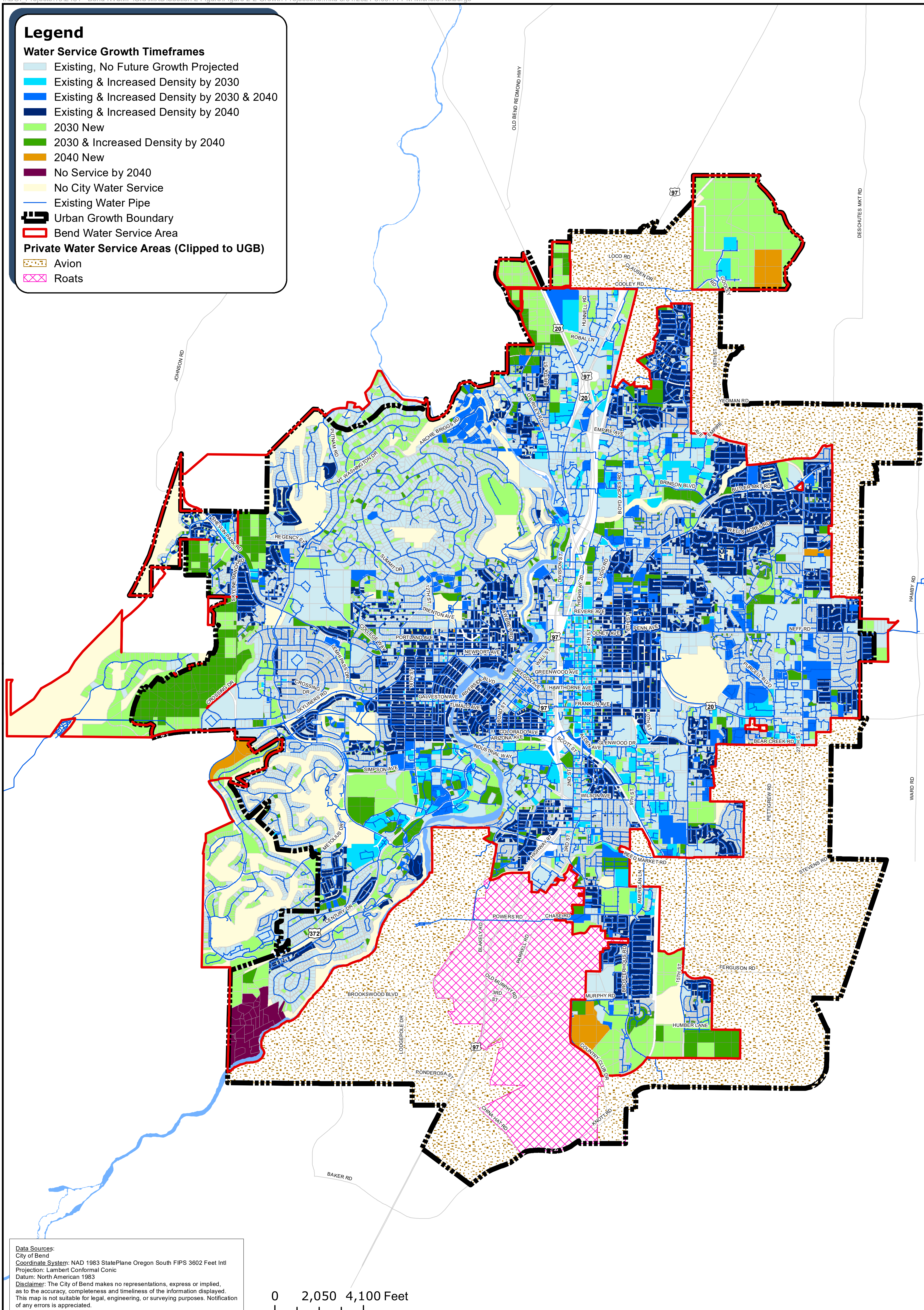
2.3 Future Demand Projections

Growth is a primary factor influencing future water demands. The location of existing and new customer connections affects storage, transmission, and distribution of future water supplies. Two future demand conditions were projected, a 10-year (2030) and 20-year (2040) horizon. The future demand projections require identifying the service areas for these horizons, along with the amount of demand associated with the 10-year and 20-year service areas.

2.3.1 Future Growth Areas

The City UGB and the City water service boundary, including the Tetherow, Westside Transect, and Awbrey Meadows developments that are located outside the UGB, along with the private water service areas within the UGB are illustrated in **Figure 2-2**. Growth is anticipated to occur through infill of existing areas and expansion to currently undeveloped areas. The figure indicates which areas have existing service and whether it is expected to increase in density due to infill along with areas projected for new service in the 2030 and 2040 horizons.

City planning data was used for existing and future employee (EMP) and housing unit (HU) projections across the City's water service area boundary. The future and projected number of employees and housing units was developed on a parcel basis by Angelo Planning Group during the City's 2016 Urban Growth Boundary Study and used in the City's 2018 Sewer Phasing Study.



Data Sources:
City of Bend
Coordinate System: NAD 1983 StatePlane Oregon South FIPS 3602 Feet Intl
Projection: Lambert Conformal Conic
Datum: North American 1983
Disclaimer: The City of Bend makes no representations, express or implied, as to the accuracy, completeness and timeliness of the information displayed. This map is not suitable for legal, engineering, or surveying purposes. Notification of any errors is appreciated.

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City of Bend
Integrated Water System Master Plan

Figure 2-2
Growth Projections

These were used to determine the number of employees and housing units in the water service area boundary for existing, 2028, and 2040 conditions. To determine the 2030 projections from the 2028 planning data, the areas with 2028 EMP or HU data were scaled by the projected average annual growth rate in EMP or HU from 2028 to 2040.

2.3.2 Future Demands

The number of employees and housing units associated with the existing, 10-year, and 20-year horizons along with the average annual increase is shown in **Table 2-11**. The 2018 housing unit and employee values were also used with the 2018 consumption and production data to calculate an average water demand per employee and per housing unit. Average demand per housing unit was calculated from the 2018 single and multi-family residential consumption and employee demand was based on averaging the 2018 non-residential consumption. The resulting per unit values were factored to match 2018 production (accounting for water loss). The calculated average demand per employee and housing unit factors are in **Table 2-12**. The average demand factors were then used with the EMP and HU estimates to calculate demand for the 2030 and 2040 horizons and peaked to project MDD and PHD shown in **Table 2-13** and **Figure 2-3**. To conservatively plan for future requirements, the projections do not reflect potential decreases in demands that might occur due to expanded conservation program measures given the uncertainty of the magnitude and timing of conservation reductions. However, the impact of potential decreases in demand were considered during the system analysis and capital improvement plan. More extensive discussion and analysis regarding conservation are included in the Water Management and Conservation Plan (WMCP) completed in parallel with this iWSMP. The MDD projections by pressure zone are in **Table 2-14**.

Table 2-11|Employee and Housing Units by Timeframe

Timeframe	Employees	Average Annual Increase	Housing Units	Average Annual Increase
2018	33,450	-	29,600	-
2030	47,533	3.0%	39,043	2.3%
2040	54,197	1.3%	47,422	2.0%

Table 2-12|Employee and Housing Demand Factors

	2018 Count	2018 Consumption (gal/day)	2018 Production (gal/day)	Unit Demand Factors (gal/day)
Employees	33,450	4,064,608	4,293,892	128
Housing Units	29,600	8,365,706	8,837,614	299

Table 2-13 | Demand Projections

Timeframe	ADD (MGD)	MDD (MGD)	PHD (MGD)	Average Annual ADD Increase
2018	13.1	28.1	57.7	
2030	17.8	38.0	78.0	2.5%
2040	21.1	45.2	92.7	1.7%

Figure 2-3 | Demand Projections

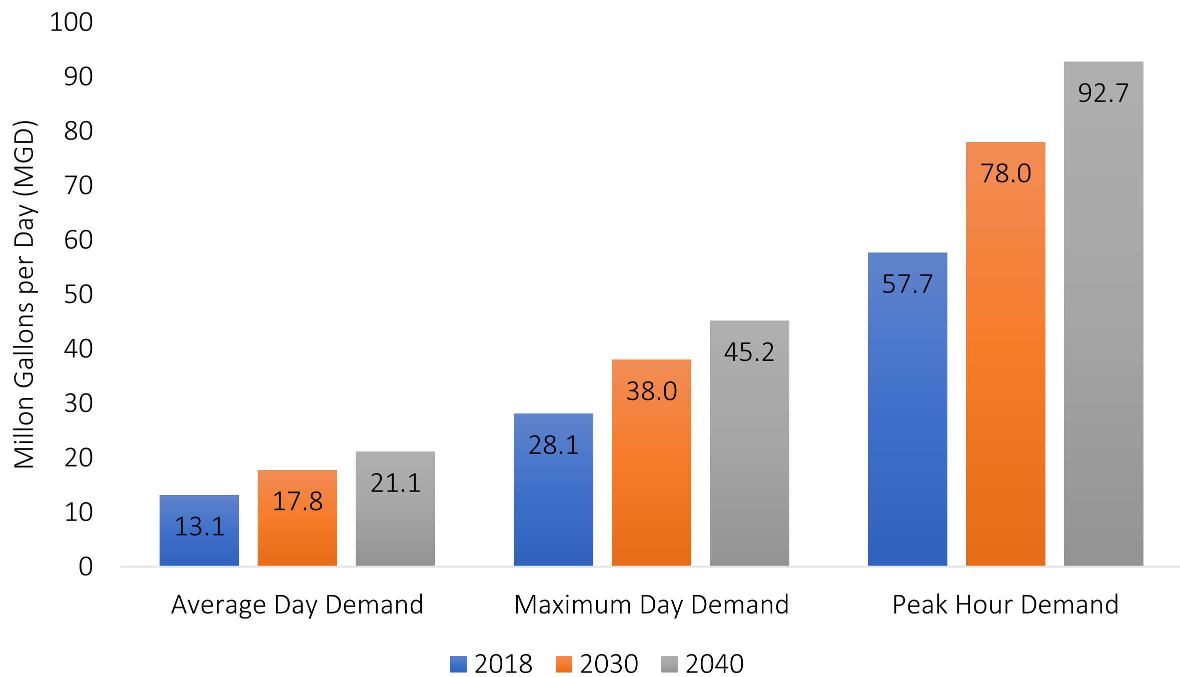


Table 2-14| Maximum Day Demand (MDD) Projections by Zone

Zone	2018 MDD (gpm)	2030 MDD (gpm)	2040 MDD (gpm)
1	582	658	691
2	611	681	715
2A	51	128	128
3	2,822	3,853	4,464
3A	18	24	28
3B	4	4	4
3C	337	415	436
3D	6	17	29
4A	1,220	1,666	2,246
4B	3,100	4,500	5,393
4C	194	255	290
4D	148	200	225
4E	341	395	415
4F	55	78	103
4H	97	113	113
4I	66	74	98
4K	50	50	50
5	5,565	6,705	8,335
5A	10	10	10
5B	25	28	29
5C	17	36	36
5D	70	117	170
6	3,267	5,460	6,375
6A	243	249	256
6B	59	64	64
7A	327	372	425
7B	125	127	129
7C	97	100	104
7D	13	13	14
System-wide	**19,519 (28.1 MGD)**	**26,391 (38.0 MGD)**	**31,375 (45.2 MGD)**

2.3.3 Demand Projection Methodology Comparison

For comparison purposes, the growth and demand projections in **Table 2-13** were compared with two other projection methodologies using the information in **Table 2-10**. One using historical average increases in production to project future production and the other using average per capita demand to project future demand. The historical information including per capita demands and average annual growth in production and service population are shown in **Table 2-15**. Projections were calculated using the annual average 5-year increase in production rate as well as the PRC future service area population projections and the 5-year average per capita demand to compare to the methodology using employee and housing unit projections. The 2030 and 2040 projections for the three methodologies are shown in **Table 2-16**. The resulting demands from each methodology are quite similar, varying less than four percent on an ADD basis. The housing unit and employee estimate selected for use in this Integrated Water System Master Plan is in the middle of the other two projection methods.

Table 2-15 | Historic Production and Population Change

Year	Service Population	Service Population Change (%)	Per Capita Demand (gpcpd)	Average Production (MGD)	Production Change (%)
2014	59,744	0.7	194	11.6	3.6
2015	60,673	1.6	204	12.4	6.9
2016	62,091	2.3	199	12.4	0.0
2017	64,905	4.5	199	12.9	4.0
2018	67,187	3.5	195	13.1	1.8
5-year Average	7,443	2.4	198	12.5	2.5

Table 2-16 | Demand Projection Comparison

Methodology	2030	2040
Service Population Estimate[1]	92,681	115,272
ADD from 5-year Average Per Capita	18.4 MGD	22.9 MGD
ADD from Employee and Housing Unit Estimates (Selected Method)	17.8 MGD	21.1 MGD
ADD from 5-year Production Change	17.7 MGD	22.7 MGD

Note:
1. Service population estimate based on 75 percent of the PRC population projection for the Bend UGB.

2.4 Summary

The City's historical customer accounts, service area population, water production, use, and loss were evaluated to determine trends in the system water requirements. Service area populations are estimated at 75 percent of the City population. The City is regularly improving its data collection and methodologies and as a result the historical data will continue to improve understanding of past and future system requirements. The future and projected number of employees and housing units, previously developed for the City on a parcel basis, was used to project growth in the water service area boundary. Unit demand factors based on 2018 consumption and production data were then applied to the employee and housing unit projections for each timeframe. This growth does not reflect potential declines due to less water use from increased conservation program measures. Projections reflect 20-year increases in average day demand requirements from 13.1 MGD to 21.1 MGD and maximum day demand from 28.1 MGD to 45.2 MGD and peak hour demand from 57.7 to 92.7 MGD. The City currently updates their plan every 10 years which gives the opportunity to track the population and demand trends and update projections. The projected demands for the next 20 years are used to evaluate the hydraulic capacity of the system and identify improvements. The actual timing of any improvements should be based primarily on when the system reaches certain demand thresholds versus specific predetermined timelines.

Section **3**

Section 3

Level of Service and Design Standards

3.1 Introduction

This section includes the planning and analysis criteria and assumptions used for the water system analysis. The City of Bend (City) has numerous objectives and considerations in achieving its mission to provide the right public services for its citizens. The City's water system is a critical component of achieving this mission by providing reliable, high quality water and service that meet regulatory standards and contribute to City policy objectives. The City's water system level of service (LOS) criteria and planning assumptions define the framework for analysis of the system including water rights, supply, storage, pumping facilities, and piping to meet existing and future requirements. Recommendations to provide water during emergency conditions including infrastructure redundancy and fire suppression capacity are incorporated into the system analysis. Consideration is also given more generally to City objectives such as financial and environmental stewardship, compliance with America's Water Infrastructure Act (AWIA), and energy efficiency. Additional consideration is also given to collaboration with the Deschutes National Forest including measurement and other compliance tasks such as maintaining and replacing fish screens, that are required as part of the United States Forest Service (USFS) Special Use Permit. The water demand forecasts developed in Section 2 are used in conjunction with the LOS criteria presented in this section for the analysis of the City water system presented in Section 4.

3.2 Level of Service Framework

The LOS criteria reflect regulatory requirements where applicable as well as City service goals. Oregon Administrative Rules (OARs) were used for specific criteria where applicable and industry standards and other regional state guidelines and best practices were considered where the OARs do not outline specific standards. Chapter 14 of City Code provides guidance and standards for outlining the use, operation, and service relating to the water system. The primary intent is to provide reliable, high quality water to City customers while maintaining reasonable rates that reflect the cost of service. The water system LOS standards also consider other City policies and programs such as conservation, climate change considerations, and synergy opportunities with other City departments such as capital projects from Transportation, Sewer, and Stormwater planning efforts.

3.3 Water Rights

The City's ability to serve reliable, high quality water at adequate capacities to meet customer demands starts with access to supply sources through water rights. The City's system relies on both surface water and groundwater rights to meet system requirements. The system benefits from the natural resiliency created by the diversification of its water rights portfolio to provide a dual source supply. To maintain reliable service the maximum rate of the City's water rights should be sufficient to allow the City to meet its maximum day demand. In addition, the annual volume of water use authorized by the City's water rights should be sufficient to meet annual demands.

Consideration should be given for the reliability of the water authorized by the water rights to conservatively anticipate drought, mitigation, natural disasters such as forest fires and more extreme weather patterns, regulatory changes, or other impacts that could reduce the actual water available under any given water right. The impact and options to reduce the impact on the system in the event of a disruption to either surface water or groundwater sources is important to maintaining reliable levels of service.

3.4 Supply

For typical operating conditions, the system supply, comprised of surface water treated at the Water Filtration Facility (WFF) and groundwater wells should be able to supply MDD under a firm capacity condition. To provide redundancy the firm capacity condition is defined as the largest capacity well or in the case of the WFF, one filter train, out of service in each pressure zone rather than the single largest supply out of service system wide.

There are many emergency conditions such as watershed wildfires, urban interface fires, surface or groundwater contamination, local earthquakes, population influx due to coastal earthquakes or other emergencies, or regional power failures that could reduce supply capacity or require supply modifications for long durations. During these long-term emergency conditions, the City's LOS is to provide average winter demand, approximately representing indoor water use, solely from either the surface water supply or groundwater supply.

The City is currently performing an initial Outback Siting Study (Siting Study) to further evaluate how recommended facilities such as pretreatment, new and rebuilt reservoirs, wells, and other water related facilities may be sited on existing and/or additional lands. These facilities will incorporate required federal security recommendations. The Siting Study also includes space considerations for potential locations for the siting of a hydropower generation building that works in conjunction with the addition of pretreatment and related facilities. Implementation of this hydropower option would only be considered if City Council chooses to proceed. A separate Hydropower Feasibility Study would need to be conducted first and was not a part of the iWSMP or Siting Study.

In the event of a wildfire or related water quality incident, pretreatment would allow the City to continue operating the WFF and provide resiliency to the overall system. Due to ongoing turbidity events from the 1979 Bridge Creek Fire, as well as risks from future fires, plans for pretreatment were part of the original WFF design. This Siting Study is an initial effort to understand land needs and potential hydraulic layout, all of which will be refined as part of a larger future Outback Facility

Plan that will finalize a location and construction of specific facilities recommended in the long-term plans for the site. The Outback Siting Study is in Appendix 3A.

Due to the lower cost of operations and lower power use of the surface water, which is supplied to the system by gravity, the City's goal is to maximize the use of that lower cost water under typical operating conditions.

3.5 Pumping Capacity

Areas served by pump stations should have some redundancy to meet average, peak, and emergency (such as fire flow) demand conditions. Pumping capacity requirements vary depending on how much storage is available to the area served by the pump station and the number of pumping facilities. For an open system, where gravity storage facilities serve the same area served by the pump station and provide peaking and fire suppression storage, it is recommended that total pumping capacity be equal or greater than MDD. Also, the firm capacity must be equal to or larger than ADD. Firm capacity is defined as a station's capacity with the largest pump out of service. In a closed system, where no gravity storage serves the area, the booster pump station must be able to provide peak hour demand (PHD) and MDD plus fire flow with the largest pump out of service.

3.6 Backup Power

During a short-term power outage, on-site automatic backup power should be available to meet average day demand (ADD) if two days of ADD is not available in standby or emergency storage. Additionally, pump stations serving areas without storage should have backup power.

3.7 Storage

Storage facilities are provided for four primary purposes: operational storage, equalization storage, emergency or standby storage, and fire storage. The total storage required is the sum of these elements. In addition, any storage unavailable for use due to providing substandard pressures or due to facility constraints, typically called dead storage should be taken into consideration in addition to the required storage components. A brief discussion of each element is provided below.

3.7.1 Operational Storage

Operational storage is the volume of water used from storage before supply sources turn on. It is used to prevent excess pump cycling, which could increase power use and lifecycle costs.

3.7.2 Equalization Storage

Equalization storage volume should be sufficient to meet normal system demands in excess of the maximum day demand and is generally considered as the difference between PHD and MDD (on a 24-hour duration basis). The equalization storage criterion is the volume required to meet demand in excess of supply capacity for 2.5 hours.

3.7.3 Emergency Storage

Emergency storage or standby storage is intended to provide water during emergencies such as pipeline failures, equipment failures, power outages or natural disasters. While any number of emergencies may occur over time, it is prudent to have enough storage to provide a minimum amount of water to meet demand while additional response can occur such as backup power turning on during a power outage or short-term supply or pipeline maintenance occurring.

The amount of emergency storage for a water system can be highly variable depending upon an assessment of risk and the desired degree of system reliability. OARs and other industry standards allow for localized decisions regarding the volume of emergency storage required. Provisions for emergency storage in other systems vary from none to a volume that would supply several days of MDD or higher. The benefit of large storage volumes for emergencies must be balanced with the cost of tank construction and water quality issues which are typically exacerbated by having large volumes of water in tanks that are not turned over regularly.

The City's dual supply sources from groundwater and surface water provide additional risk mitigation, reducing the potential for emergencies where only storage is available to supply the system since the vulnerability of each source along with the backup power requirements to address power emergencies, provide some redundancy in serving the system. As a result, in reviewing the range of industry practices and with consideration to the City's specific configuration, the LOS standard for emergency storage is to provide two days (48 hours) of ADD, reduced by the firm supply capacity with backup power. Even if adequate backup power is available, the standby storage should be a minimum of 200 gallons per Equivalent Residential Unit (ERU), which is approximately sixty percent of the average day use per ERU.

3.7.4 Fire Storage

While the distribution system provides water for domestic uses, it is also expected to provide for fire suppression. The amount of water recommended for fire suppression purposes is based on the size and duration of the anticipated fire which is typically associated with the local building type and size or the land use of a specific location. **Table 3-1** presents assumptions for minimum fire flow requirements by land use type. Fire storage should be available for the largest single fire requirement based on the land use in any zone the storage tank serves.

Table 3-1 | Fire Flow Requirement by Land Use

Land Use	Fire Flow Requirement (gpm)	Duration (hours)	Fire Storage Volume (gallons)
Residential	1,500	2	180,000
Commercial/Public	2,500	3	450,000
Central Business District	3,500	5	1,050,000

3.8 Distribution System

The distribution pipe network conveys water throughout the system to meet demands and fire flow requirements at adequate pressure and velocity. The pressure and velocity requirements vary based on the system demand conditions. A minimum 8-inch pipe distribution pipe and 16-inch transmission pipe diameter criteria is also required to meet the velocity and pressure requirements, particularly during fire flow conditions. Conformance to the pressure ranges may not always be possible or practical due to topographical relief, existing system configurations and economic considerations. In some areas, individual service line booster pumps or pressure reducing valves (PRVs) may be installed by the customer to help satisfy pressure needs. The distribution system criteria are in **Table 3-2**.

Table 3-2 | Pressure and Velocity Criteria

Attribute	Evaluation Criterion	Value
Service Pressure	Minimum during MDD plus fire flow	20 psi
	Minimum during PHD	30 psi
	Standard Range	40-100 psi
	Maximum	120 psi
Pipe	Maximum Velocity for ADD or MDD	5 feet per second
	Maximum Velocity for PHD	8 feet per second
	Maximum Velocity during Fire Flow	12 feet per second
	Minimum Distribution Pipe Diameter	8-inch
	Minimum Transmission Pipe Diameter	16-inch

3.9 Other Criteria

In addition to hydraulic criteria, some more general level of service considerations are used in evaluating the system as part of this Integrated Water System Master Plan (iWSMP). These inform the assumptions around the longevity of infrastructure, prioritization of infrastructure improvements, and case-by-case considerations for improvements that do not have a uniformly applicable level of service.

3.9.1 Life Cycle Assumptions

Maintaining infrastructure and planning for its natural lifecycle is important to providing ongoing levels of service with the existing system. Assessing how long water system infrastructure, including tanks, pumping facilities, wells or pipes will last while maintaining the adequate level of service requires many considerations and is best assessed periodically for each individual facility. However, for planning assumptions, general guidelines were set for evaluating the useful life of new infrastructure as well as the life cycle of conducting a full rehabilitation of existing infrastructure. These life cycle assumptions are needed to assess infrastructure improvement requirements. The assumed useful life of various infrastructure is listed in **Table 3-3**.

Table 3-3 | Life Cycle Assumptions

Facility	New Facility Life Cycle (years)	Maintenance of Existing Facility Life Cycle (years)
Storage Tank	75	56
Well or Pump Station	40	30
Pipeline	100	-

3.9.2 Redundancy

Redundant service provides flexibility in operations and allows continued service when one part of the system is unavailable. Redundancy for all infrastructure must be balanced with the cost to construct and maintain extra infrastructure. Many of the LOS criteria incorporate redundancy, such as having firm supply and pumping capacity requirements to account for ongoing service in the event a single piece of infrastructure, such as a pump, is offline. Additionally, as mentioned, the City's dual supply source provides some resilience in supplying at least typical indoor water demand—as measured by water used during the winter months—should either supply source be completely unavailable, such as during a severe watershed fire or groundwater contamination.

Redundancy should be evaluated to understand the number of customers which could be impacted if a single piece of infrastructure, from supply sources, PRVs, pipe connections, or isolation valves were inoperable. Although not set standards, this plan identified some measures for redundancy analysis as pressure zones served by only one PRV vault, single-feed pipes that serve over 50 gallons per minute (gpm) demand, and pipes that required more than four valves to isolate. However, the improvements required, or maintenance considerations will be evaluated more on a case-by-case basis depending on factors such as the cost or feasibility of adding redundancy and the number of customers or amount of demand impacted. As a result, a uniform level of service is not defined, but in each analysis and improvement redundancy is considered as a goal where feasible.

3.9.3 Standards and Specifications

Section 2-5 of the City standards and specifications outlines detailed information about water system components and appurtenances including some of the information in this iWSMP and much more specific information than is evaluated in this system-wide analysis.

3.10 Summary

The City's Level of Service criteria for the water system aim to provide reliable, high quality water and service that meet regulatory standards and support the City's numerous objectives and considerations. The Level of Service criteria and planning assumptions define the framework for analysis of the system including water rights, supply, storage, pumping facilities, and piping to meet existing and future requirements. The specifics are in **Table 3-4.** Even where specific criteria are not defined, guidelines for determining infrastructure life cycles for maintenance and improvements as well as considering infrastructure redundancy is important in determining system improvements. As individual criteria are used to evaluate the system, consideration is also given more generally to City objectives such as financial and environmental stewardship, compliance with America's Water Infrastructure Act (AWIA), and energy efficiency. Additional consideration is also given to collaboration with the Deschutes National Forest including measurement and other compliance tasks such as maintaining and replacing fish screens, that are required as part of the United States Forest Service Special Use Permit.

Table 3-4 | Level of Service Summary

Attribute	Evaluation Criterion	Value
Water Supply	Firm Supply Capacity	Greater than MDD assuming storage is adequate for equalization and fire suppression
	Emergency Power	At least two independent sources if adequate standby storage is not available
Storage	Total Storage Capacity	Sum of dead, equalization, fire, operational, and standby
	Dead Storage	Storage that is unavailable for use or that can provide only substandard quality, flows and pressures
	Equalization Storage	Difference of PHD and max supply capacity for 150 min
	Fire Suppression Storage	Largest fire flow in a zone for duration of that flow
	Operational Storage	The volume of water before sources turn on to prevent excess pump operation or cycling
	Standby Storage	48 hours of ADD minus firm supply capacity with backup power, with a minimum of 200 gallons per ERU
Pump Stations	Minimum No. of Pumps	2
	Firm capacity pumping to storage	ADD
	Total capacity pumping to storage	MDD
	Firm capacity pumping to system	MDD plus fire flow or PHD, whichever is greater
	Emergency Power	At least two independent sources adequate to serve ADD plus largest fire flow (where standby power and fire suppression storage are not adequate/available)
Service Pressure	Minimum MDD plus fire flow	20 psi
	Minimum PHD	30 psi
	Standard Range	40-100 psi
	Maximum	120 psi[1]
Distribution Piping[2]	Maximum Velocity for ADD or MDD	5 feet per second
	Maximum Velocity for PHD	8 feet per second
	Maximum Velocity during Fire Flow	12 feet per second
	Minimum Future Pipe Diameter	8-inch
Fire Suppression	Minimum Fire Flow Requirements[3]	Residential: 1,500 gpm for 2 hours Commercial/Public: 2,500 gpm for 3 hours Central Business District: 3,500 gpm for 5 hours

Notes:
1. For pressures above 80 psi, installation of individual pressure reducing valves is recommended for compliance with plumbing code.
2. Velocity criteria are primarily for designing pipe improvements and these criteria alone will not typically result in recommendations for existing system improvements.
3. For all fire flow evaluations, it is assumed that flow for only one fire at a time must be available.

Section **4**

Section 4

System Analysis

4.1 Introduction

This section describes the analysis of the City of Bend (City) water system. The system is evaluated using the level of service criteria, goals, and recommendations in Section 2 with a comprehensive approach incorporating condition, capacity, criticality, and operations analyses. The analysis reviews existing, 10-year and 20-year planning horizons to determine existing and future system surpluses and deficiencies. The deficiencies and recommendations inform the improvements identified in Section 6.

4.2 Comprehensive System Analysis Approach

The City has completed an extensive analysis of its water system that collected and looked at many data sources and established rigorous evaluation criteria. The City's existing water system as described in Section 1 was analyzed to meet both existing and future demands as well as typical and emergency operations. The approach for determining 10-year and 20-year future demand projections is in Section 2. The system is evaluated using the level of service (LOS) criteria in Section 3.

The City has made a significant investment in evaluating the system in a robust manner far exceeding the regulatory requirements in the Oregon Administrative Rules (OARs), which primarily address water quality and some capacity requirements. The water quality analysis is in Section 5. The analysis done for this Integrated Water System Master Plan (iWSMP) incorporates condition, capacity, criticality, and operations assessments, for all major facilities and the pipe network. The analysis incorporated numerous methodologies including Geographic Information System (GIS) data review, facility site evaluations, numerical analysis, traditional hydraulic modeling, and innovative optimization modeling that includes advanced algorithms to explore an extensive range of system modifications against complex decision-making considerations. Figure 4-1 illustrates the components and approach used in this iWSMP analysis.

The facility condition assessment was done through background GIS, construction drawing, and other data review as well as site visits and the results were also used in the optimization done through Optimizer Water Distribution System (WDS) software. The facility capacity assessment primarily utilizes a spreadsheet review that is then validated with the distribution system assessment. The distribution assessment and pipe and valve criticality assessments leverage steady state and extended period simulation (EPS) hydraulic modeling done through a variety of platforms including InfoWater, InfoWater Valve Criticality Modeling module, Optimizer WDS, and Optimizer Opticritical software. The operations analysis was done using an EPS simulation of existing conditions in InfoWater for the water age assessment and in Optimizer WDS for the existing operations assessment.

The value of this comprehensive analysis is to allow the City to accurately assess and continue to leverage the benefits of the historic investments that have been made to the system and the full extent of investments required moving forward. This will benefit existing customers and provide for future growth within the service area. The results of the analysis were used in the optimization process, which utilizes the Optimizer WDS software to determine optimal solutions to system deficiencies. Optimization uses genetic algorithms to run millions of EPS hydraulic model simulations to balance the best hydraulic performance at the overall lowest life cycle and capital cost. The optimization results inform the Capital Improvement Plan (CIP) and operational program recommendations and prioritization outlined in **Section 6**.

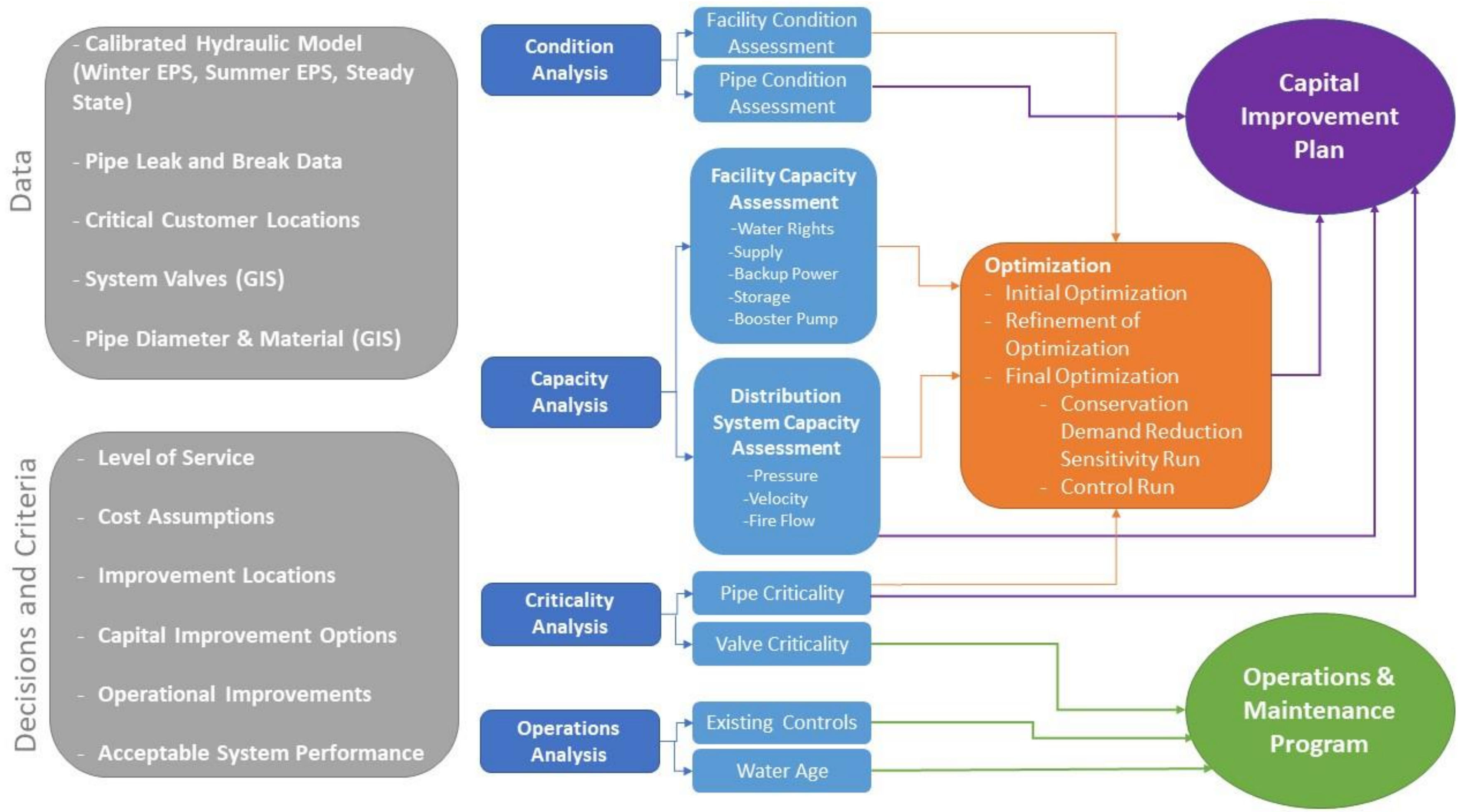
4.3 Condition Analysis

An analysis of the existing system infrastructure was done to evaluate the facility and pipe condition. This is the City's first master planning effort to address the condition of all existing facilities and piping on a programmatic level.

The condition analysis identifies current deficiencies at each facility and helps set priorities and develop an approach to address deferred facility maintenance and extend their useful life. The facility condition assessment recommended improvements are used in the Optimization Analysis to evaluate the ability of existing facilities to meet existing and future requirements and determine the cost and benefit of improvements at existing facilities compared to constructing new facilities.

A recommendation was developed to prioritize which pipes should be replaced first as part of a comprehensive pipe replacement program. Ultimately the City will need to determine what level of funding will be made available to determine the rate of ongoing pipe replacement.

Figure 4-1|Comprehensive System Analysis Components



4.3.1 Facility Condition Assessment

To provide an evaluation of the necessary investment in the existing system, a condition assessment of the City's active wells, storage facilities, and booster pump stations was performed. Facilities were assessed through a review of background data (e.g., operational narratives, power consumption records, construction drawings, property ownership, parcel size and zoning, etc.) and onsite visits. The onsite examination assessed physical and operating conditions (e.g., buildings, tanks, valves, pumps, motors, electrical equipment, safety elements, site access, security, etc.). An estimate of the value of the facility based on its existing assets was completed. The condition of each facility was assessed for over a dozen categories including things such as access, mechanical, electrical, fire protection and more as detailed in the complete Infrastructure Condition Assessment Report. Each element was assessed on five general criteria: sanitary, safety, structural, level of service, and security.

Based on the assessment, each facility was ranked, and improvements were identified that are required to maintain current facilities and extend their useful life. Facilities have a mix of elements, each containing a range of conditions from excellent to very poor, however, to assess the overall condition of a facility, a Facility Condition Index was applied with possible overall ratings of Excellent, Good, Fair, Poor, and Very Poor. The index is based on the ratio of overall deferred or backlog maintenance to the estimated cost of replacing the facility.

Figure 4-2 shows the Facility Condition Index rating for each facility. The detailed maintenance and improvement recommendations and their associated costs are identified for each facility in the Infrastructure Condition Assessment Report. The recommended improvements are intended to restore all components of the facilities to Good condition.

4.3.2 Pipe Condition Assessment

Pipes have a certain useful life and to maintain system performance should be lined or replaced prior to failure. Many variables affect the lifespan of a particular pipe including material, liner material (if applicable), age, soil conditions, water quality and installation methods to name a few. The City, like many utilities, is developing an understanding of how long their pipe will last and where they should focus their replacement efforts.

Having a condition-based replacement program is essential to keep system piping in working order and within appropriate life cycle expectations. The City's investment in pipe replacement will need to increase over time and this analysis provides some proposed prioritization for how that might occur. No in-situ pipe condition analysis was completed so the future pipe replacement itself will serve as a critical data source for refining the program and informing the adequacy of the proposed investment levels, which should be reassessed as part of each subsequent water master planning effort.

Currently the City has been replacing approximately 1 mile of pipe per year as part of the condition-based replacement program (additional replacement occurs as part of the CIP). Much of their historical replacements have been focused on specific breaks, undersized piping, or materials they know to be substandard. Based on its current 440 miles of existing pipe that corresponds to approximately a 400-year life cycle. The City's goal is to increase the funding to allow for approximately 2 miles of pipe per year to be replaced, reducing to a 200-year replacement rate.

The City's pipe GIS data (2018) was used to assign each pipe in the system a replacement rating based on material, diameter, valve frequency, and break history. A higher rating indicates worse pipe condition. Certain types of materials, such as steel, cast iron, or galvanized iron are older and more prone to leaks and no longer meet the City's material standards. These materials were more heavily weighted, contributing to a higher rating. Ductile Iron pipe was given a 0 rating since it is the City's current standard for pipe material. Additionally, small diameter pipe that no longer meet City standards received higher ratings.

Replacement ratings used for material and diameter are shown in **Table 4-1**. Small diameter steel pipe received the highest material and diameter rating of 3.5. The criteria assigned to break and leak history at specific pipes and the number of valves required to isolate the pipe also contributed to the overall condition rating. The ratings for these criteria are in **Table 4-2**. The assessment to determine the number of valves required to isolate each pipe is outlined in the Criticality Analysis later in this section.

Table 4-1 | Rating for Material and Diameter

Material	Pipe Diameter (inches)		
	1"-6"	8"-14"	16"-36"
Cast Iron	3	2	2.5
Galvanized Iron	2.5	1.5	2
PVC	2	1	1.5
Steel	3.5	1	1.5
Other	0.5	0	0

Table 4-2 | Rating for Break, Leak and Valve Isolation

Criteria	Count	Rating
Break/Leak History	1+	2
Number of Valves Closed to Isolate Pipe	1 - 4	0
	5 - 6	3
	6 - 7	4

Based on the criteria the breakdown of replacement rating by length in miles and diameter groups is shown in **Table 4-3**. **Figure 4-3** illustrates pipe replacement ratings across the system. Based on a condition replacement program of approximately two miles of pipe per year (200-year replacement rate), ratings of 5.5 to 7.5 could be addressed in one year. Over the 20-year horizon ratings of three and higher could be replaced, allowing for some initial build-up time to increase funding for the program. Ultimately pipes that are identified for improvements due to hydraulic deficiencies including criticality, fire flow, and capacity will not be listed as part of the pipe replacement program, however, do contribute to the overall replacement rate and life-cycle goal of the City's program. As an example, some of the localized fire flow improvements are due to undersized piping. As such fire flow CIP projects are identified individually and not included in the general pipe replacement program. Prioritization of pipes in the replacement program and coordination with other CIP projects is discussed in **Section 6**.

Table 4-3 | Pipe Replacement Length by Rating (miles)

Rating	Pipe Diameter (inches)			Total Miles	Cumulative Total Miles
	1" - 6"	8"-14"	16"-36"		
7.5	0.00	0.00	0.03	0.03	0.03
7	0.07	0.00	0.00	0.07	0.1
6.5	0.30	0.00	0.13	0.43	0.53
6	0.22	0.33	0.00	0.55	1.08
5.5	0.33	0.00	0.56	0.89	1.97
5	0.34	1.40	0.00	1.74	3.71
4.5	0.29	0.00	0.23	0.52	4.23
4	0.00	0.81	0.29	1.10	5.33
3.5	1.29	0.00	0.00	1.29	6.62
3	21.93	2.40	0.96	25.29	31.91
2.5	1.58	0.00	0.76	2.34	34.25
2	0.40	18.90	0.01	19.31	53.56
1.5	0.00	0.00	8.61	8.61	62.17
1	0.00	1.20	0.00	1.20	63.37
0.5	29.64	0.00	0.00	29.64	93.01
0	0.01	296.05	45.65	341.70	434.72
Total[1]	**56.38**	**321.10**	**57.24**	**434.72**	

Note:
1. Pipes identified for capacity improvements are not included in the pipe replacement totals.

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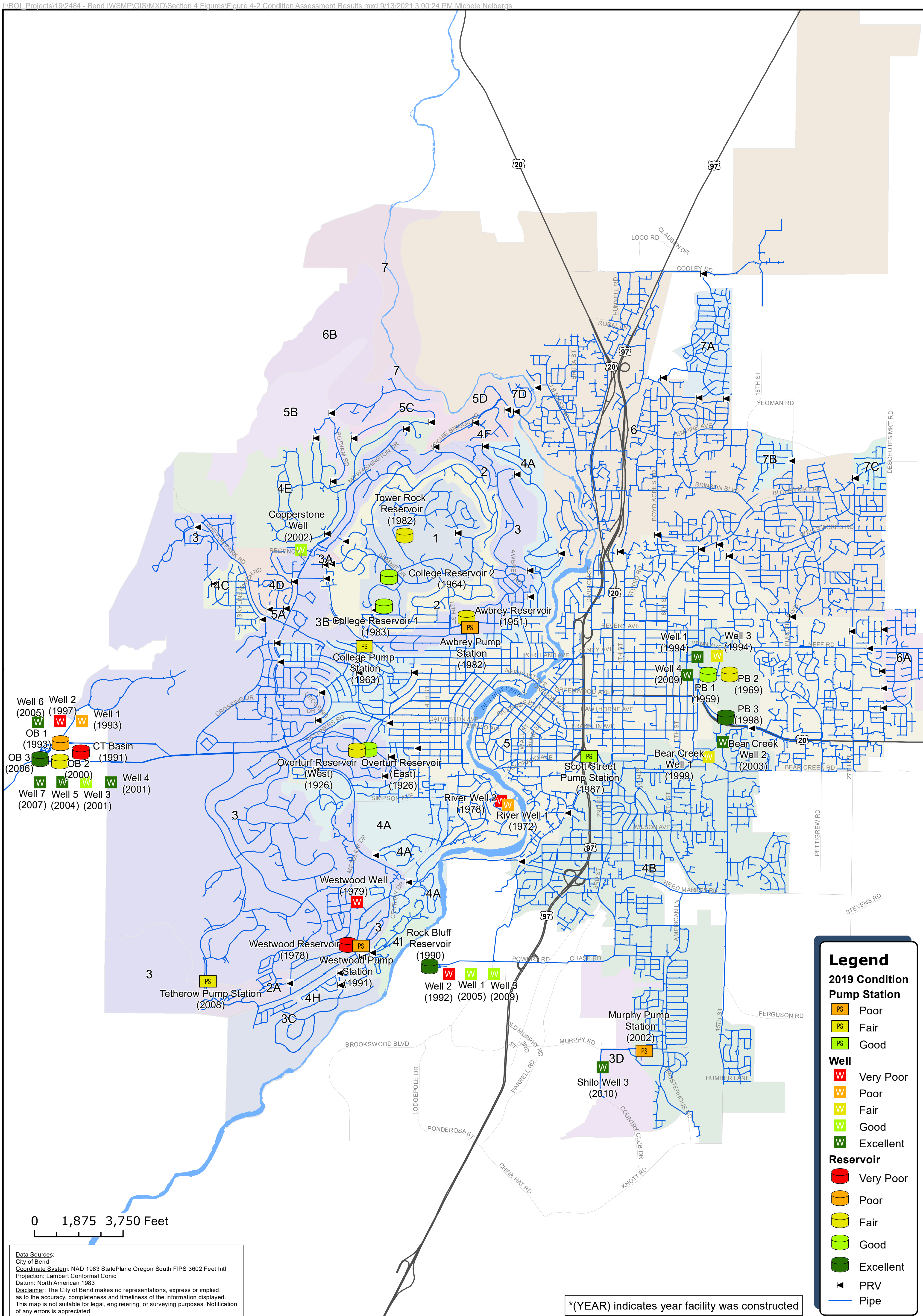
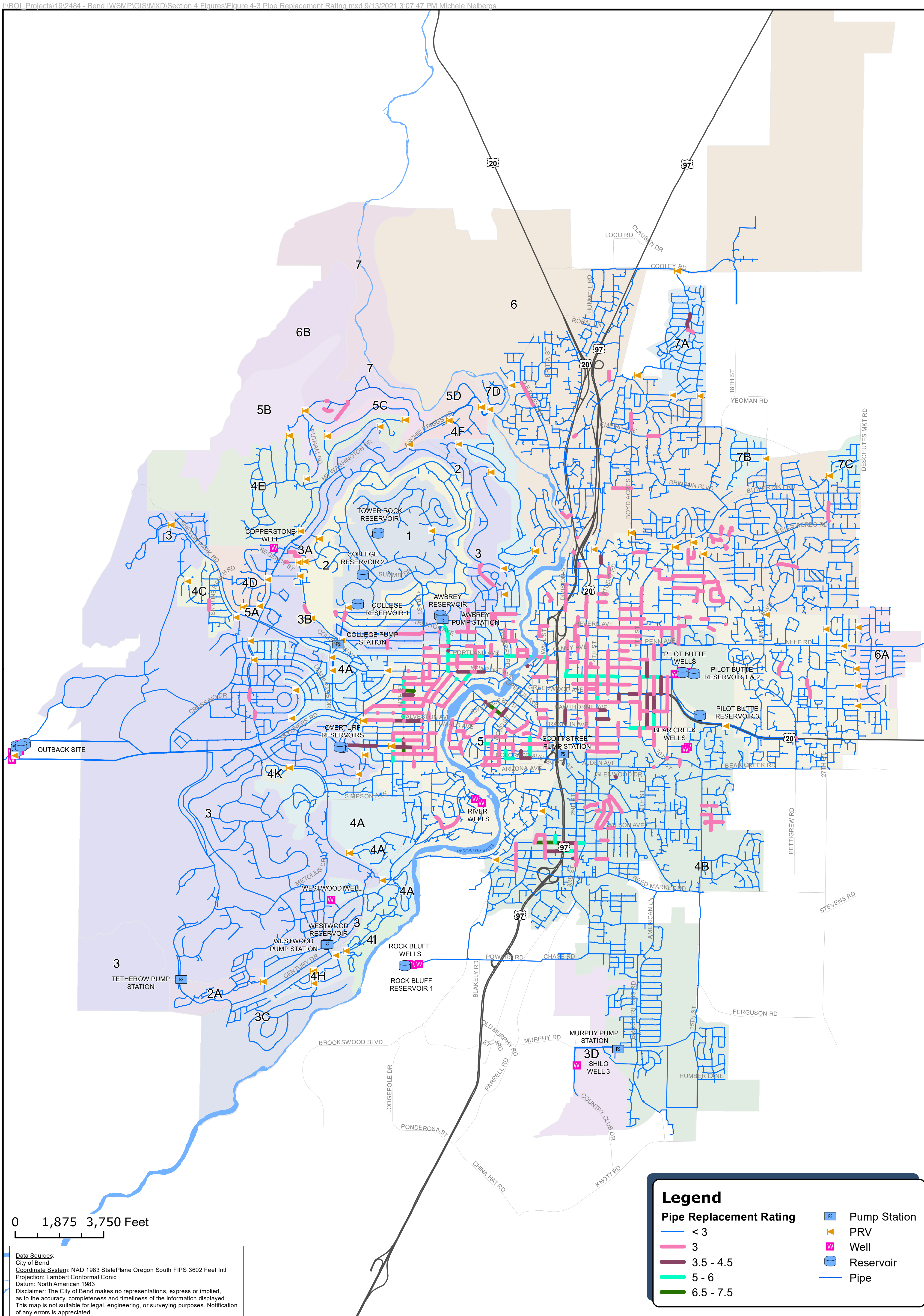


murraysmith

City of Bend
Integrated Water System Master Plan

Figure 4-2
Condition Assessment Results

I:\BOI_Projects\19\2484 - Bend IWSMP\GIS\MXD\Section 4 Figures\Figure 4-3 Pipe Replacement Rating.mxd 9/13/2021 3:07:47 PM Michele.Neibergs



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City of Bend
Integrated Water System Master Plan

Figure 4-3
Pipe Replacement Rating

September 2021 19-2484

4.4 Capacity Analysis

Many of the specific LOS criteria in **Section 3** address the hydraulic capacity requirements of the system. These are intended to evaluate the capacity of the system components including water rights, supply, storage, pumping, and pipe to reliably provide water to City customers under a variety of demand, emergency, or operational conditions.

The capacity analysis includes several numerical comparisons of facility capacities relative to demand conditions, based on unique requirements for different system assets consistent with the LOS criteria. A hydraulic model is used to evaluate the overall interaction of the system components, particularly the pipe network capacity to convey water from wells, storage, and booster pump stations to customers distributed throughout the system.

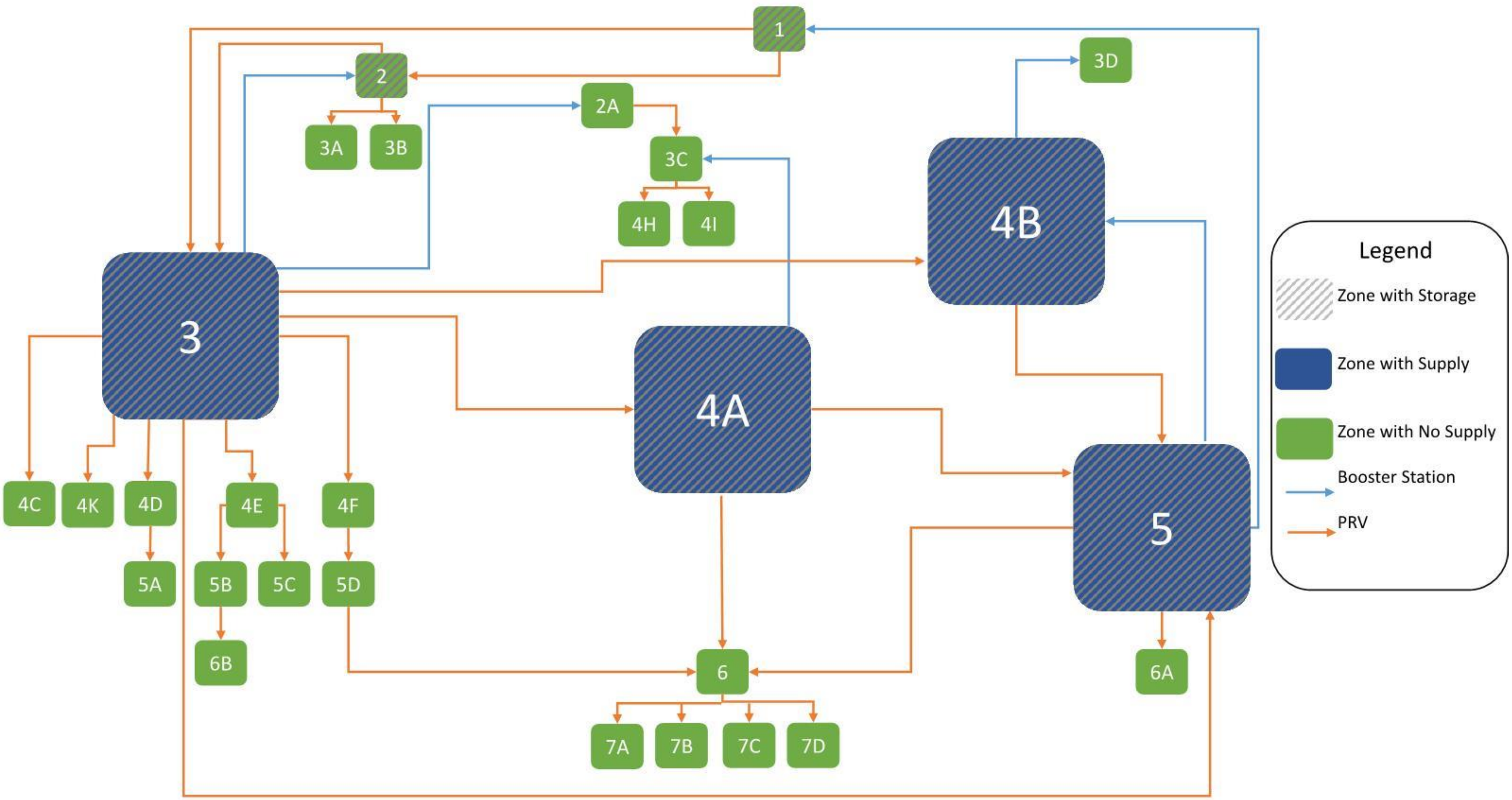
The facility and distribution system capacity assessment results are used in the Optimization Analysis described later in this section to determine recommended improvements to address deficiencies in meeting the LOS criteria.

4.4.1 Facility Capacity Assessment

The facility capacity assessment compares existing and projected demand requirements to the City's existing water rights (surface water and groundwater), supply capacity at the Water Filtration Facility (WFF) and wells, storage reservoir, and pump station capacity. To support the City's LOS goals for redundancy and meet regulatory requirements where applicable, the analysis generally includes conservative assumptions regarding system capacity, such as assuming the largest supply source is out of service in each zone. Additionally, it uses the City's current limiting surface water right (limited by special permits and City ordinance), rather than the City's total historic water rights portfolio. The analysis incorporates these considerations as well as the LOS requirements to illustrate the adequacy of existing facilities to meet future demand conditions and indicate where improvements are necessary.

Many of the facilities are designed to serve the pressure zone they are in, as well as other subzones. **Figure 4-4** shows the interconnectivity of the system with regards to supply and storage and the pressure reducing valve (PRV) and booster pump station connections that can convey the supply and storage to other zones and subzones. The analysis considers supply groups based on where water can be served, and storage groups based on which subzones each zone with storage can serve. Additional detail about each facility, its respective capacity and interconnectivity are in **Figure 1-3** and in **Section 1**.

Figure 4-4 | Pressure Zone Supply and Storage Group Connectivity



4.4.1.1 Water Rights Analysis

Table 4-4 presents the City's water rights for both groundwater and surface water sources as compared to the maximum day demand (MDD) over the 10-year and 20-year planning horizons. The specific capacity and limitations on the City's water rights are discussed in **Section 1**.

As indicated in **Table 4-4**, the City's surface water and groundwater rights are sufficient to provide the City's maximum day demand through 2040.

Table 4-4 | Water Rights Analysis

Water Source	Water Right (gpm)	Total Water Right (gpm)	MDD (gpm)			Surplus/Deficiency (gpm)		
			2018	2030	2040	2018	2030	2040
Surface	8,169	38,798	19,519	26,391	31,375	19,279	12,407	7,423
Groundwater	30,629							

More extensive discussion and review of the City's water rights requirements are included in the Water Management and Conservation Plan (WMCP) completed in parallel with this iWSMP. The WMCP analysis considers additional restrictions on the City's surface water supply, fluctuations in demand throughout the day, and the City's water right needs beyond the 2040 horizon covered in this iWSMP.

4.4.1.2 Supply Analysis

For the supply analysis, a spreadsheet calculation of the balance of available supply relative to demand was done. Zones with groundwater or surface water supply sources and the subzones without supply that they serve were grouped together into supply groups. The supply groups for this analysis are shown in **Table 4-5** and reflected in **Figure 4-4**. The system must be able to provide MDD in each zone with firm capacity, or the largest supply out of service. The City uses a combination of surface water and groundwater to supply the system. For Zone 3, the firm capacity is calculated as one membrane filtration train out of service at the WFF. For every other zone with supply the firm capacity assumes the largest well in the zone is out of service.

The City operates the system to maximize use of the surface supply when feasible and uses groundwater supply only to meet demands above the maximum available surface water supply or to meet localized demand requirements. During existing peak demand periods, the City fully utilizes its available surface water rights. The surface water is used as the first supply since it is less expensive to use than the groundwater wells which require pumping. This also allows more consistent flows through the WFF, which provides greater operational stability. The potential for hydropower generation could also be maximized with use of the surface water supply and contribute to the City's goals to reduce fossil fuel use but requires additional study and would require City Council approval. The surface water supply is more vulnerable to a watershed water quality disruption, such as a wildfire, and additional pretreatment at the facility would increase the resilience and ability to depend on maximum use of this supply. The wells are more easily operated to meet fluctuations in demand above the base supply from the WFF.

The City's capacity from existing wells and the WFF to meet existing and future demands by zone and system-wide is in **Table 4-6**. Though there are some zones showing a current deficit, the overall excess system-wide supply can help meet demands via valve connections to zones with excess supply. By 2030, system-wide supply deficiencies exist. Since no additional surface water rights are available, additional well supply will be required to meet future MDD.

Table 4-5|Supply Groups

Primary Supply Group	Zones Supplied
3	3, 2, 2A, 3A, 3B, 3C, 4C, 4D, 4E, 4F, 4H, 4I, 4K, 5A, 5B, 5C, 5D, 6B
5	5, 1, 6, 6A, 7A, 7B, 7C, 7D
4A	4A
4B	4B, 3D

Table 4-6|Supply Analysis

Zone Group	Total Capacity (gpm)	Firm Capacity (gpm)	MDD (gpm)			Surplus/Deficit (gpm)		
			2018	2030	2040	2018	2030	2040
3	16,519	14,950[1]	4,974	6,524	7,377	9,976	8,426	7,573
4A	700	0	1,220	1,666	2,246	(1,220)	(1,666)	(2,246)
4B	5,700	4,500	3,106	4,517	5,421	1,394	(17)	(921)
5	6,500	4,600	10,220	13,684	16,330	(5,620)	(9,084)	(11,730)
System-wide	29,419	**24,050**	**19,519**	**26,391**	**31,375**	**4,531**	**(2,341)**	**(7,325)**

Note:
1. Firm capacity for zone group 3 is based on one of the three active membrane filtration trains out of service at the WFF.

The City also has a level of service requirement to supply average winter demands using solely the groundwater or solely the surface water sources. Based on the ability to move supply water across all zones, particularly to meet the lower winter demand, the analysis was done system wide. **Table 4-7** summarizes the City's capacity to achieve that objective. There is adequate supply from either the groundwater or surface water sources alone to meet winter demand.

Table 4-7 | Winter Demand Supply Analysis

Supply	Total Capacity (gpm)	Firm Capacity (gpm)	Average Winter Daily Demand[2] (gpm)			Surplus/Deficit (gpm)		
			2018	2030	2040	2018	2030	2040
Groundwater	21,250	17,450	3,386	4,578	5,443	14,064	12,872	12,007
Surface Water	8,169	6,600[1]				3,214	2,022	1,157

Notes:
1. Firm capacity for zone group 3 is based on one of the three active membrane filtration trains out of service at the WFF.
2. Average Winter Demand based on the 2018 ratio of average day demand (ADD) to Winter Demand of 37 percent.

4.4.1.3 Backup Power Analysis

To provide resilience and reliable water delivery during an emergency, in the event of a power outage, the system should have adequate backup power to meet average day demand (ADD) through on-site backup power or two days of ADD in standby storage. **Table 4-8** and **Table 4-9** present an analysis of the City's backup power capacity for water supply sources and booster pumping stations, respectively. The City's primary supply, the WFF has backup power to operate during a power outage. The Westwood and Scott Street Pump Stations do not have backup power. They are redundant facilities to zones that can be served by wells or pump stations with backup power; as a result, they are not included in the analysis.

As shown in **Table 4-8**, most supply sources lack backup power, and three of four zone groups only have one supply source with backup power, resulting in a deficiency. However, there is considerable excess capacity in Zone Group 3, which can be used to offset deficits in most of the system. By 2040, the backup power analysis indicates a system-wide deficit. The backup power requirement can be met by adding generators to new supply wells.

As shown in **Table 4-9**, the College Pump Station and Murphy Pump Station have current and future deficits. The Murphy Pump Station is already equipped with a backup power supply; it simply has insufficient pumping capacity to meet the fire flow requirement. The City is currently designing and planning to construct a higher capacity replacement of the Murphy Pump Station that can operate with the existing generator so it will have adequate standby capacity at the completion of the improvement. Zone 2, served by the College Pump Station can be supplied from Zone 1 through PRV connections allowing the excess backup power capacity in Zone 1 to serve the deficiency in Zone 2. No improvements are necessary to meet the emergency power requirements.

Table 4-8 | Backup Power Analysis of Supply Sources by Zone Group

Zone Group	Facility	Backup Power Available	Total Capacity (gpm)	Backup Firm Capacity (gpm)	Fire Flow (gpm)	ADD (gpm)			Surplus/Deficit (gpm)		
						2018	2030	2040	2018	2030	2040
3	WFF[1]	Yes	8,169	6,600	Met through storage	2,326	3,051	3,450	8,293	7,568	7,169
	Copperstone Well	No	950	0							
	Outback Well 1	No	800	0							
	Outback Well 2	No	950	0							
	Outback Well 3	No	1,050	0							
	Outback Well 4	Yes	1,150	1,150							
	Outback Well 5	No	1,050	0							
	Outback Well 6	No	1,100	0							
	Outback Well 7	Yes	1,300	1,300							
4A	Westwood Well	Yes	700	0	Met through storage	570	779	1,050	130	(79)	(350)
4B	Bear Creek Well 1	No	1,050	0	Met through storage	1,452	2,112	2,535	(352)	(1,012)	(1,435)
	Bear Creek Well 2	Yes	1,100	0							
	Rock Bluff Well 1	No	750	0							
	Rock Bluff Well 2	No	800	0							
	Rock Bluff Well 3	No	800	0							
	Shilo Well 3	No	1,200	0`							
5	Pilot Butte Well 1	No	750	0	Met through storage	4,779	6,399	7,636	(3,629)	(5,249)	(6,486)
	Pilot Butte Well 3	No	900	0							
	Pilot Butte Well 4	Yes	1,150	0							
	River Well 1	No	1,800	0							
	River Well 2	No	1,900	0							
System-wide			**29,419**	**9,050**		**9,127**	**12,340**	**14,671**	**4,442**	**1,229**	**(1,102)**

Notes:

1. WFF firm capacity is based on one of the three active membrane filtration trains out of service.

Table 4-9 | Backup Power Analysis of Booster Pumping Stations by Zone

Zone	Facility	Backup Power Available	Total Capacity (gpm)	Backup Firm Capacity (gpm)	Fire Flow (gpm)	ADD (gpm)			Surplus/Deficit (gpm)		
						2018	2030	2040	2018	2030	2040
1	Awbrey Pump Station	Yes	3,600	3,600	Met through storage	272	307	323	3,328	3,293	3,277
2	College Pump Station	No	2,200	0	Met through storage	286	318	335	(286)	(318)	(335)
2A, 4H, 4I	Tetherow Pump Station	Yes	3,800	3,800	2,500	100	147	158	1,200	1,153	1,142
2A, 4H, 4I, 3C	Tetherow Pump Station	Yes	3800	3800	2,500	258	341	362	1,042	959	938
3D	Murphy Pump Station	Yes	1,500	1,500	2,500	3	8	13	(1,003)	(1,008)	(1,013)

4.4.1.4 Storage Analysis

Storage in the system is intended to serve four purposes: operational, equalization, fire suppression, and standby storage (if adequate standby power is not provided). The total distribution storage required is the sum of the four components plus dead storage. Dead storage is the volume of water not available for system use due to operational constraints or that provides substandard customer pressures.

The system has 15 tanks as described in **Section 1**. For the analysis, zones with storage were grouped together with the subzones that they serve through PRVs or pump stations, as outlined in **Table 4-10** and illustrated in **Figure 4-4**. Fire suppression storage was determined assuming the single highest fire flow requirement base on land use across the zones the storage serves which is also indicated in **Table 4-10**.

Table 4-10|Storage Groups and Fire Flow Requirements

Storage Group	Zones Served	Highest Fire Flow Requirement (gpm)	Duration (hours)
1	1	1,500	2
2	2, 3A, 3B	2,500	3
3	3, 4D, 4C, 4K, 4F, 2A, 3C, 4H, 4I, 4E,5B, 5D, 6B,5C,5A	2,500	3
4A	4A	2,500	3
4B	4B, 3D	2,500	3
5	5, 6A, 6, 7A, 7B, 7C, 7D	3,500	5

Dead storage was calculated as all unavailable water in tanks to maintain levels for various purposes including to provide 20 pounds per square inch (psi) to the highest customer in the zone, provide adequate contact time at the WFF to meet regulatory requirements, or provide adequate suction pressure for service line booster pumps or pump stations. Tower Rock dead storage is based on providing minimum pressure to high elevation customers. Outback 2 dead storage is the level required to maintain adequate contact time in the Contact Time (CT) Basin. Outback 3 dead storage is the level required to maintain adequate suction pressure at the individual service line boosters in the nearby Tree Farm Development and Awbrey Reservoir's dead storage level is based on maintaining a minimum level to provide adequate suction pressure for the Awbrey Pump Station. The dead storage components could potentially be addressed through operational or other system modifications and are used in this analysis to determine any additional existing or future storage volumes required.

Operational storage was determined based on summer tank operations as the difference between pump on and off settings. Equalization storage was calculated as the difference between the peak hour demand (PHD) and total supply capacity for 150 minutes. Standby storage represents 2 days of the difference between average day demand (ADD) and firm supply capacity with backup power. Standby storage can also be reduced to a minimum of 200 gallons per equivalent residential unit (ERU) if adequate backup power exists at supply sources to meet at least ADD. Reducing the volume of standby storage can also help with operations and improving water age so balancing the available storage during an emergency with the unused storage that can negatively impact water age and quality is an important operational consideration.

The storage analysis in million gallons (MG) is shown with the full standby storage requirement in Table 4-11 and with the minimum standby storage (assuming 200 gallons per ERU) requirement in Table 4-12. The maximum available volume for each tank is based on the high operational level of each tank and is generally set below the maximum tank level to avoid tank overflows.

The system has significant existing storage deficiencies with the larger standby storage requirement, however, by using the standby power criteria to reduce the standby storage requirement, the existing system has adequate storage system-wide. Although some zone groups have deficiencies, they can leverage surplus storage from high zones through valve connections. The ability to move storage across the system from surplus to deficient zone groups was validated using the hydraulic model analysis. By 2030 there are system-wide storage deficiencies that will require approximately 2.25 MG of additional storage and another 3.5 MG by 2040 for a minimum additional storage requirement of 5.75 MG. The additional storage is needed in Zone 3, Zone 5, and Zone 4B.

Table 4-11 | Storage Analysis with Larger Standby Storage Requirement

Storage Group	Tank	Max Operated Volume (MG)	Dead/Unavailable (MG)	Storage Requirements (MG)											Surplus/Deficit (MG)		
				Fire	Operational	Equalization			Standby			Total					
						2018	2030	2040	2018	2030	2040	2018	2030	2040	2018	2030	2040
1	Tower Rock	0.90	0.01[1]	0.18	0.06	0.15	0.17	0.17	0.24	0.27	0.28	0.63	0.68	0.70	0.26	0.21	0.19
2	College 1, College 2	1.44	0.00	0.45	0.22	0.17	0.18	0.20	0.85	0.95	1.01	1.69	1.81	1.87	(0.25)	(0.37)	(0.43)
3	Outback 2, Outback 3	6.51	3.08[2]	0.45	0.38	0.24	0.75	1.03	1.78	2.38	2.71	2.85	3.96	4.58	0.58	(0.53)	(1.15)
4A	Overturf East & West, Westwood	3.27	0.00	0.45	0.83	0.30	0.45	0.64	1.64	2.24	3.02	3.22	3.97	4.94	0.05	(0.70)	(1.67)
4B	Pilot Butte 2, Rock Bluff	2.45	0.00	0.45	0.25	0.12	0.57	0.85	4.18	6.08	7.30	5.01	7.35	8.85	(2.56)	(4.90)	(6.40)
5	Awbrey, Pilot Butte 1, Pilot Butte 3	10.10	1.46[3]	1.05	2.01	1.67	2.63	3.34	12.98	17.54	21.06	17.70	23.23	27.46	(9.07)	(14.59)	(18.83)
System-wide		**24.67**	**4.55**	**3.03**	**3.76**	**2.64**	**4.74**	**6.23**	**21.67**	**29.47**	**35.39**	**31.10**	**41.00**	**48.41**	**(10.98)**	**(20.88)**	**(28.29)**

Notes:
1. Dead Storage based on high elevation customers maintaining 20 psi.
2. Dead storage at Outback 2 based on maintaining 21 feet of storage in the CT Basin for contact time. Dead storage in Outback 2 based on maintaining 10.5 feet of storage to provide adequate suction pressure at Tree Farm service line booster pumps.
3. Dead Storage based on maintaining 6 feet of storage for adequate Awbrey Pump Station suction pressure.

Table 4-12 | Storage Analysis with Minimum Standby Storage Requirement

Storage Group	Tank	Max Operated Volume (MG)	Dead/Unavailable (MG)	Storage Requirements (MG)											Surplus/Deficit (MG)		
				Fire	Operational	Equalization			Standby			Total					
						2018	2030	2040	2018	2030	2040	2018	2030	2040	2018	2030	2040
1	Tower Rock	0.90	0.01[1]	0.18	0.06	0.15	0.17	0.17	0.24	0.27	0.28	0.63	0.68	0.70	0.26	0.21	0.19
2	College 1, College 2	1.44	0.00	0.45	0.22	0.17	0.18	0.20	0.26	0.29	0.31	1.10	1.15	1.17	0.34	0.29	0.27
3	Outback 2, Outback 3	6.51	3.08[2]	0.45	0.38	0.24	0.75	1.03	1.78	2.38	2.71	2.85	3.96	4.58	0.58	(0.53)	(1.15)
4A	Overturf East & West, Westwood	3.27	0.00	0.45	0.83	0.30	0.45	0.64	0.50	0.68	0.92	2.08	2.41	2.84	1.19	0.86	0.43
4B	Pilot Butte 2, Rock Bluff	2.45	0.00	0.45	0.25	0.12	0.57	0.85	1.27	1.85	2.22	2.10	3.12	3.77	0.35	(0.67)	(1.32)
5	Awbrey, Pilot Butte 1, Pilot Butte 3	10.10	1.46[3]	1.05	2.01	1.67	2.63	3.34	3.94	5.33	6.40	8.67	11.02	12.80	(0.03)	(2.38)	(4.17)
System-wide		**24.67**	**4.55**	**3.03**	**3.76**	**2.64**	**4.74**	**6.23**	**7.99**	**10.80**	**12.84**	**17.42**	**22.33**	**25.86**	**2.70**	**(2.21)**	**(5.74)**

Notes:
1. Dead Storage based on high elevation customers maintaining 20 psi.
2. Dead storage at Outback 2 based on maintaining 21 feet of storage in the CT Basin for contact time. Dead storage in Outback 2 based on maintaining 10.5 feet of storage to provide adequate suction pressure at Tree Farm service line booster pumps.
3. Dead Storage based on maintaining 6 feet of storage for adequate Awbrey Pump Station suction pressure.

4.4.1.5 Booster Pump Station Analysis

There are six booster stations in the existing system. The criteria for booster stations depends on whether the zone served has gravity storage (open system) or not (closed system). In an open system, assuming the storage is adequate for fire suppression and equalization, the booster pump station total capacity must be equal to or larger than MDD for the zones it serves. Also, the firm capacity must be equal to or larger than ADD. In a closed system, the booster pump station must be able to provide PHD with the largest pump out of service and MDD plus fire flow with the largest "routinely used" pump out of service.

The MDD and ADD analyses of the pump stations serving zones with storage are in **Table 4-13** and **Table 4-14 respectively.** The Awbrey Pump Station and College Pump Station have sufficient capacity to meet the MDD and ADD requirements of their respective open zones through the 20-year planning period. The Scott Street Pump Station serves as a backup supply to Zone 4B and is not intended to meet system demands. As a result, it is not included in the analysis.

Table 4-13|Open System MDD Analysis

Zones Served	Booster Station	Total Capacity (gpm)	MDD (gpm)			Surplus/Deficit (gpm)		
			2018	2030	2040	2018	2030	2040
1	Awbrey	3,600	582	658	691	3,018	2,942	2,909
2, 3A, 3B	College	2,200	632	708	747	1,568	1,492	1,453

Table 4-14|Open System ADD Analysis

Zones Served	Booster Station	Total Capacity (gpm)	Firm Capacity (gpm)	ADD (gpm)			Surplus/Deficit (gpm)		
				2018	2030	2040	2018	2030	2040
1	Awbrey	3,600	2,400	272	307	323	2,128	2,093	2,077
2, 3A, 3B	College	2,200	1,100	296	331	349	804	769	751

The analysis of the pump stations serving zones without storage is in **Table 4-15** and **Table 4-16**. The Tetherow Pump Station directly serves Zone 2A and can serve Zones 3C, 4H, and 4I through a PRV connection. Those zones can also be served by the Westwood Pump Station. These three zones could be served by either pump station or a combination of the two operating together. Although the Westwood Pump Station does not have adequate capacity, the Tetherow Pump Station can serve all four zones. The Tetherow Pump Station has a minimal deficiency by 2040 that does not merit additional pump capacity since the pumping capacity will be a bit higher than shown under fire flow conditions when the pump is operating farther out on its curve and pressure criteria are lower than typical operating requirements. In addition to the spreadsheet analysis, the Tetherow Pump Station capacity was validated through the hydraulic model and determined not to require improvements. As shown in **Table 4-16**, the Murphy Pump Station has insufficient capacity to meet the MDD plus fire flow demand requirements for Zone 3D. The City is currently designing and planning to construct a higher capacity replacement of the Murphy Pump Station that will address the deficiency.

Table 4-15 | Closed System PHD Analysis

Zones Served	Booster Station	Total Capacity (gpm)	Firm Capacity (gpm)	PHD (gpm)			Surplus/Deficit (gpm)		
				2018	2030	2040	2018	2030	2040
2A	Tetherow	3,920	3,220	117	294	294	3,103	2,926	2,926
2A, 3C, 4H, 4I[1]	Tetherow	3,920	3,220	1,269	1,674	1,780	1,951	1,546	1,440
3C, 4H, 4I[1]	Westwood	2,275	1,375	1,151	1,380	1,486	224	(5)	(111)
3D	Murphy	1,500	1,200	13	35	60	1,187	1,165	1,140

Note:
1. Zones 3C, 4H, and 4I can be served by the Westwood Pump Station directly or the Tetherow Pumps Station via a PRV connection.

Table 4-16 | Closed System MDD+Fire Flow Analysis

Zones Served	Booster Station	Total Capacity (gpm)	Firm Capacity (gpm)	Fire Flow (gpm)	MDD (gpm)			Surplus/Deficit (gpm)		
					2018	2030	2040	2018	2030	2040
2A	Tetherow	3,920	3,220	2,500	51	128	128	669	592	592
2A, 3C, 4H, 4I[1]	Tetherow	3,920	3,220	2,500	552	728	774	168	(8)	(54)
3C, 4H, 4I[1]	Westwood	2,275	1,375	1,500	501	601	647	(626)	(726)	(772)
3D	Murphy	1,500	1,200	2,500	6	17	29	(1,306)	(1,317)	(1,329)

Note:
1. Zones 3C, 4H, and 4I can be served by the Westwood Pump Station directly or the Tetherow Pumps Station via a PRV connection.

4.4.2 Distribution System Capacity Assessment

Distribution system performance was assessed using the City's hydraulic model to evaluate the service pressure and velocity criteria summarized in **Section 3**. Pressures should not fall below 30 psi under PHD conditions and 20 psi under MDD plus fire flow conditions. Where feasible operating pressures should remain between 40 and 80 psi with a maximum of 120 psi. Pipe flow velocity criteria were also used during the distribution system analysis to indicate potential areas of undersized piping. Distribution piping was assessed based on a maximum velocity of 5 feet per second (fps) under ADD and MDD conditions and 8 fps under PHD conditions. Typically, velocity criteria alone will not drive an improvement, but are used to determine capacity constraints and inform improvements to address overall system capacity limitations.

4.4.2.1 Hydraulic Model

The City's existing hydraulic model in InfoWater software by Innovyze was updated and calibrated under both steady state and EPS conditions in 2018, as documented in the City's Calibration memo in **Appendix 4A**. The calibrated model was used to evaluate the performance of the distribution system under existing and future demand conditions to identify deficiencies and evaluate the adequacy of improvements.

4.4.2.1.1 Modeling Conditions

Distribution system analysis was initially performed using the steady state model scenarios for existing, 10-year, and 20-year conditions for ADD, MDD, PHD and MDD plus fire flow conditions to identify deficiencies. The Optimization Analysis described later in this section was completed using a 2040 EPS scenario. Operational Analysis described later in this section were done using the model existing MDD and winter demand condition EPS scenarios.

4.4.2.1.2 Demand

Existing demand was allocated in the model during the 2018 calibration based on the location of meters using AMI data, which was updated to match 2018 production. The AMI data was also evaluated to determine hourly use patterns for winter and summer periods for Zones 1, 2, 3, 4A, 4B, 5, and 6. The AMI peaking factors by zone were used to determine a representative PHD peaking factor relative to MDD for each primary zone.

Future water demands were calculated based on unit values associated with the number of employees and housing units projected in identified growth areas. The projected demands are outlined in Section 2.

4.4.2.1.3 Fire Flow

Fire flow requirements are based on land use type as per the City of Bend Standards and Specifications. For residential areas, the fire flow requirement is 1,500 gpm. Commercial and publicly owned properties have a requirement of 2,500 gpm. The Central Business District area has a requirement of 3,500 gpm.

4.4.2.2 Distribution System Results

A steady state system analysis was performed to assess the ability of the City's current distribution system to provide water for existing and projected future demands and fire suppression.

4.4.2.2.1 Existing Condition Analyses

The system was modeled under existing ADD, MDD and PHD conditions. Under each scenario there are areas of pressures below 40 psi and above 120 psi across the system. In part this is due to a wide range in elevation throughout the system. In addition, some low pressures are a result of head loss due to conveying water from the Outback Facility to the rest of the system. It should be noted that areas of low pressure exist in the Tree Farm development, however this was a known condition when the area was developed. Service line booster pumps provide adequate service pressure and 20 psi minimum pressure during fire flows to customers. The booster pumps were not modeled as part of this analysis, however requirements to provide a minimum suction pressure of 7 psi was evaluated for each of the service line boosters. In addition, in all demand scenarios there are areas of high pressure above 120 psi. In these areas it is recommended that customers install PRVs on their service lines consistent with plumbing code requirements. The range of system pressures for ADD and PHD conditions are shown in **Figure 4-5**. Low pressures generally occur during PHD due to higher head loss and the high pressures during ADD.

Under existing ADD and MDD scenarios, a few areas exceed velocity requirements. Most of these are very small segments of facility site piping at Outback or other facilities. The most significant velocity exceedance of up to 8 fps during MDD occurs in the Awbrey transmission line that conveys flow from Outback to the Awbrey Reservoir. High velocities in the Awbrey transmission line are of particular concern because the pipe is seventy years old and the primary corridor to convey water from the Outback Facility to meet the demands on the east side of the system in Zone 5 and Zone 6. Existing velocity exceedances are shown in **Figure 4-5**.

Under the MDD plus fire flow scenario, there are areas in the system that cannot adequately meet fire flow requirements. The deficiencies and flow available at each hydrant are shown in **Figure 4-6.** The deficiencies are primarily due to small diameter and/or dead-end pipe. Improvements to address fire flow deficiencies were primarily evaluated using the steady state InfoWater model and are identified in **Section 6**.

4.4.2.2.2 Future Scenario Analyses

Future scenarios were run with future demand projections and existing system infrastructure to identify all future system deficiencies. As expected, due to significant increases in demand and future deficiencies in supply and storage, there are many areas in the system that have pressures below 30 psi and velocities that exceed 8 fps if the existing system infrastructure were to serve 2040 PHD. These deficiencies are useful to illustrate potential areas for improvement that were used in the Optimization Analysis that ultimately determined what supply and pipe improvements were needed to meet future system requirements. Future system deficiencies are shown in **Figure 4-7**.

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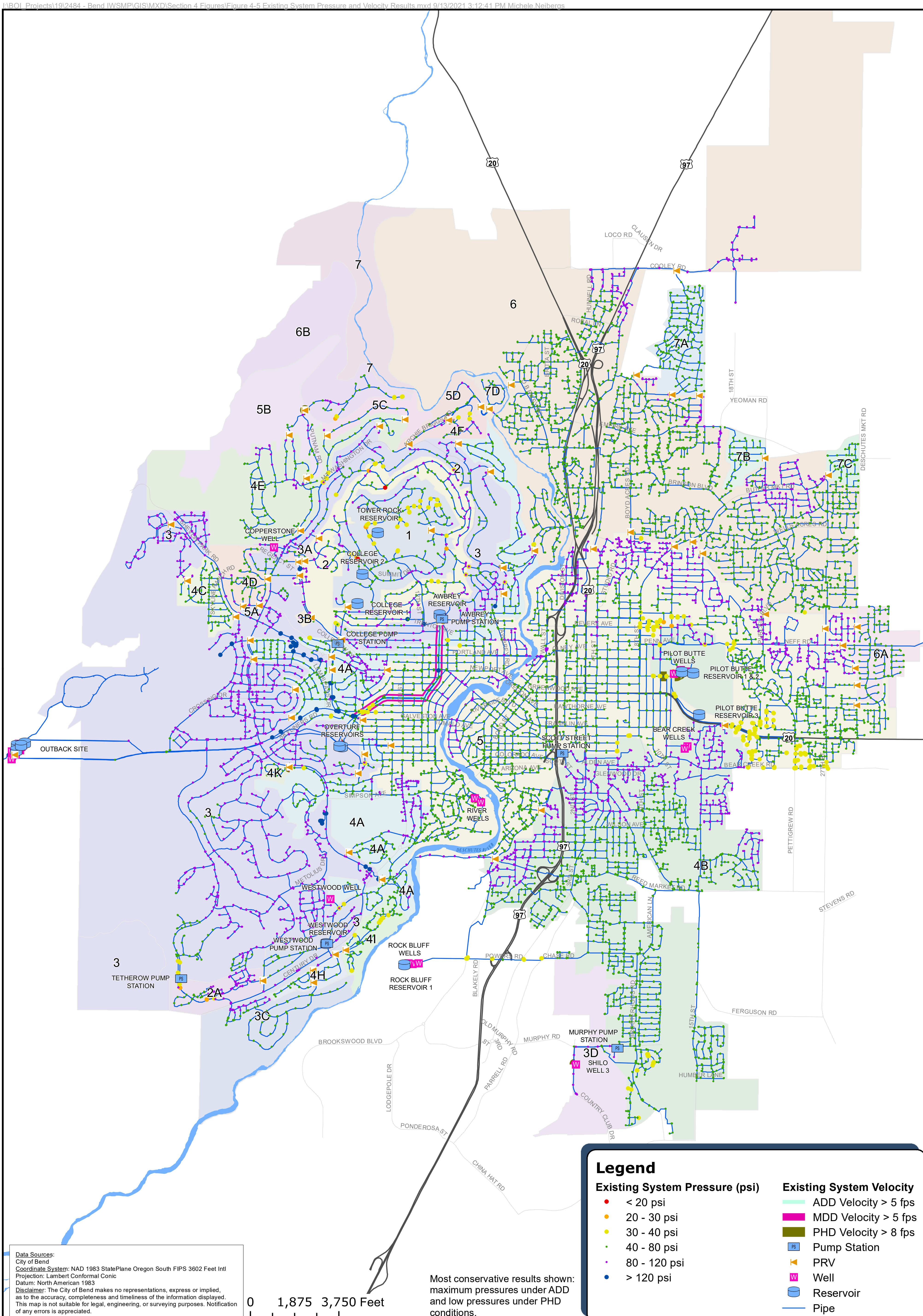

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Figure 4-5
Existing System Pressure & Velocity Results

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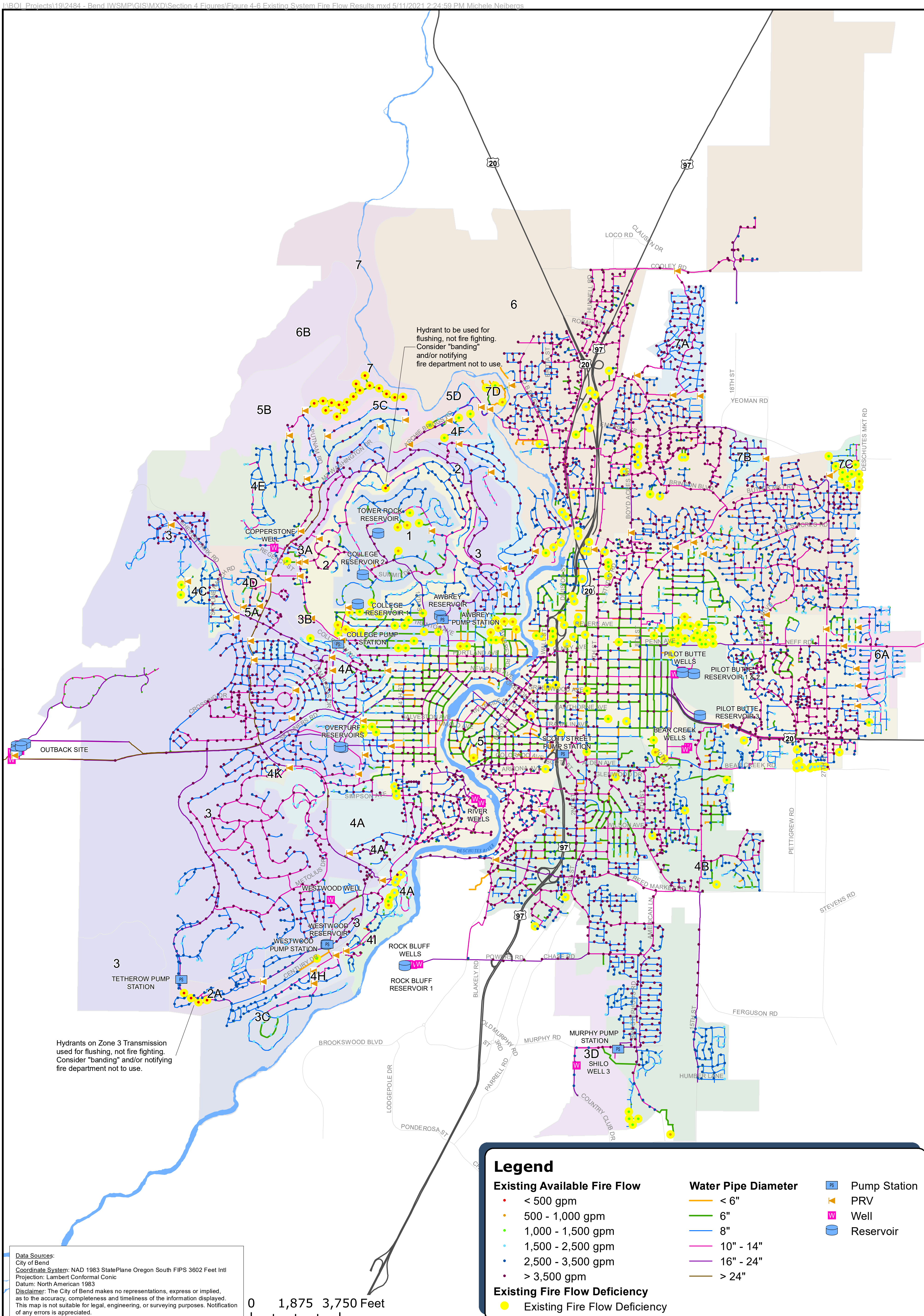

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Figure 4-6
Existing System Fire Flow Results

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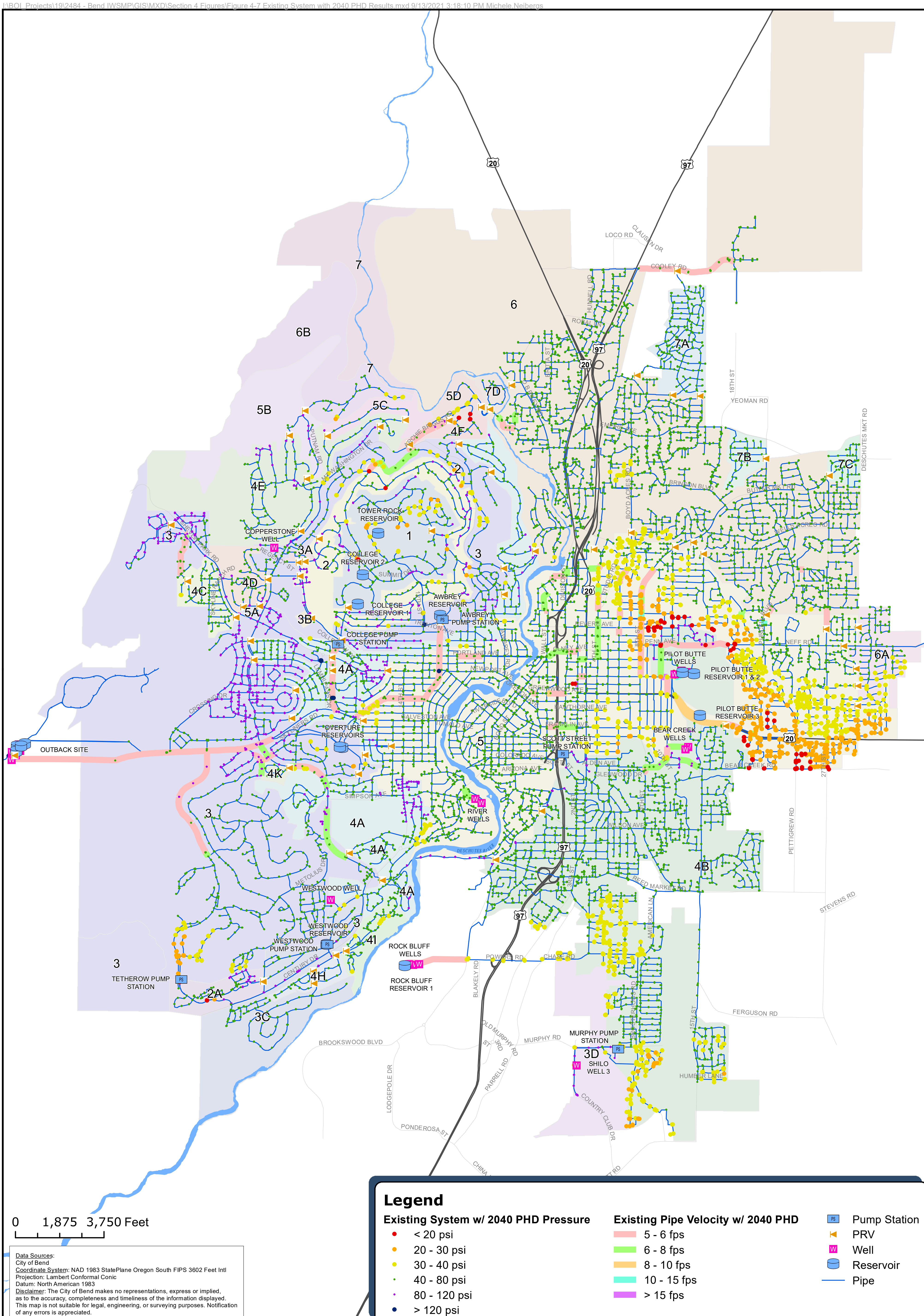

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4.5 Criticality Analysis

In addition to a hydraulic capacity assessment, a review of the consequence of failure of supply, pipe, and valve assets was conducted. This criticality or consequence of failure analysis provides a more detailed look at the redundancy and resiliency of the system to an unplanned interruption in service due to asset failure or other emergency condition. This criticality analysis is in addition to the America's Water Infrastructure Act (AWIA) Risk and Resilience Assessment that the City recently completed.

A review of the supply critically was completed, and the hydraulic model was used to identify critical system pipes and valves that would result in significant demand impacts, low pressures, or disruptions in service if a pipe or valve failed. The pipe criticality assessment indicates how much demand (also related to number of customers) is impacted if a pipe breaks and the valve criticality analysis determines the number of valves required to isolate a pipe. These analyses were completed using the 2018 MDD EPS scenario imported into the Optimatics software Opticritical. The valve criticality evaluation that determines the number of valves required to isolate an area if a valve breaks was done in the InfoWater Valve Criticality Modeling extension using the 2018 steady state model.

The pipe criticality results were used to identify improvements to increase redundancy in areas where a single pipe break could isolate a significant amount of demand. The valve criticality assessment was used with other criteria to determine ratings and prioritization for the pipe condition assessment. The valve break assessment provides data for the City to identify where valve installations should be made and prioritizes valve exercising during operation and maintenance programs.

4.5.1 Supply Criticality Assessment

The capacity assessment of the supply sources, previously described, has some resiliency included since the analysis assumes firm capacity, or the largest supply source, in each supply zone, is out of service. However, given the large, and preferential use of the surface water supply, a high-level discussion with City staff was conducted concerning the potential for supply disruption or failure at the WFF, beyond the single membrane filtration train being out of service assumed in the capacity assessment. The anticipated largest disruption or reduction in capacity at the WFF was determined to be the result of a water quality issue, such as a wildfire, that would impact sediment loads in the influent water. A pretreatment facility is the most feasible option to address this potential vulnerability and was included as part of the original WFF design but was deferred during the WFF upgrades. An initial study to evaluate the feasibility and planning level costs of such a facility is being conducted as part of this iWSMP, with a more detailed Outback Facility Plan to follow. **Appendix 3A** includes the details of the Outback Siting Study.

4.5.2 Pipe Criticality Assessment

A pipe is considered critical if when broken and exposed to atmospheric pressure it cuts off supply to a significant demand or number of customers, to critical customers or causes pressures to drop below 20 psi. The Opticritical hydraulic model was used to iteratively break each pipe to determine if hydraulic LOS criteria were violated. The analysis identifies areas fed by a single pipeline. The City provided locations of large and/or critical customers and these were also considered in the evaluation. The analysis was run under 2018 MDD, and critical areas were identified as those that do not have redundant piping and impact more than 50 gpm of demand. The 50 gpm threshold is the equivalent of approximately 100 single-family connections on a MDD basis.

In addition, two transmission pipe corridors that convey significant supply throughout the system were identified as critical to system operations. These include the Outback and Awbrey transmission pipes. Although each facility pipe is critical to the system in different respects, many areas have redundant feeds through other well supplies or PRVs or serve a smaller portion of the system. However, these two transmission lines convey a large portion of the system supply, are critical to maximizing surface water use, and cannot be rerouted through other corridors. The critical pipes are shown in **Figure 4-8**. Improvements are included in **Section 6** to provide redundancy for each of these critical pipes.

4.5.3 Valve Criticality Assessment

The valve criticality analysis was completed using the City's GIS valve layer by associating isolation valves in the system with the nearest pipe. The Opticritical model was then used to simulate the number of valves required to isolate each pipe after a break. The larger the number of valves required, the more time and effort is required to isolate the area and the potential for a greater number of customers to be impacted by the isolation. The relative number of valves required to close a pipe were used in rating pipes for replacement in the pipe condition assessment.

Another analysis was completed to determine how many valves are needed to isolate an area if a valve was broken. These results can be used to prioritize valve exercising and adding additional isolation valves as part of operation and maintenance programs.

The number of valves to isolate a pipe and to isolate a broken valve are shown in **Figure 4-9**.

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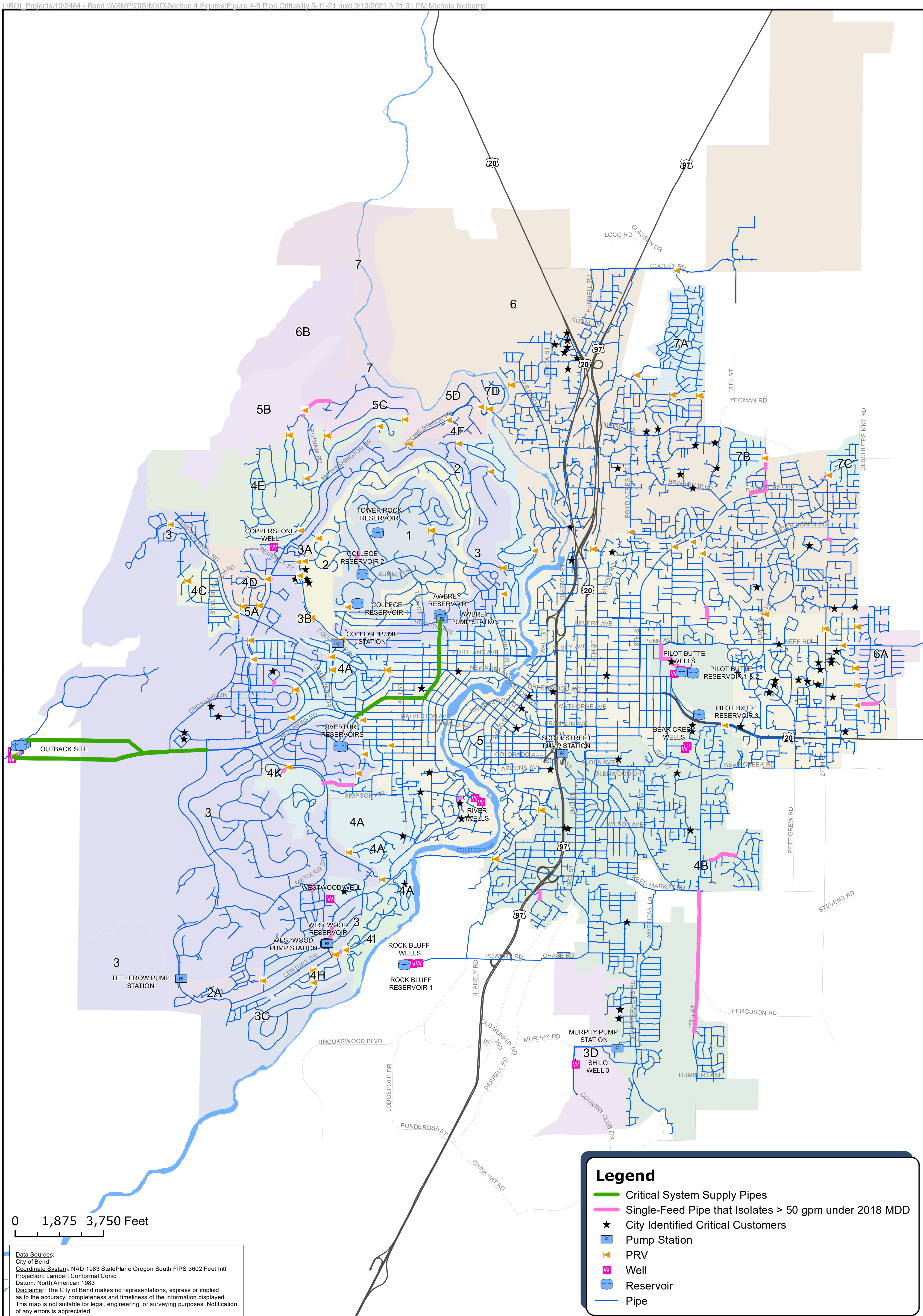

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Figure 4-8
Pipe Criticality

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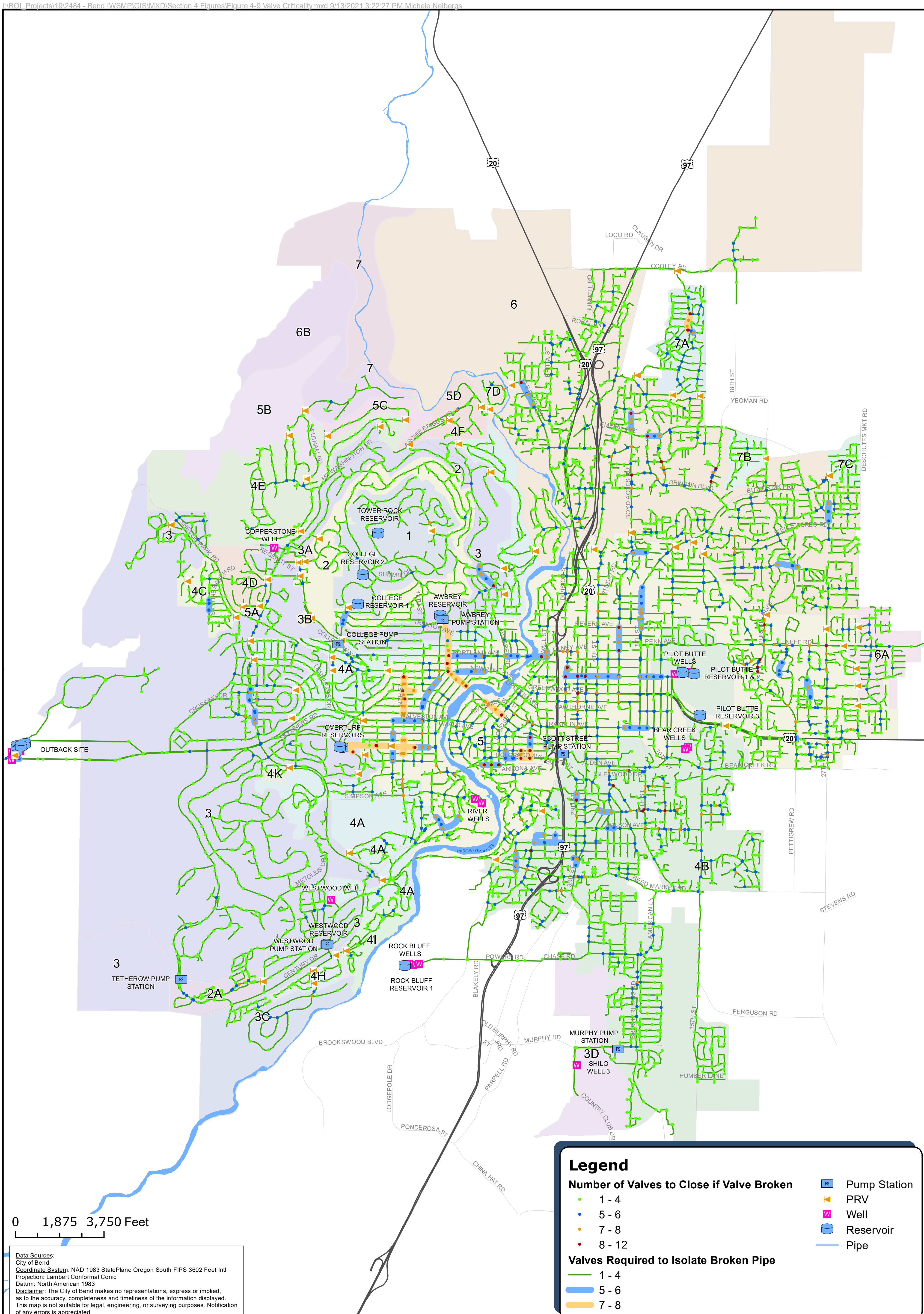

Data Sources:
City of Bend
Coordinate System: NAD 1983 StatePlane Oregon South FIPS 3602 Feet Intl
Projection: Lambert Conformal Conic
Datum: North American 1983
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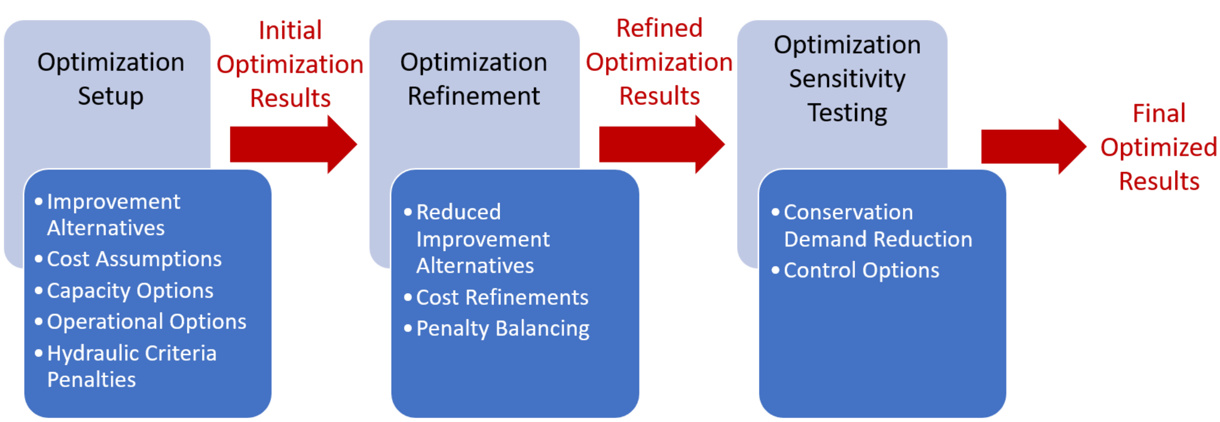
Figure 4-9 Valve Criticality

4.6 Optimization Analysis

To evaluate options for addressing the deficiencies previously identified in this section including facility and pipe capacity, criticality, and condition deficiencies, a formal optimization process was utilized, similar to the process the City conducted in the 2009-2010 master planning effort. A complex software, Optimizer WDS (Optimizer), was utilized. The software uses a genetic algorithm running the EPANet hydraulic model using cloud computing to find the best hydraulic performance at the lowest overall life cycle and capital costs. Optimizer utilizes EPS hydraulic model simulations to evaluate hundreds of thousands of asset combinations comparing improvement life cycle cost and hydraulic performance objectives to determine a range of optimized solutions. Just prior to this planning effort, City staff received some training in the software to increase their familiarity with and understanding of the software. Optimization reduces bias in the evaluation process by allowing for the identification of hundreds of improvement options instead of a few that are typically evaluated using traditional hydraulic modeling methods. The optimization primarily focused on 2040 MDD conditions and optimized solutions were refined to identify the system CIP, which is outlined in **Section 6**. Optimizer was also used to evaluate existing system operations, with more detail in the Operations Analysis discussion. The optimization process components are in **Figure 4-10**.

Figure 4-10|Optimization Process



4.6.1 Optimization Setup

Numerous steps are required to build the optimization model and formulation in the Optimizer platform. The decisions that Optimizer is given to select a solution comprise the formulation for the scenario being analyzed. The required setup includes adding improvement alternatives, assigning life cycle and capital costs to each improvement, providing a range of capacity and operational decisions to each alternative, and setting hydraulic criteria penalties.

4.6.1.1 Hydraulic Model Import

The optimization software operates using an EPANet hydraulic platform. Optimizer was used to evaluate the 2040 MDD scenario to determine system improvements to meet 2040 conditions and for the existing MDD scenario to determine optimized controls for operating the current system. The InfoWater 2040 MDD and 2018 MDD EPS scenarios utilized as part of the Distribution System Assessment were setup with some of the baseline decisions, such as improvement alternative locations and basic operational ranges and then exported to EPANet compatible files for use in the 2040 improvements and existing controls Optimizer analyses.

4.6.1.2 Improvement Alternatives

To evaluate solutions a broad array of potential system improvements was identified. The location of deficiencies determined during previous system analyses, review of the previous optimization effort and input from City staff were used to identify potentially viable project site locations. The alternative options in **Figure 4-11** were determined during a workshop with City Engineering & Infrastructure Planning, Utility, and Water Resources Department staff as well as team members from GSI, Clearwater Engineering, and Murraysmith. These are the full suite of locations that were considered for improvements during the initial optimization process.

The new facility improvement options included additional wells, gravity storage, or pump stations with some being constructed at existing facility sites and some at new sites. New pumped ground storage and PRVs were also included in the alternatives. Increasing the size of existing piping and new pipe alignments were added as options.

4.6.1.3 Cost Assumptions

Optimizer uses costs associated with operating and making improvements to infrastructure to find lower cost solutions that can also minimize hydraulic criteria penalties. The improvement costs are based on life cycle costs that incorporate capital and operation costs. Operation and maintenance costs were developed based on the average 2018 City budget allocation and include expenses such as repairs, chemicals, electricity, and generators. Capital costs include components required for new construction, design, and administrative expenses and in the case of existing facilities are based on the recommended improvements from the Facility Condition Assessment.

The capital and operating costs were assessed over the useful life of each asset and converted to an equivalent uniform annual cost (EUAC) accounting for assumptions for inflation and the discount rate. The EUAC allows a more equitable comparison of each improvement in the Optimization by accounting for infrastructure costs associated with different useful lifespans. Further detail about how costs were generated and applied is provided in **Appendix 6A**, **Appendix 6B**, and **Appendix 6C** and the resulting costs for the CIP are in **Section 6**.

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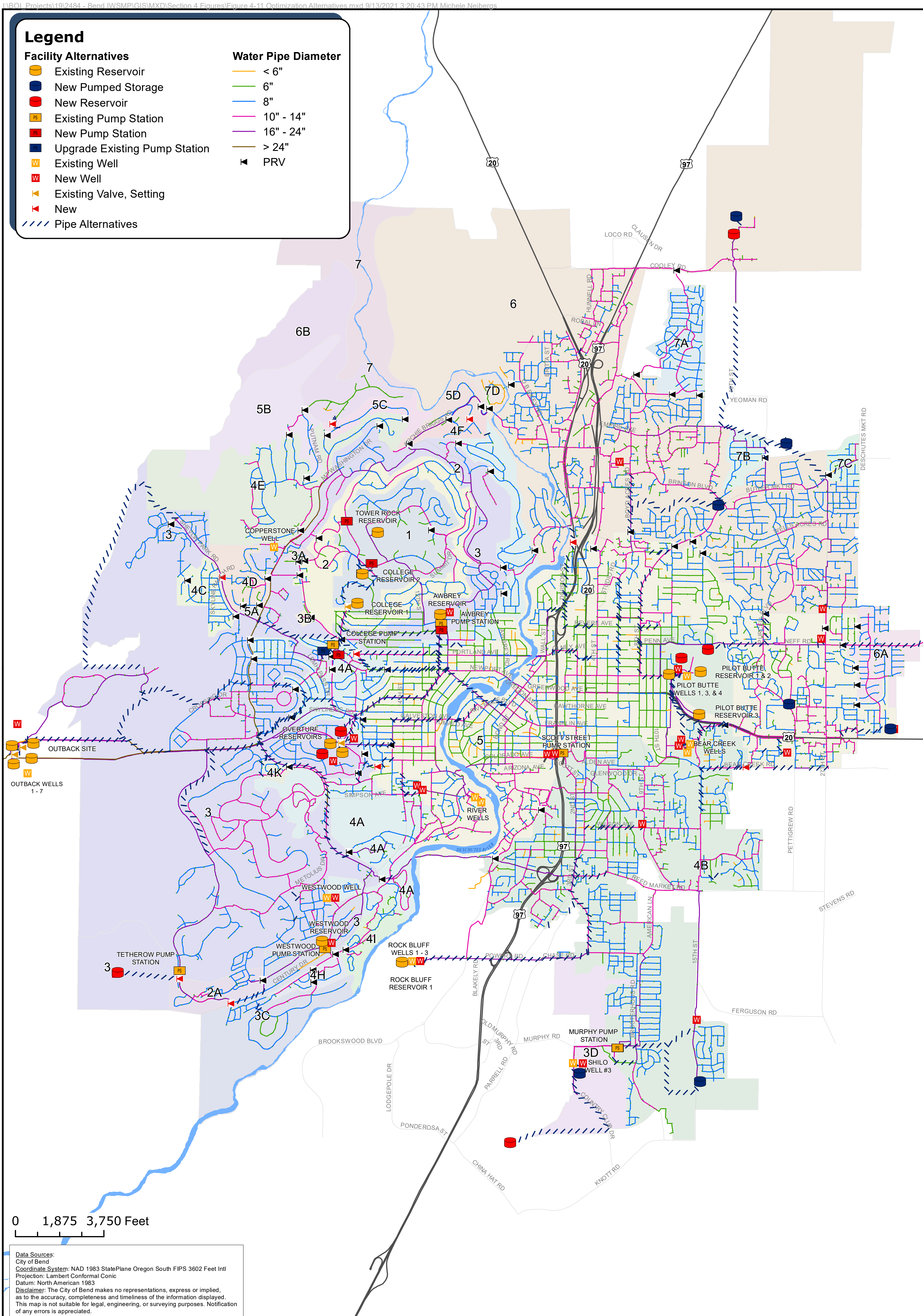

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City of Bend
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Projection: Lambert Conformal Conic
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Figure 4-11 Optimization Alternatives

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4.6.1.4 Capacity and Operational Options

For each type of improvement, the range of options used in the Optimizer formulation are summarized in Table 4-17. For each improvement there is the option to be “selected” to convey water in the system and incur the associated life cycle cost. For existing “selected” facilities, the cost is based on improvements identified in the condition assessment; or if the facility is not selected it could be decommissioned. College Pump Station was the only existing facility with an option to increase capacity. For new well, storage, booster pump station, pipe, and PRVs, the life cycle cost of the new infrastructure was applied to those that were selected. Existing pipes could either be replaced with a larger diameter pipe and incur a capital cost or left in service as is at no additional cost. For selected facilities, a range of operational decisions were also considered by Optimizer including booster pump controls and settings for PRV or flow control valves (FCV).

4.6.1.5 Hydraulic Criteria Penalties

Optimizer seeks to minimize the life cycle cost associated with improvements while also minimizing the hydraulic penalties associated with hydraulic performance criteria. Although there are no actual costs associated with not meeting the hydraulic performance criteria, the penalties are assigned relative dollar values in Optimizer to compare with the actual cost associated with facility or pipe improvements. By assigning relative dollar values to the hydraulic penalties, Optimizer is able to compare potential project costs to the “costs” of not addressing hydraulic deficiencies. The magnitude of penalty costs requires some iterative trial and error and seek to balance the severity of the criteria violation with the improvements required to address it. For example, low pressure penalties that violate regulatory requirements and impact water quality health and safety standards are given much higher penalties than velocity criteria. While high velocities are important, they do not typically lead to water quality health and safety concerns. However, given the criticality of some facilities, such as the Awbrey transmission main, the velocity criteria violation on that pipe was penalized more heavily than a standard distribution pipe since the impact of a failure, which could be accelerated with long-term velocity exceedance. The type of penalties associated with hydraulic criteria and which type of facilities they were specifically applied to are in Table 4-18. The penalties align with not meeting level of service criteria that apply to the respective infrastructure. For supply, which includes wells and the WFF, a penalty was applied if the maximum day demand was not met by supply. Additionally, a penalty was applied for using groundwater over surface water to meet the level of service aiming to maximize surface water. Storage reservoirs are assigned penalties to ensure levels and volumes are maintained within level of service requirements. To meet pressure and velocity level of service, penalties are assigned for hydraulic solutions outside of the level of service ranges. The penalties are used in Optimizer to balance the cost of infrastructure improvements while still aiming to meet system level of service criteria.

Table 4-17 | Optimizer Capacity and Operational Options

Infrastructure Type	Status	Options	Number of Facilities
Well	Existing	▪ Selected/Not Selected ▪ Range of On/Off Level Control Settings	20
	New	▪ Selected/Not Selected ▪ Range of capacities representing between 1 - 3 wells per location ▪ Range of On/Off Level Control Settings	25
Gravity Reservoir	Existing	▪ Selected/Not Selected ▪ Range of volumes (HGL fixed)	15
	New	▪ Selected/Not Selected ▪ Range of volumes (HGL fixed)	7
Pumped Reservoir	New	▪ Selected/Not Selected ▪ Range of volumes ▪ Range of pump station discharge pressure settings	7 (3 with Associated and Dependent Well Option)
Pump Station	Existing	▪ Selected/Not Selected ▪ Range of On/Off Level or Discharge Pressure Control Settings ▪ 1 Option to Increase Capacity	6
	New	▪ Selected/Not Selected ▪ Range in capacity ▪ Range of On/Off Level or Discharge Pressure Control Settings	4
PRV and FCV	Existing	▪ Selected/Not Selected ▪ Range of flow or pressure settings	4 Key System Valves (Outback Surface Water FCV, Outback Groundwater PRV, Awbrey FCV, Overturf FCV) and numerous PRV settings
	New	▪ Selected/Not Selected ▪ Range of pressure settings	9
Pipe	Existing	▪ Range of Diameters	11.5 Miles
	New	▪ Selected/Not Selected ▪ Range of Diameters	29.3 Miles

Table 4-18|Optimizer Hydraulic Criteria Penalties

Criteria	Infrastructure	Penalty
Supply	Well and WFF	▪ Not Meeting Minimum System-wide Flow ▪ Operating Cost Associated with Pumping and/or Treating
Storage	Reservoirs	▪ Outside Range of Minimum & Maximum Level ▪ Not Meeting Minimum Return Level ▪ Not Meeting Minimum Zone Volume
Pressure	Service Meters (Model Junctions)	▪ Outside Range of Minimum & Maximum Pressure
Velocity	Pipe	▪ Above Maximum

4.6.2 2040 Optimization

The Optimizer model was run for a 2040 MDD EPS scenario, which included diurnal patterns to simulate 2040 PHD. Millions of individual solutions were run and analyzed, through several major iterations of the analysis, each one resulting in a workshop with City staff to discuss the results. At each workshop, the City and consultant team would "reality check" the results and provide input on what should be investigated further or refined in subsequent runs. Much of the discussion focused on the type and location of the infrastructure being selected and why. Three major optimization iterations were used to determine an optimized solution of capital improvement and operational settings to serve existing and future demands while minimizing hydraulic deficiencies.

Because optimization evaluates millions of combinations of system improvements, the result is not a single, optimized solution, but rather a range of solutions since somewhat different infrastructure could result in similar hydraulic conditions. For example, to improve velocity conditions in a pipe, one solution could be to upsize the pipe diameter, and another could be to send less flow through the pipe by using different supply sources that convey water through other pipes. Each of these choices could result in reasonable hydraulic penalty solutions, but with a different combination of infrastructure improvements.

Figure 4-12 illustrates the pareto curve output from Optimizer that is used to investigate the trends across solutions. Each dot on the curve represents a unique solution comprised of specific infrastructure improvements and their associated life cycle and hydraulic penalty costs. As discussed previously what makes the optimization process unique is its goal of reducing the cost of both in parallel. In general, large gains are made initially as the random starting scenario is modified, and adequate improvements are made in the system to address large hydraulic penalties, causing the penalty cost to drop at much greater rates than the associated infrastructure cost. The genetic algorithm used in the optimization process chooses the best "offspring" or solution set from each run and uses it as the solution set for the next run. The optimization continues to run until both life cycle costs, and penalty costs are minimized, or the maximum number of trial iterations are exhausted. Solutions from the initial bend in the curve, the area just before the curve flattens, and a few solutions in the flattened part of the curve are evaluated for similarities and differences to determine trends in the solutions. Within each of these areas, the specific solutions chosen for evaluation is more nuanced.

Figure 4-13 shows a more detailed section of the pareto curve to illustrate which are more optimal solutions within each review and the tradeoff between system improvements and hydraulic penalties. Where the pareto graph shows a more significant drop in penalty cost for a smaller increase in infrastructure cost, the solution is likely better than the prior solution. Similarly, a solution that has a large increase in infrastructure cost, but minimal decrease in hydraulic penalty costs is likely not a preferred solution.

The optimization requires an iterative process of investigating the trends across several locations and solutions within the pareto. This helps reduce the number of alternatives in future simulations and focus on continually more optimized solutions. Similarly, since no solution eliminates all hydraulic penalties, investigating trends in areas where hydraulic issues persist helps reduce penalties that likely have no feasible solution and focus on penalties that are significantly impacted by the infrastructure selected solution. Each of these iterations results in a more optimized solution but requires a revisit of the optimization setup outlined above to continue to refine the process and results.

Figure 4-12|Pareto Curve

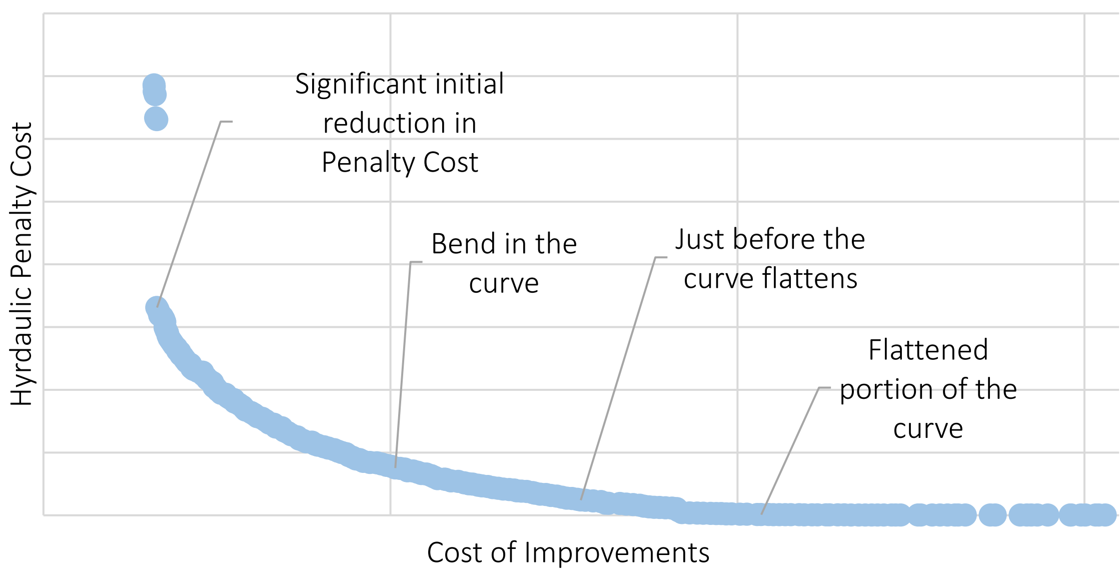
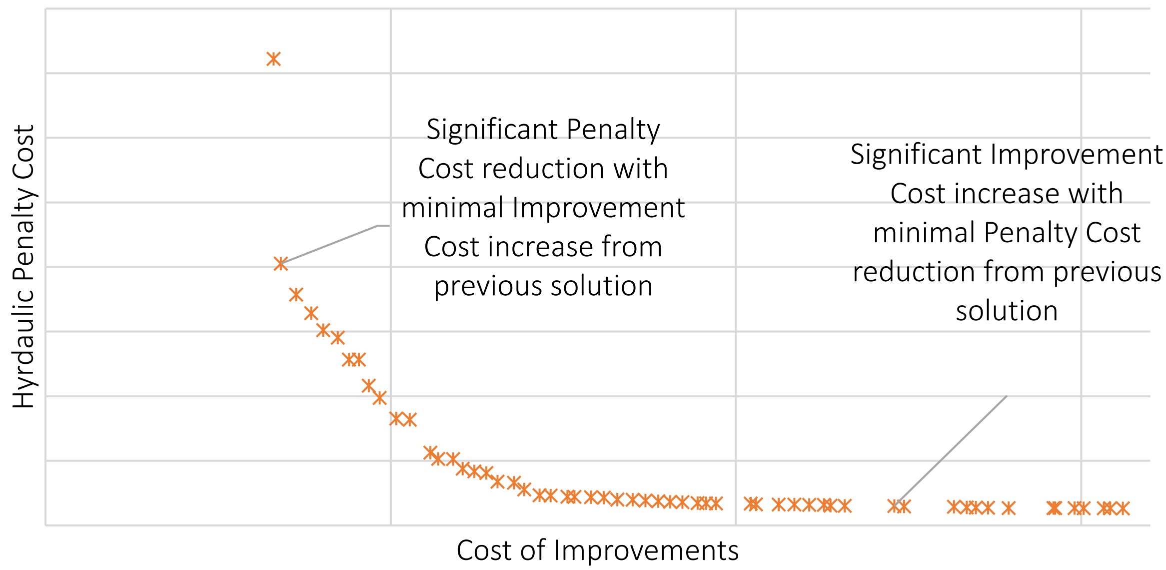


Figure 4-13 | Flattened Pareto Curve Solutions



4.6.2.1 Initial Optimization Results

The optimization was initially run with three types of scenarios to narrow the impact of some key decisions and further focus the optimization setup. These three scenarios differed between either what alternative improvements were made available during or what hydraulic penalties were applied. The three scenarios included 1) All available improvement alternatives and options; 2) Well locations not at existing facility sites being excluded as alternatives; 3) A maximum required standby storage penalty applied based on the storage analysis difference between the standby storage and minimum standby storage analyses. These scenarios were selected to illustrate the impact of some basic assumptions that could influence the direction the optimization algorithms took. By illustrating the trends across the scenarios, it helped narrow the number of alternatives and decisions, but focus on more feasible, optimized solutions.

The initial three optimization scenarios illustrated trends that led to decision modifications for the refinement optimization. These decisions included:

- Remove the pumped storage alternatives that were consistently not selected as cost-effective improvements.
- Include all other improvement alternatives, including wells at new sites, since outside of the pumped storage, nearly all other improvement options were showing in trends across viable solutions.
- Given the constructability challenges, further evaluate the benefit of any facility improvements on Pilot Butte – beyond required investment in the existing facilities.

- Reduce the standby storage penalty to reflect the minimum requirement.
- Update tank penalty levels to not be lower than fifty percent of the tank volume.
- Reduce penalties to the minimum allowable pressure for areas where trends showed no viable solution to keep pressures in the reasonable range.
- Incorporate potential cost modifications for land acquisition and synergy cost reductions for pipe projects that could be constructed as part of roadway projects.

4.6.2.2 Optimization Refinement

The refinement optimization incorporated decisions made from the initial optimization and involved several additional smaller refinements such as including additional velocity penalties to the Awbrey transmission main given its criticality to the system. The refinement phase also did individual testing of numerous pareto solutions to determine the tradeoffs between different selected alternatives, the sizing of selected improvements, and the magnitude and location of hydraulic penalties. Ultimately, only solutions that met the minimum supply and storage requirement penalties—determined during the Facility Capacity Assessment—were used for ongoing refinement. Pipe improvements were refined by grouping pipe projects within corridors to similar diameters to reflect constructability since the optimization would periodically select the minimal required diameter by pipe segment, resulting in smaller pipe diameters for short runs within larger diameter pipe improvement projects. Lastly, numerous similar solutions were used to “seed” some final optimization runs to eliminate the initial random selection of the software and more immediately focus the algorithms on viable solutions. Each of these refinements and checks involved numerous optimization simulations and reviews to continue to refine the selected solution.

4.6.2.3 Optimization Results

After doing numerous refinements of the results and reviewing incremental solutions with City staff, the selected solution includes over nine miles of pipe projects including upsizing existing pipe and constructing new pipe alignments. These are in addition to some improvements identified as part of the fire flow and criticality analysis. The solution indicates some existing facilities are not necessary by 2040 to meet the level of service criteria if the other improvements are constructed. Those existing facilities could be decommissioned or used only for standby or backup purposes including the Outback CT Basin, Overturf Reservoirs, Westwood Pump Station, Westwood Well, Westwood Reservoir, and the Scott Street Pump Station. The City may elect to continue operation of some of these facilities but minimize the investment in deferred and ongoing maintenance. The recommended 2040 solution includes six new pressure reducing valves (PRVs), seven new wells and 14 MG of new storage (8 MG additional storage if existing reservoirs are decommissioned). Detailed information on each of the improvements, the associated cost, and prioritization of the CIP are in **Section 6**.

4.6.2.4 Optimization Sensitivity Results

Once a nearly final solution was selected from the initial and refinement processes, it was run through several additional optimization simulations to determine whether the sensitivity of the improvements identified were due to a reduction in demand or operational modifications in controls.

4.6.2.4.1 Conservation Program Demand Reduction

As part of the update to the City's WMCP completed concurrently with this iWSMP, an additional analysis was included to determine the water conservation potential of the City's system. A water savings and cost effectiveness analysis were completed, including use of the Maddaus Water Management Demand Side Management Least Cost Planning Decision Support System (DSS Model). The DSS model evaluated numerous conservation measures that could reduce indoor or outdoor water use. The measures were combined into conservation programs to estimate the cost of implementing specific measures and the associated reduction in demand. After several iterations with City staff, a recommended program of conservation measures was selected for implementation. If the recommended measures from the analysis are implemented over the next 20-years, the projected system-wide MDD is estimated to be reduced by 5.1 million gallons per day (MGD). The demand reductions were applied system-wide and the resulting demand projections are in **Table 4-19**.

Table 4-19 | Demand Projections with Conservation

Timeframe	MDD with Conservation (MGD)	MDD without Conservation (MGD)	Projected Decrease Due to Conservation (MGD)
2030	35.0	38.0	3.0
2040	40.1	45.2	5.1

The reduced demand projections for the selected conservation program were then used in this iWSMP analysis to determine any reduction in future system deficiencies and associated reductions in the required system infrastructure improvements identified during the optimization. The impact on the supply and storage deficiencies without conservation demand reductions (from **Table 4-6** and **Table 4-12**) and with demand reductions are in **Table 4-20**.

Table 4-20 | Supply and Storage Analysis with Conservation Demand Projections

Timeframe	Supply Deficiency		Storage Deficiency	
	Without Conservation (gpm)	With Conservation (gpm)	Without Conservation (MG)	With Conservation (MG)
2030	(2,341)	(222)	(2.21)	(1.31)
2040	(7,325)	(3,797)	(5.74)	(2.72)

4.6.2.4.2 Conservation Demand Sensitivity Results

After selecting a recommended optimization solution of improvements, an additional "sensitivity" analysis was considered to determine which improvements could be eliminated due to a reduction in demand from the conservation program projections and modeling work done in the WMCP update. More extensive discussion and analysis regarding conservation are WMCP. The analysis followed the same process as the original optimization, but the 2040 MDD analyzed reflected the 5.1 MGD projected reduction. The results indicated that three supply wells and approximately 4 MG of storage improvements could be unnecessary if demands were at the lower projections. The costs for implementing the conservation program and associated reduction in improvement costs due to conservation demand reductions are discussed in Section 6 and used to inform the prioritization of the improvements.

4.6.2.4.3 Operations Sensitivity Results

Another sensitivity check completed on the final optimized solution was the significance of changes to control settings across the selected facilities. Although the specific operations of the system will vary significantly across a 20-year timeframe, the optimization was run with varying control decisions to determine whether operational modifications had a significant impact on the infrastructure requirements. Some pipe improvements were reduced based on modifying the operational settings so that supply was balanced across certain facilities and velocity or pressure penalties were not unnecessarily created by over or under relying on certain facilities to meet demand before additional supply was introduced through control modifications.

4.7 Operations Analysis

The existing system has many supply options for meeting demands and pump, valve, and pipe corridor options for conveying water throughout the system. The City has numerous objectives to balance when it operates the system; focusing on delivering high quality water to its customers that includes meeting the hydraulic level of service criteria, observing water right requirements and limitations, maximizing the use of the less expensive gravity fed surface water supply source, balancing the use and wear across facilities, and minimizing costs. The Operation Analysis focused on reviewing system control operations and water age to determine potential operational improvements.

4.7.1 Existing Conditions Controls Assessment

The controls at each facility influence how water moves and what sources are required to meet demand. The optimization of the controls was intended to determine individual facility control settings as part of a system-wide control scheme that maximizes use of surface water supply and reduces hydraulic penalties. Optimizer was used to evaluate the existing MDD scenario to determine optimized controls for current system operations. The InfoWater 2018 MDD EPS scenario established as part of the Distribution System Assessment was exported to an EPANet compatible file for use in the existing controls Optimizer analysis. The hydraulic deficiency penalties and many of the control options used in the 2040 Optimization formulation were leveraged to optimize the control settings for the existing MDD conditions.

The City's Operations staff are effectively balancing the many objectives in its current operations, so no extensive modifications are recommended, however, the model is also setup for use to determine the impact of future operational modifications to the system. The resulting recommended control modifications are in **Appendix 4B**.

4.7.2 Water Age Assessment

Water age was evaluated for existing conditions using the winter demand and operation conditions in the InfoWater winter EPS scenario developed during the 2018 model calibration. Water age refers to the amount of time water is in the distribution system prior to being used by the customer. The age is influenced by factors such as pipe diameter, system connectivity, facility operations and demand. Water age is not specifically regulated so there are not set limits, however water that remains in the system for extended periods of time can result in low chlorine residuals and the build-up of disinfection byproducts along with secondary water quality issues such as unpleasant taste, color, or odor. The City is looking to reduce the water age in the system, where possible, to improve these attributes.

Water age is typically a concern during low demand winter conditions, particularly where water may sit in a storage tank for longer periods before being turned over. The City's low demand during winter months and use of surface water supply, which unlike the well supply is not as directly controlled by numerous tank levels throughout the system, results in high water age in many of the tanks. In some areas it is possible to change system operations to turn over water more frequently. These changes could include turning off facilities, changing pump station control settings, increasing settings at zone PRVs, or closing isolation valves to require water to travel through an alternate system corridor. In other cases, it is difficult to change operations to improve water age. Examples of these areas include dead-ends and small, single-feed PRV zones. For these areas, flushing is recommended to increase turnover.

The InfoWater model was run for 30 days with winter demand and control settings. **Figure 4-14** shows the relative water age, classified as low, medium, and high, for each pipe and tank in the system with existing operations, as well as after some recommended changes to operations. Zone 1 and 2, as well as the Pilot Butte Reservoirs specifically, improve with the recommended changes.

Zone 1 is supplied by the Awbrey Pump Station and the Tower Rock Reservoir. There is a small amount of demand in the Zone during winter conditions and limited connectivity to the rest of the system. To improve water age, a potential operational change could be to shut off the College Pump Station and raise the PRV settings on valves that feed from Zone 1 to Zone 2 and from Zone 2 to Zone 3. Although it will require additional energy costs to pump water to Zone 1 and then reduce it, by making these operational changes water is forced to cycle through Zone 1 and be conveyed to Zone 2 and Zone 3, which also reduces the water age in the Tower Rock Reservoir. It is important to note that the PRV settings should not be set so high as to drain Awbrey, Tower Rock, College 1, and College 2 Reservoirs substantially.

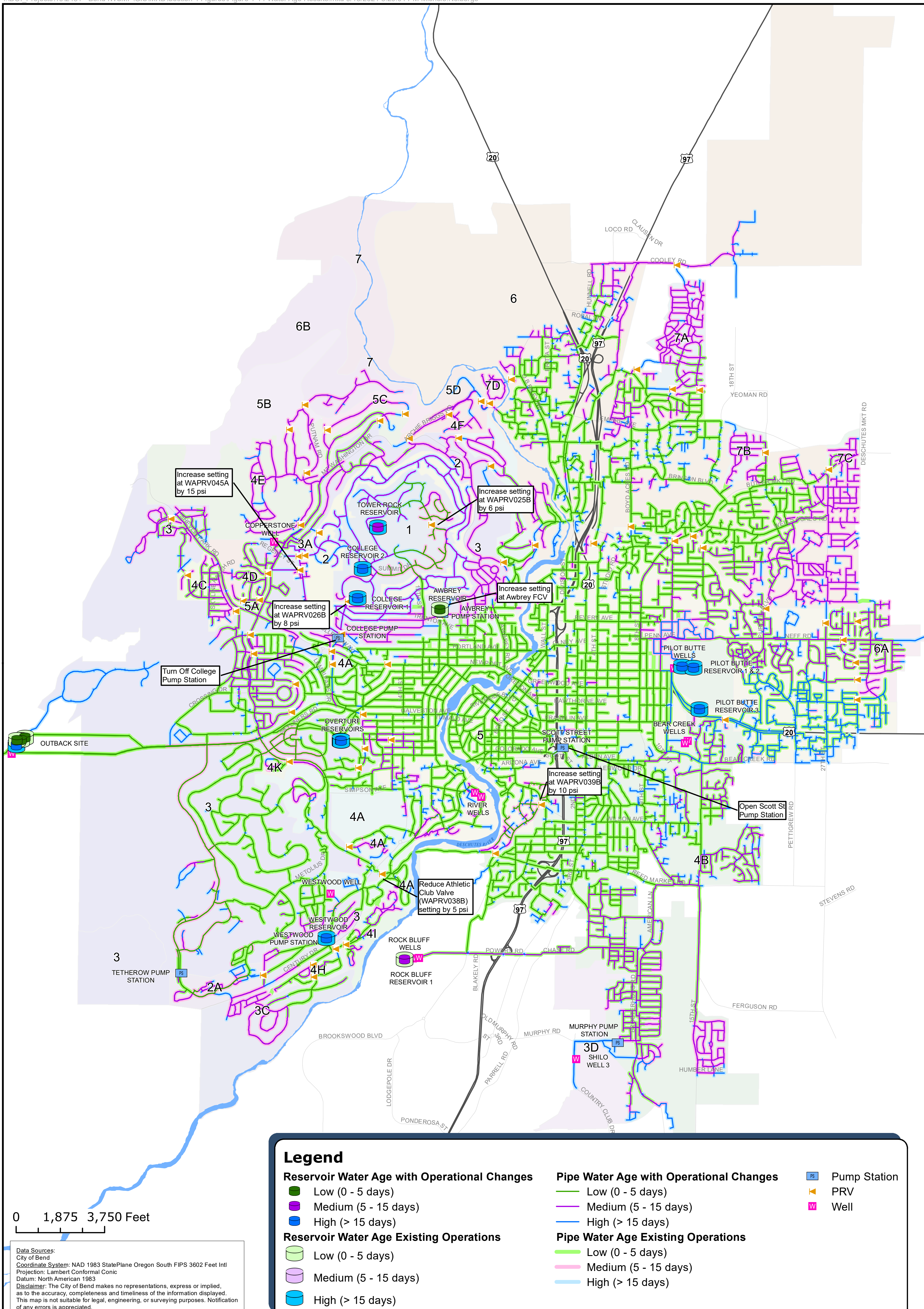
Zone 5 is hydraulically split into an east and west portion connected by piping that crosses the Deschutes River. Awbrey Reservoir primarily serves the west side of Zone 5 and Pilot Butte 1 and Pilot Butte 3 Reservoirs serve the east. Due to Awbrey's proximity to surface water supply from Outback, higher hydraulic grade line (HGL), and suction supply to the Awbrey Pump Station, the Awbrey Reservoir does not have high water age because it turns over much more frequently than the Pilot Butte Reservoirs. Pilot Butte 2, which serves Zone 4B, does not turn over often due to the low winter demand in Zone 4B and its location relative to surface water supply. To improve the tanks on the east side of the system the pressure setting was reduced at the Athletic Club PRV (WAPRV038B), which conveys flow from Zone 3 to 4B, to increase the flow from the Pilot Butte 2 Reservoir to meet Zone 4B demand prior to the Athletic Club Valve opening. This results in Pilot Butte 2 Reservoir draining and filling more frequently reducing the water age in the tank. Additionally, changes could be made at Wilson and Bond PRV (WAPRV039B) to increase flow from Zone 4B to Zone 5. This improves water age in Zone 5 near the PRV and in Pilot Butte 2 Reservoir.

Another operational change identified was having Scott Street Pump Station run. Scott Street pumps from Zone 5 to 4B. With the pump station on, water is cycled from Zone 5 to 4B which improves the age of water in the Zone 5 Pilot Butte Reservoirs. As a result of changing the primary supply path from Athletic Club PRV that is from Zone 3, more water moves from the west side of Zone 5 to the east, causing the Awbrey Reservoir to drain more rapidly. To minimize this, it is recommended that the setting at the Awbrey FCV be increased.

Figure 4-15 through Figure 4-17 show the tanks with improved turnover and decreased water age because of the outlined operational changes.

It should be noted that the change in water age in certain areas with the operational modifications does not impact the total demand in the system. Therefore, when the operational change causes a flow path to change, the quality in another area may be impacted as less water moves through that area. As a result, it is recommended that operational changes vary throughout the winter to ensure water is moving through different flow paths. As an example, the City could operate the system as they currently do during the first half of the winter and then make the recommended changes shown on Figure 4-14 for the second half. Additionally, the City could consider prioritizing automation at these valve locations where it does not currently exist to make operational changes easier to implement and change more frequently.

I:\BOI_Projects\19\2484 - Bend IWSMP\GIS\MXD\Section 4 Figures\Figure 4-14 Water Age Results.mxd 9/13/2021 3:20:04 PM Michele.Neibergs



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City of Bend
Integrated Water System Master Plan

Figure 4-14
Water Age Results

September 2021

19-2484

Figure 4-15|Pilot Butte 1 & Pilot Butte 3 Water Age

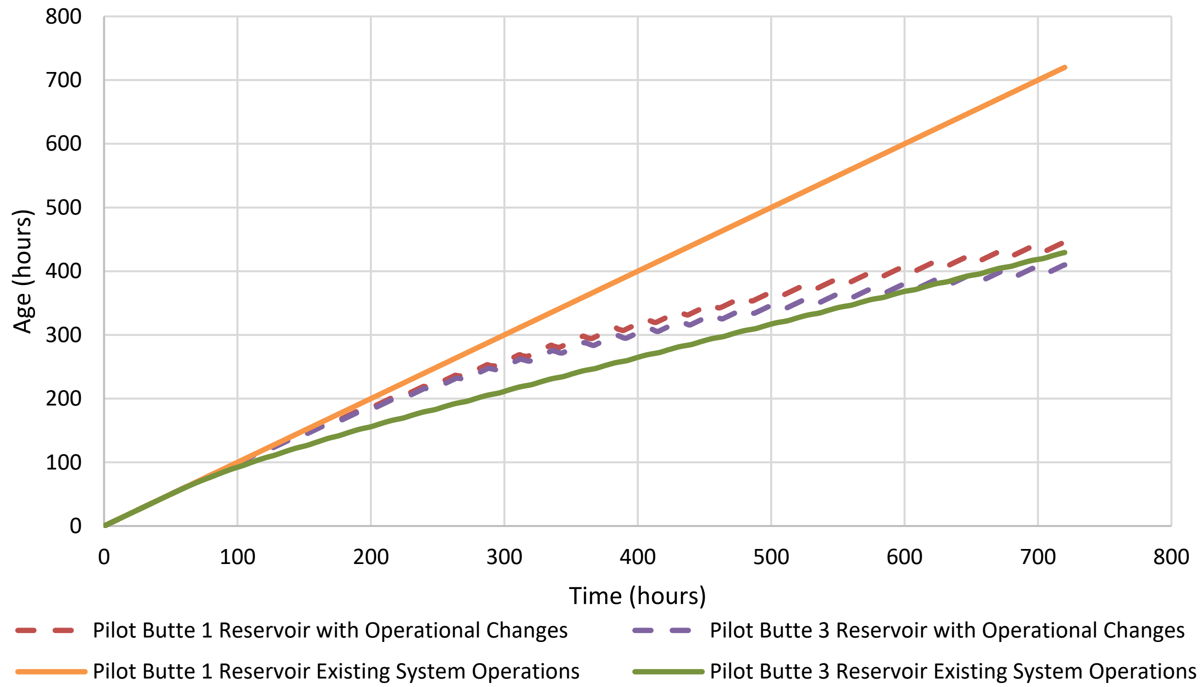


Figure 4-16|Pilot Butte 2 Water Age

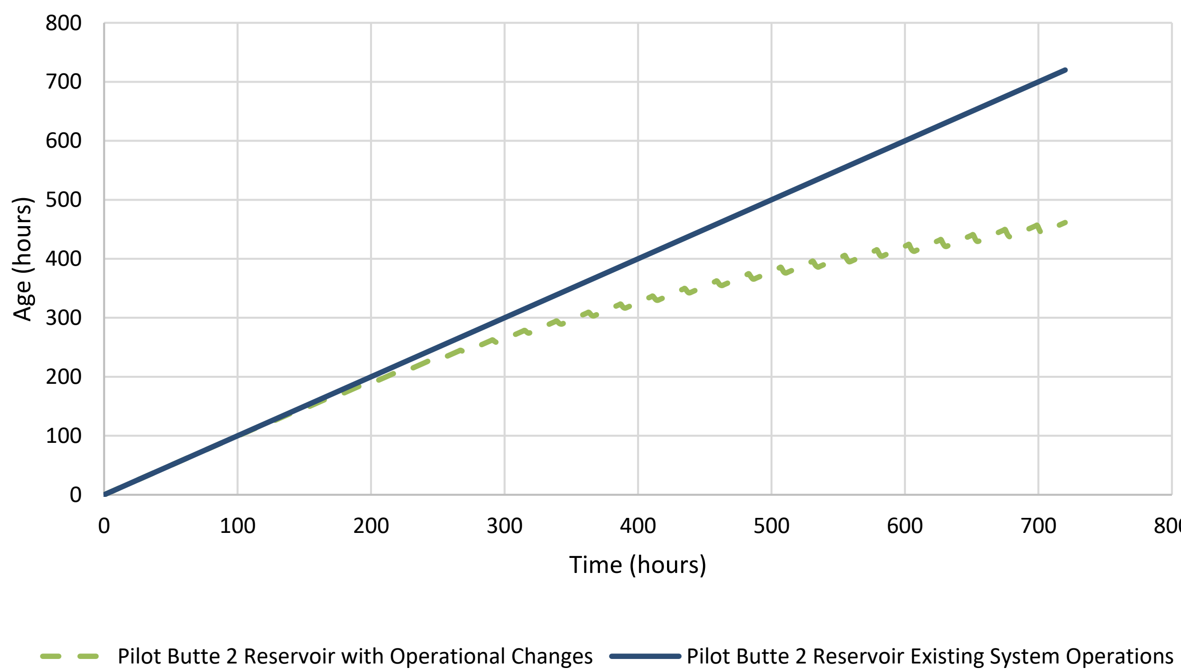
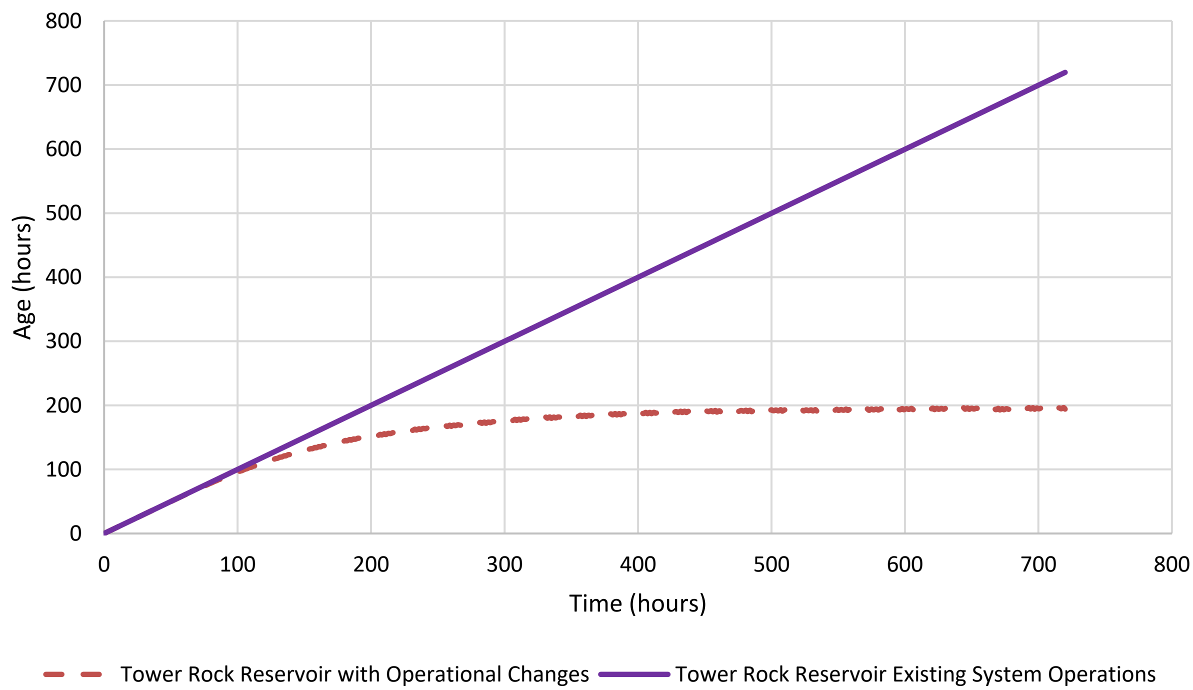


Figure 4-17|Tower Rock Water Age



4.8 Summary

The comprehensive system analysis of the City's water system included assessments of current infrastructure conditions, existing and future system capacity, asset criticality, and existing operations. Extensive hydraulic modeling and optimization were utilized, in addition to standard qualitative and quantitative assessments of the system. Overall, the City has a robust system that provides many ways to convey water. In addition, the value of having both surface and groundwater sources cannot be overstated from a resiliency standpoint. However, significant investment is needed to address deferred maintenance on the existing pipe and facilities to provide adequate fire flow and increase redundancy to continue service in the event of a critical asset failure. A summary of the results of each component of the system analysis is included below. Detailed information on each of the improvements recommended from the analysis, the associated cost, and prioritization are in **Section 6**.

4.8.1 Condition Analysis Summary

The condition analysis focused on the existing system infrastructure to identify what improvements are required at each facility to extend its useful life and comply with current standards as well as develop a long-term pipe replacement program. Condition analysis and improvements are important to ensure investment in the existing infrastructure to maintain its performance and extend its useful life.

The City has over 440 miles of pipe and 20 active wells, 6 booster pump stations, and 15 storage facilities, in addition to the Water Filtration Facility and dozens of control valve vaults. These assets range in age, but the oldest facilities are approaching 100 years. The City conducts regular and proactive maintenance of the system. However, as the infrastructure ages and safety, structural, and security standards change over time, the maintenance required to repair and replace the existing infrastructure increases. Additionally, as the pipe network ages the City will need to increase the replacement rate and target undersized and substandard pipe to avoid pipe failures and maintain consistent service.

4.8.2 Capacity Analysis Summary

The capacity analysis identifies how much additional supply, storage volume, or pipe upsizing is required to meet Level of Service criteria for existing and future demand conditions. In addition to maintaining the existing pipe and facilities, the system also requires investment in pipe to address existing fire flow, velocity, and pressure deficiencies, as well as future improvements to provide capacity for growth. No new well or storage facilities are needed to meet existing system capacity requirements, however, by the 10-year horizon, additional well supply with backup power and storage will be needed and further wells and storage to meet 20-year projected demands. Facilities are needed to meet demand thresholds and if demands are lower than those projected (i.e., due to reductions from the conservation program) the number of new facilities will be reduced. The City has adequate water rights to meet 20-year demand projections but will need existing groundwater rights to be available at all facilities across the system to have operational flexibility and optimally utilize its wells.

4.8.3 Criticality Analysis Summary

The criticality analysis focused on identifying critical infrastructure without redundancy or secondary service options that could significantly disrupt system operations and impact a substantial amount of demand or customers if it were out of service. The criticality analysis focused on determining which assets would have a significant impact or consequence if they were unavailable to serve the system due to failure, reduced capacity, or other unanticipated issues.

Most areas of the system have redundancy, where two or more system elements (i.e., looped pipe, multiple PRV vaults, etc.) can provide water to the area and could continue to serve customers for a period if one component of the system was offline. So, although every asset in the system adds value and is important for long-term system performance, identifying the areas without multiple service options is critical to build a more resilient system that can maintain service in the event part of the system was offline.

The WFF capacity is critical to providing reliable supply to the system. The construction of a pretreatment facility is recommended in the near-term as a solution to provide resilience for a wildfire or other water quality event that might cause high total dissolved solids and/or sediment loads. If one of these described events were to occur without pretreatment the capacity of the WFF could be reduced or nearly eliminated . As previously mentioned, the Outback Siting Study

(**Appendix 3A**) evaluates how recommended facilities such as pretreatment, new and rebuilt reservoirs, wells, and other water related facilities may be sited on existing and/or additional lands at the Outback Facility, which will be further refined as part of an Outback Facility Plan. Pipe improvements are recommended to address areas where single pipe breaks could result in a significant disruption to service, including the Awbrey and Outback transmission mains. Valve criticality can be used to inform ongoing maintenance programs to target locations to exercise existing valves and add new valves to the system to reduce how large an area must be isolated from service during maintenance.

4.8.4 Optimization Analysis Summary

The optimization analysis uses advanced hydraulic modeling techniques to evaluate and determine optimal improvements and modifications to the system to balance the cost of improvements with the improvements to Level of Service. The optimization analysis included extensive setup of improvement alternatives, ranges of operational decisions, and establishing costs for system improvements and hydraulic penalties. The analysis included numerous refinements and evaluations of the sensitivity of the solution to various parameters, resulting in millions of combinations of improvement options. The optimization process reduced the many inputs and iterations to a single recommended solution to meet 2040 projected demands. This solution includes over twenty miles of pipe projects, seven new wells, six new pressure reducing valves (PRVs), and 14 MG of new storage. In addition, four existing storage reservoirs, one well, and one pump stations can be considered for decommissioning or used in standby or backup status with reduced investment in deferred and ongoing maintenance. As the City continues to expand its Conservation Program it should continually assess the impact on demands and the potential reduction in required facility improvements. In addition to the existing Conservation Program, newly proposed conservation measures in the WMCP could eliminate the need for three of the new wells and 4 MG of the additional storage.

4.8.5 Operations Analysis Summary

The operations analysis focuses on the operational settings used at the existing infrastructure. The analysis indicates that the City is successfully leveraging its existing facility operations to maximize surface water use and meet hydraulic requirements. Water age will continue to be an issue in portions of the system during low demand conditions and will improve as demand increases due to growth but can also be improved through operational modifications during low demand periods to circulate water in different ways throughout the system. Operational modifications to address water age should be balanced with increased energy costs due to pumping and reduced water cycling and operations costs associated with making operational changes, as well as any water quality concerns associated with reversing flow in pipes.

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Section 5

Section 5

Water Quality and Regulations

5.1 Introduction

This chapter contains an analysis of the City's water quality and compliance with relevant regulations.

5.2 Water Quality Review and Regulatory Compliance

Both state and federal agencies regulate public drinking water systems. For the federal government, the U.S. Environmental Protection Agency (EPA) establishes standards for water quality, monitoring requirements, and procedures for enforcement to comply with the Safe Drinking Water Act (SDWA). Oregon, as a primacy state, has been given the primary authority for implementing EPA's rules within the state. The state agency which administers most of EPA's drinking water rules is the Oregon Health Authority (OHA), Drinking Water Services (DWS). DWS rules for water quality standards and monitoring are adopted from EPA. DWS is required to adopt rules at least as stringent as federal rules. To date, DWS has elected not to implement more stringent water quality or monitoring requirements. The State program is outlined in Oregon Administrative Rules (OAR) and is comprised of monitoring the water supply for specified chemical and physical contaminants. By State law (OAR 333-061-0036), the City is required to maintain an ongoing water quality testing and monitoring program. The OHA requires that the source water supplies be monitored for primary and secondary contaminants. Primary drinking water standards establish absolute concentration limits called Maximum Contaminant Levels (MCL) and Maximum Contaminant Level Goal (MCLG). MCLs are enforceable standards, while MCLGs are non-enforceable public health goals.

In some areas not directly related to water quality, DWS rules cover a broader scope than EPA rules. These areas include general construction standards, cross connection control, backflow installation standards, and other water system operation and maintenance standards. The complete rules governing DWS in the State of Oregon are contained in OAR Chapter 333, Division 61, Public Water Systems.

5.2.1 City Sources

The City provides water to a population of approximately 67,000 people in six primary pressure zones that have storage reservoirs, via approximately 25,500 connections. The City supply sources include surface water from the Bend Municipal Watershed (BMW) and groundwater from the Deschutes Regional Aquifer pumped from 20 active City groundwater wells at eight sites. The eight groundwater sites are considered well fields by the state and sampling is only required at any one of the wells for each site.

5.2.2 Regulations

Since being introduced in 1974, the SDWA has been amended twice, once in 1986 and then again in 1996. The intent of these amendments is to strengthen the 1974 SDWA, primarily in setting regulations to ensure that public water supplies are safe. The EPA was mandated by Congress to establish rules and regulations relating to the SDWA and subsequent Amendments. The OHA administers the SDWA Regulations in Oregon through the 1981 Oregon Revised Statute that has been periodically amended after the original passage. OAR 333-061 outlines the requirements. The regulations that apply to the City's water system are in **Table 5-1**.

Table 5-1 | Drinking Water Rules

Regulation	Type	Rule
Primary Drinking Water Regulations (NPDWR)	Chemical Contaminants	Chemical Contaminant (IOC, SOC, VOC)
		Radionuclides
		Arsenic
		Lead and Copper
	Microbial Contaminants	Groundwater
		Disinfectant and Disinfection Byproducts
		Total Coliform & Revised Total Coliform
	Right-to-Know	Consumer Confidence Report
		Public Notification
Secondary Drinking Water Regulations (NSDWR)	Aesthetic	Aluminum, Chloride, Color, Copper, Foaming Agents, Iron, Manganese, pH[1], Sulfate, Threshold Odor Number, Total Dissolved Solids, Zinc
	Cosmetic	Fluoride, Silver
	Technical	Aluminum, Chloride, Copper, Corrosivity, Iron, Manganese, pH[1], Total Dissolved Solids, Zinc
Contaminant Candidate List	NA	NA
Surface Water Treatment Rule (SWTR)	NA	NA

Note:
1. pH = Potential Hydrogen

5.2.2.1 Chemical Contaminant Rules

Chemical contaminants have been regulated in phases, which are referred to as the Chemical Contaminant Rules. The chemicals regulated fall into three categories: Inorganic Contaminants (IOCs), Synthetic Organic Contaminants (SOCs), and Volatile Organic Contaminants (VOCs). The Contaminant Rules regulate over 65 chemicals and establish recommended MCLGs and enforceable MCLs for each contaminant. The number of samples and monitoring frequency is based on numerous factors and can be reduced for some contaminants based on historic sampling levels. The Standardized Monitoring Framework is used to standardize, simplify, and consolidate drinking water monitoring requirements across the contaminant groups. The monitoring framework is divided into 9-year compliance cycles which are further divided into three 3-year compliance periods.

5.2.2.1.1 Impact of the Chemical Contaminant Rules on the City

The City is in compliance with all applicable Chemical Contaminant Rules. Table 5-2 below shows the City's current sampling schedule for each of the chemical contaminants. The asbestos testing requirement is every 9 years, but currently the City is not required to test for asbestos because no asbestos cement pipe has been identified in the system.

Table 5-2|Chemical Contaminant Rule Testing Frequency

Contaminant Category	Source	Testing Frequency	Number of Samples	Notes
Inorganic Contaminants	All	9 Years	1/site	OHA Granted Monitoring Reduction
Synthetic Organic Contaminants	All	3 Years	2/site	2 Consecutive QT Samples Required
Volatile Organic Contaminants	Surface Water	Annually	1/site	
	Groundwater	3 years	1/site	
Nitrate	All	Annually	1/site	
Nitrite	All	9 years	1/site	OHA Granted Monitoring Reduction

5.2.2.2 Radionuclide Rule

The Radionuclides Rule (RR) sets MCLGs at zero for all radionuclides because they are known cancer-causing contaminants. The MCLs are for combined radium-226 and radium-228, gross alpha particle radioactivity, beta photon emitter radioactivity, and uranium. The current MCL standards are combined radium of 5.0 picocurie per liter (pCi/L), gross alpha of 15.0 pCi/L (not including radon and uranium) and uranium of 30.0 microgram per liter (µg/L). The MCL of beta photon emitters is 4 millirems (a traditional unit of radiation dose equivalent) per year.

5.2.2.2.1 Impact of the Radionuclide Rule on the City

The City is in compliance with the provisions set forth in the Radionuclide Rule. **Table 5-3** details the City's current sampling schedule for radionuclides.

Table 5-3|Radionuclide Testing Frequency

Radionuclide Category	Source	Testing Frequency	Number of Samples
Radium 226/228	Bridge Creek, Rock Bluff Wells, Outback Wells, Westwood Well	9 Years	1/site
	River Wells, Pilot Butte Wells, Bear Creek Wells, Copperstone Well, Shiloh Wells	6 Years	
Gross Alpha Particle Radioactivity	All	9 Years	1/site
Uranium	All	9 Years	1/site

5.2.2.3 Arsenic Rule

The Arsenic Rule MCL is 0.01 milligrams per liter (mg/L). The MCLG for arsenic is zero because it is a known cancer-causing contaminant. If any arsenic concentration exceeds half of the MCL (0.005 mg/L), it must be reported in the annual Consumer Confidence Report (CCR). The rule applies to all community and non-transient, non-community water systems. All water systems that exceed the MCL of 10 parts per billion are required to come into compliance within 5 years after publication of the final rule.

5.2.2.3.1 Impact of Arsenic Rule on the City

The City is currently in compliance with all provisions set forth in the Arsenic Rule and collects one sample every 9 years for each site. No samples to date have exceeded the MCL.

5.2.2.4 Surface Water Treatment Rule

The Surface Water Treatment Rule (SWTR) was implemented in 1989 to reduce the potential for pathogenic contamination in drinking water. The rule has been updated multiple times, with the last rule implemented in 2006. It applies to all public water systems that use surface water or groundwater under the direct influence of surface water (GWUDI). The SWTR addresses:

- Criteria under which filtration is required
- Performance criteria for filtration
- Disinfection requirements for both filtered and unfiltered systems
- Monitoring requirements for all surface water supplies

The SWTR started by requiring that source waters be treated to achieve a minimum 3-log (99.9 percent) removal and/or inactivation of Giardia cysts and a 4-log (99.99 percent) removal and/or inactivation of enteric viruses. A 2-log (99 percent) removal of cryptosporidium has also been added to the rule.

5.2.2.4.1 Impact of Surface Water Treatment Rule on the City

The City constructed a membrane filtration system in 2016 and utilizes coagulation and hydrogen potential (pH) adjustment facilities for particulate removal. They have also installed a chlorination system for disinfection of surface water and conducted a tracer study in 2016 to determine contact time requirements. The City is currently in compliance with the SWTR rules.

5.2.2.5 Revised Total Coliform Rule

The Revised Total Coliform Rule (RTCR) was published in 2013, with minor corrections in 2014, and is a revision to the Total Coliform Rule (TCR). The TCR establishes a zero MCL for total coliform (TC), which can be an indicator of disease-causing pathogens. The RTCR establishes testing procedures should a sampling location test positive for TC, including requiring that E. coli testing be done for any positive TC sample.

The required number of samples taken each month depends on the population served by the water system. **Table 5-4** provides a summary of the sampling requirements for various populations served. Per these requirements, the City must collect at least 70 samples each month.

Table 5-4 | Total Coliform Sampling Requirements

Population Served	Minimum Number of Samples per Month
41,001 to 50,000	50
50,001 to 59,000	60
59,001 to 70,000	**70**
70,001 to 83,000	80

General Note: The City's current service population is noted in **Bold** in the table.

5.2.2.5.1 Impact of TCR and RTCR on the City

The City is currently in compliance with all provisions set forth in the RTCR. The City currently collects at least 70 monthly samples for total coliform analysis from approximately 40 sites in the distribution system. When the City's population served exceeds 70,000, which is projected to occur in the next few years, the number of required monthly samples will increase from 70 to 80.

5.2.2.6 Lead and Copper Rule

The Lead and Copper Rule (LCR), establishes action levels of 0.015 mg/L for lead and 1.3 mg/L for copper based on the 90th percentile of samples. An AL exceedance is not a violation but can trigger other requirements including additional service and source monitoring, corrosion control treatment, public education, or lead service line replacement. The major difference between this regulation and most others is that the water is to be monitored at the customer's tap instead of the treatment plant discharge point. Lead and copper must be monitored at the customer's tap every 6 months at the highest risk locations. Systems can qualify for reduced monitoring if samples are below the AL for multiple consecutive years. The City system is on reduced monitoring of every 3 years.

If the action levels are exceeded for either lead or copper, the water system must collect source water samples and submit all data to the state with a treatment recommendation to reduce concentrations below the action level. In addition, the water system must also provide a public education program to its customers within 60 days of the action level exceedance. The public education program must be continued as long as the water system exceeds the lead action levels.

All water systems that exceed the lead or copper action levels are also required to conduct a corrosion control study. Corrosion control studies must compare the effectiveness of pH and alkalinity adjustment, calcium adjustment, and addition of a phosphate- or silica-based corrosion inhibitor. Large and medium systems are also required to monitor many other water quality parameters at the entry point to the distribution system and customer taps.

5.2.2.6.1 Impact of LCR on the City

The City water system is in full compliance with the provisions set forth in the LCR. The City currently must test 30 samples every 3 years. The City must send the LCR results to the customers sampled within 30 days of receiving the results and make OHA aware of the customer notification within 90 days of submitting the results to customers.

5.2.2.7 Disinfectants and Disinfection Byproducts Rule

Stage 1 of the Disinfectants/Disinfection Byproducts Rule (Stage 1 DBPR) applies to all water systems that treat with a chemical disinfectant, such as chlorine, for either primary or residual treatment. The rule establishes MCLGs and MCLs for total trihalomethanes, haloacetic acids, chlorite, and bromate. Bromate testing is only required for systems that use ozone, which the City does not. It also establishes maximum residual disinfectant level goals (MRDLGs) and maximum residual disinfectant levels (MRDLs) for three chemical disinfectants: chlorine, chloramines, and chlorine dioxide (OAR 333-061-0036(4)(i)). The Stage 1 DBPR Rule also attempts to reduce general Disinfection Byproducts (DBP) formation by requiring specific levels of total organic carbon (TOC) removal by enhanced coagulation.

The Stage 2 Disinfectants/Disinfection Byproduct Rule (Stage 2 DBPR) builds on the Stage 1 DBPR by requiring different monitoring and reducing some MCLs for Disinfection Byproducts. The Stage 2 DBPR requires the use of locational running annual averages (LRAA) to determine compliance with the MCLs for Total Trihalomethanes (TTHMs) and Five Haloacetic Acids (HAA5). This differs from the running annual average approach outlined in Stage 1 DBPR, where compliance was determined by calculating the running annual average of samples from all monitoring locations across the system. Stage 2 monitoring is intended to identify and add testing locations that are more likely to exhibit higher DBPs than a random system sampling. The MCLs for the DBPR are shown in Table 5-5.

Table 5-5|DBPR Limits

Contaminant	MCL (mg/L)
Total Trihalomethanes (TTHM)	0.080 LRAA
Chloroform	0.07
Bromodichloromethane	0
Dibromochloromethane	0.06
Bromoform	0
Five Haloacetic Acids (HAA5)	0.060 LRAA
Monochloroacetic acid	0.07
Dichloroacetic acid	0
Trichloroacetic acid	0.02
Bromoacetic acid	-
Dibromoacetic acid	-
Bromate	0.010
Chlorite	1.0
Chlorine/Chloramines	4.0

Note:
1. All systems must monitor during month of highest DBP concentrations.
2. Systems on quarterly monitoring must take dual sample sets every 90 days at each monitoring location.

5.2.2.7.1 Impact of the D/DBP Rule on the City

The City is in compliance with all Disinfectant/ Disinfection Byproduct (D/DBP) Rules and currently collects two samples every three months. Samples are collected from the raw surface water source and from other sites agreed upon with OHA.

5.2.2.8 Groundwater Rule

The final Groundwater Rule was published in November 2006 and took effect in Oregon in December 2009. The Groundwater Rule seeks to reduce the risk of illness caused by microbial contamination and includes treatment technique requirements, compliance monitoring, and source water monitoring. Treatment technique requirements include providing treatment that reliably achieves 4-log treatment of viruses and correcting all significant deficiencies. Compliance monitoring is composed of testing for minimum disinfectant residual concentrations. Source water monitoring adds fecal indicator bacterial testing of the water source, as well as regulatory steps, should a source water test return positive.

5.2.2.8.1 Impact of the Groundwater Rule on the City

The City currently uses chlorine disinfection at all its groundwater supply locations and is in compliance with monitoring requirements for bacteria sampling.

5.2.2.9 Consumer Confidence Report Rule

The CCR Rule (OAR 333-061-0043) requires systems to prepare and distribute an annual water quality report summarizing information about source water, detected contaminants, compliance, and educational information characterizing the risks from exposure to contaminants in an understandable manner. The CCR must be provided to OAR and delivered to customers by July 1 annually.

5.2.2.9.1 Impact of the CCR Rule on the City

The City is in compliance with Consumer Confidence reporting requirements and makes the CCR available on their website. **Appendix 5A** has an example of the City's CCR.

5.2.2.10 Public Notification Rule

The Public Notification Rule (OAR 333-061-0042) requires systems to inform customers of any violation of National Primary Drinking Water Regulations or any situation posing a risk to public health. Should the violation occur in an area of the system that is physically or hydraulically isolated from the rest of the system, the City may limit the issuance of the public notice to only the affected area. Ten required elements must be present in each public notice and are detailed in OAR 333-061-0042(4)(a)(A-J). A copy of the public notice must be sent to OHA as required in OAR 333-061-0040(1)(i). There are three tiers of violations with required response times, with the most severe violation, Tier 1, requiring notice to the public and OHA within 24 hours of learning of the situation.

5.2.2.10.1 Impact of the Public Notification Rule on the City

The City has a procedure in place for notifying the public in accordance with the Public Notification Rule if required.

5.2.2.11 National Secondary Drinking Water Regulations

The National Secondary Drinking Water Regulations set non-mandatory water quality standards for 15 contaminants. These are not enforceable but recommended secondary maximum contaminant levels (SMCLs). They establish guidelines for managing aesthetic concerns such as taste, color, and odor that are not considered a risk to human health at the SMCL. Although the SMCLs are not enforced, public notice is required if the fluoride SMCL is exceeded. A list of the SMCLs is presented below in **Table 5-6.**

Table 5-6|Secondary Drinking Water Standards

Contaminant	SMCL
Aluminum	0.05 - 2.0 mg/L
Chloride	250 mg/L
Color	15 color units
Copper	1.0 mg/L
Corrosivity	Non-corrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 TON (threshold odor number)
pH	6.5 - 8.5
Silver	0.1 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L

5.2.2.11.1 Impact of the Secondary Drinking Water Standards on the City

The City currently meets all Secondary Drinking Water Standards. Although they meet regulatory requirements, the City is always working to provide high quality water to its customers and is doing modeling analysis to improve the turnover rate in some of its tanks during non-peak seasons to improve taste and odor issues due to water age.

5.2.2.12 Contaminant Candidate List and Unregulated Contaminant Monitoring Rule

The 1996 amendment to the SDWA requires the EPA to list unregulated contaminants that are known or anticipated to occur in public water systems. Every 5 years, the EPA must publish this list of contaminants called the Contaminant Candidate List (CCL). EPA uses the CCL to identify priority contaminants for decision making and information collection. After publishing, EPA must also review at least five contaminants from the list and determine if they will be regulated in a separate process called Regulatory Determinations.

The EPA also requires larger public water systems to monitor for some unregulated contaminants as part of the Unregulated Contaminant Monitoring Rule (UMCR) to provide a basis for future regulatory actions.

5.2.2.12.1 Impact of the CCLs and UCMR on the City

The CCLs have no direct impact on the City, as the lists by themselves do not impose any requirements on public water systems. However, the EPA may promulgate future regulations based on the listed contaminants. If this occurs, the City will need to follow specific requirements that are contained in the regulations.

The City complies with sampling and testing requirements of the UCMR.

5.3 Summary

By State law (OAR 333-061-0036), the City is required to maintain an ongoing water quality testing and monitoring program. This program is administered by OHA and is comprised of monitoring the water supply for specified chemical and physical contaminants. OHA requires that the source water supply be monitored for the primary and secondary contaminants. Primary contaminant levels are not to be exceeded for health reasons, while secondary contaminants should not be exceeded to improve water color, taste, and odor.

The City is required to monitor inorganic compounds, volatile organic compounds, synthetic organic compounds, and radiological constituents. Distribution system water quality testing requirements include monitoring of many types of components including bacteriological, inorganic chemical, physical, disinfection by-products and disinfection residual, radionuclides, organic chemicals, and any other chemicals for which the state board of health determines maximum contaminant levels.

The City water system is of high quality and complies with all water quality regulations. The most immediate change in the City's water quality sampling could be reaching the threshold of 70,000 people served, which will trigger an increase from 70 to 80 required total coliform samples per month.

Section **6**

Section 6

Capital Improvement Plan

6.1 Introduction

This chapter describes the water system Capital Improvement Plan (CIP) for the City of Bend (City) service area to address system condition and hydraulic deficiencies to serve existing and 20-year projected demands. Although the projects are identified to address the 20-year projections, due to funding and staffing constraints they are being implemented over a timeframe longer than 20-years. Projects are grouped in three timeframes. The 10-year horizon covers years 2021 through 2030. The 20-year covers years 2031-2040 and the remaining projects are beyond 2040. The total project cost (2020 dollars) for the entire CIP is $391 million. The cost for the 10-year timeframe is approximately $133 million, in the 11- to 20-year timeframe it is approximately $137 million. The projects slated for beyond 2040 have a total cost of approximately $121 million.

6.2 Cost Estimates

All project descriptions and estimates represent American Association of Cost Engineers (AACE) International Class 5, planning-level accuracy and opinions of costs (+50 percent -30 percent). Total project costs will depend on actual labor and material costs, site conditions, competitive market conditions, regulatory requirements, project schedule, and other factors. During the design phase final sizing, location, and project components should be verified and a Preliminary Engineering Report (PER) completed. As part of the PER, the cost estimate should be refined. Therefore, project feasibility and any associated risks should be carefully reviewed prior to making specific financial decisions or establishing yearly project budgets to help ensure adequate funding.

Detailed costs using different methodologies based on facility type were derived for use in the optimization model. Unit costs were developed for each type of water system infrastructure considered in the optimization process (e.g., waterlines, new wells, booster stations). The project costs provide the basis for constructing new or upgrading existing infrastructure. Operations and maintenance (O&M) costs provide the basis for annual expenditures to operate and maintain the infrastructure in the water system.

The overall life cycle cost analysis, performed as part of the optimization, utilized an Equivalent Uniform Annual Cost (EUAC) approach to equitably compare infrastructure types that have differing useful lives. EUAC costs were then converted to 2020 dollars. All costs in this section reference U.S. dollars. The Engineering News Record Construction Cost Index (ENR CCI) basis is 12,341 (Seattle, August 2020), which can be used as a reference to future ENR CCI values to escalate to costs in future years. The detailed cost methodology is in Appendix 6A, Appendix 6B, and Appendix 6C.

6.3 Project Categories

As discussed in Section 4, the City has made a significant investment in evaluating the system in a comprehensive and integrated approach, meeting and in some cases exceeding the regulatory requirements. The unique process of optimization allowed for an extensive range of system improvements to be evaluated and ensures that the most hydraulically beneficial and cost-effective solutions are implemented. From these solutions, a comprehensive CIP was developed to address the deficiencies in facility and pipe condition, facility and distribution system capacity, and criticality identified through the system analysis outlined in Section 4.

Projects are grouped into five categories based on the primary deficiency they address: facility capacity, facility condition, pipe capacity, pipe replacement, and other.

6.3.1 Facility Capacity

Facility capacity projects were intended to ensure the system provides the hydraulic capacity to meet regulatory requirements and the City's level of service standards. Many of the identified projects are new facilities with the purpose of meeting future projected demands. This category of projects includes new reservoirs, wells, and pressure reducing valve (PRV) stations.

6.3.2 Facility Condition

Facility condition projects were identified based on the results of the condition assessment. An onsite examination of physical and operating conditions at each facility was performed for all the City's wells, reservoirs, and pump stations. Each facility was ranked, and improvements were identified that are required to maintain current facilities and extend their useful life. Maintenance improvements at facilities include upgrades to pumps and motors, electrical and instrumentation control, and reservoir coatings. The detailed maintenance and improvement recommendations and their associated costs are identified for each facility in the Infrastructure Condition Assessment Report.

6.3.3 Pipe Capacity

Pipe capacity projects were identified to address distribution system deficiencies. These include projects to address velocity, fire flow, and redundancy deficiencies as well as increase hydraulic performance and increase capacity for future projected demands. These projects include upsizing existing system piping and constructing new piping.

6.3.4 Pipe Replacement

The City is committed to an ongoing pipe replacement program. As part of the pipe condition assessment, a replacement rating based on material, diameter, valve frequency, and break history was assigned to each pipe in the system. Pipes with a higher score indicate worse condition and are intended to be prioritized for replacement sooner. The City intends to upsize any 6-inch or smaller piping to 8-inch as part of pipe replacement.

6.3.5 Planning/Conservation

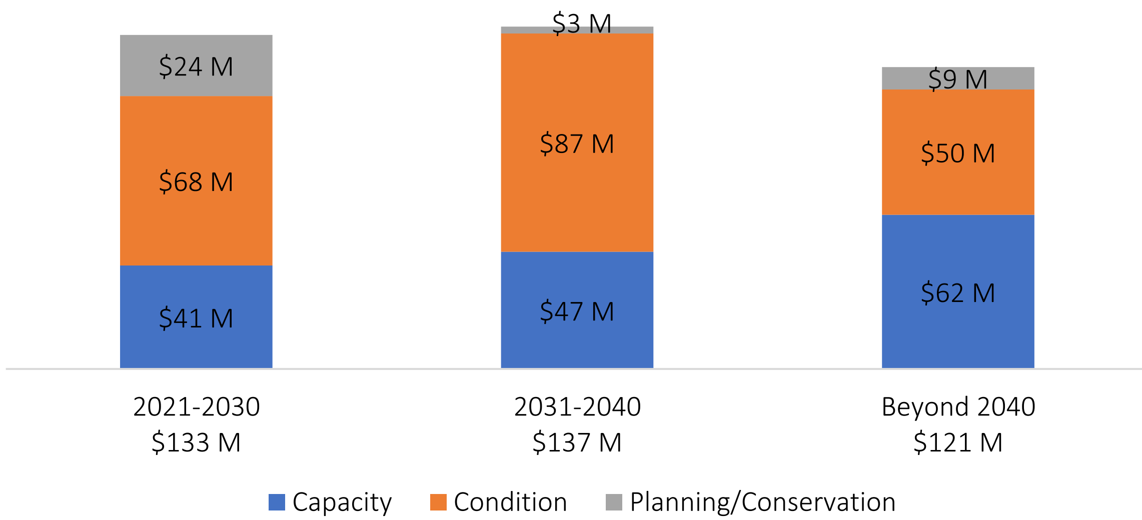
Projects in the Planning/Conservation category are intended to capture projects that are not a result of the deficiencies described in **Section 4**. These projects contribute to the capacity, condition, and resilience of the system and include things such as regular updates to planning documents including ongoing and regulatorily required updates and progress reports for the Water Management and Conservation Plan (WMCP) and related conservation and demand management programs, improvements and planning at the Outback Site, and other projects that are discussed further in this section.

6.4 Projects

Project locations are depicted in **Figure 6-1**. Timing and prioritization of projects are based on input from the City based on funding and implementation considerations. The projects are organized in 10-year periods from 2021-2030 and 2031-2040 and then extend beyond 2040. The cost estimates (2020 dollars) for each timeframe by project type are in **Figure 6-2**. Additionally, most pipe replacement program projects have not been allocated a specific timeframe and will be determined by the City to leverage synergy with other projects such as collection system or transportation projects. The replacement pipes are displayed by rating with the intention that those with higher score are replaced sooner than those with lower ratings. Some of the projects, such as new supply and storage may need to be accelerated to meet demands and other improvements deferred to stay within budget. Or projects may be delayed if demands are lower than projected, for example due to increased conservation program efforts. Projects should be evaluated annually through City reviews of demand growth, available budget, and where development is occurring in the service area.

In addition to the descriptions provided in this section, individual project plates have been developed for each pipe and facility project and are included in **Appendix 6D**.

Figure 6-2 | CIP Cost by Timeframe (2020 Dollars)



6.5 Projects Years 2021-2030

Projects planned for years 2021 to 2030 are displayed in **Figure 6-3**. The projects are organized by project type. The facility types include capital maintenance, decommission, new, and replace. For pipe projects the categories are upsize, replace, new.

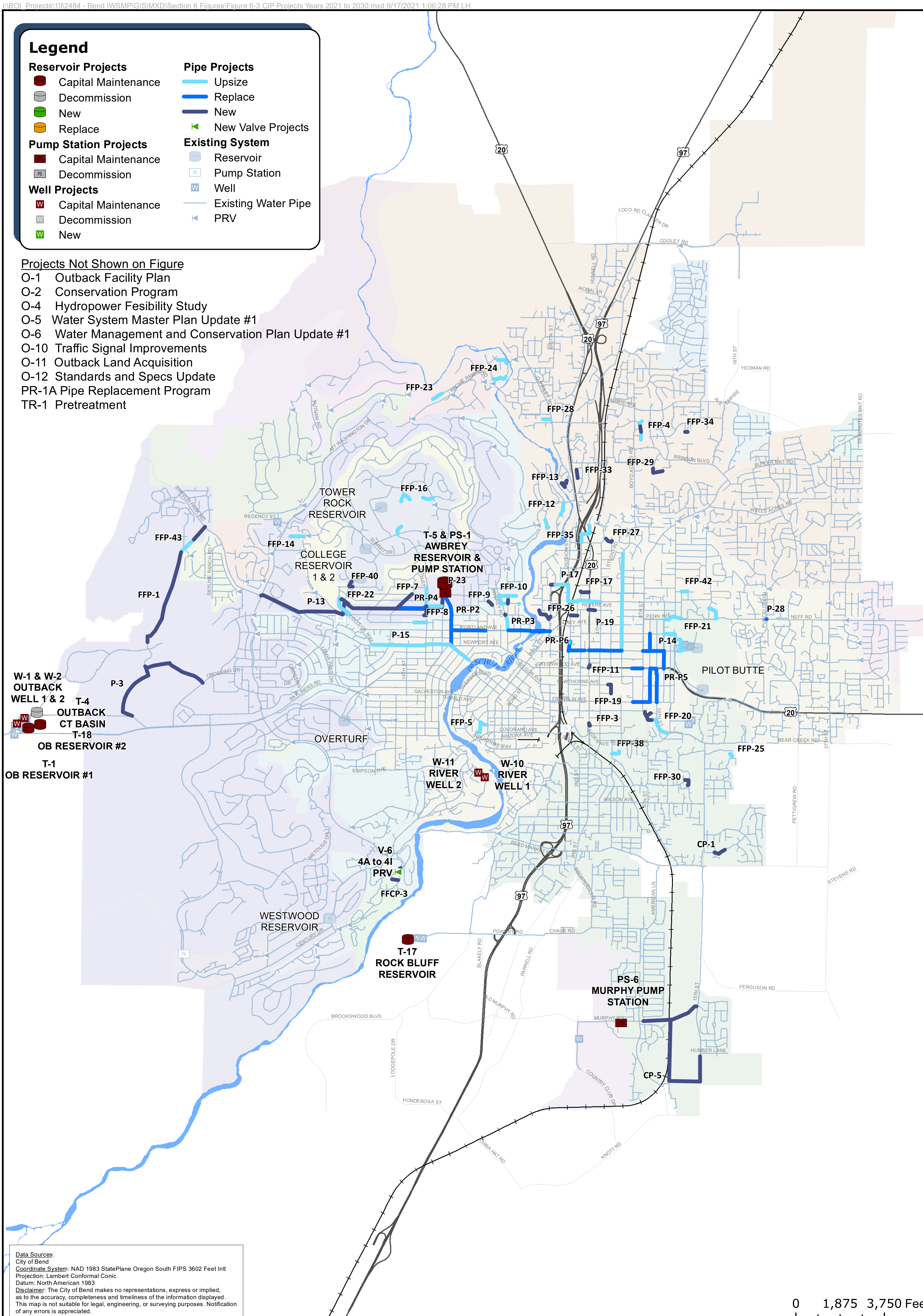
The projects prioritized over the next 10 years are intended to address facility condition and piping condition and capacity deficiencies. There are several projects at current facilities. These projects include condition related improvements to the Awbrey Pump Station, Outback Reservoir 1, Awbrey Reservoir, Outback Wells 1 and 2, and the River Wells. Included in facility condition projects is the decommissioning of the Outback Contact Time (CT) Basin. The intent is that the contact time requirements can be met by Outback Reservoir 1, or the Outback Facility Plan will identify another configuration to meet contact time. Additionally, interior coating is slated for the Rock Bluff Reservoir and Outback Reservoir 2.

Also included in the 10-year horizon are a few major piping projects including a new 30-inch Awbrey transmission main that will address capacity issues in the current transmission main and increase capacity for future growth. Upsizing is also planned for portions of piping along Newport Avenue. Many smaller pipe projects to address fire flow deficiencies (identified with FF in the project ID) are also included. A yearly pipe replacement program is planned. In addition to the pipe replacement program, specific pipe replacement projects have been identified near the Awbrey and Pilot Butte Reservoirs. A new PRV from Zone 4A to 4I is included as well.

An update to the Integrated Water System Master Plan (iWSMP), the state required 10-year update to the WMCP, the 5-year WMCP Progress Report, implementation of the conservation program and Standards and Specifications document are planned for the 10-year timeframe as well. Lastly, improvements to the Outback Site including an Outback Facility Plan, to further refine and finalize in detail the work done in the Outback Siting Study including recommended facilities such as pretreatment, new and rebuilt reservoirs, wells, and other water related facilities that may be sited on existing and/or additional lands. The potential for hydropower generation, if approved by City Council and after a Hydropower Feasibility Study, would also be considered as part of the plan. A detailed list and description of all proposed 10-year projects is in Table 6-1 with project plates for each pipe and facility project in Appendix 6D.

For this timeframe, the City has grouped many of the projects that are occurring around major facilities. These include the Awbrey Butte Distribution Improvements (1WABD), Outback Facility Improvements (1WOFI), River Well Improvements (1WWCM), Rock Bluff Reservoir Coating (1WROC), and Pilot Butte Distribution Improvements (1WPDI).

I:\BOI_Projects\19\2484 - Bend IWSMP\GIS\MXD\Section 6 Figures\Figure 6-3 CIP Projects Years 2021 to 2030.mxd 9/17/2021 1:06:28 PM LH



murraysmith

City of Bend
Integrated Water System
Master Plan

Figure 6-3
CIP Projects
Years 2021 to 2030

Table 6-1 | Projects Years 2021-2030

Project ID	Project Name	Project Category	Type of Improvement	Description	Recommended Sizing	Growth Allocation	Cost (2020 $)
CP-1	Ironwood Court Redundant Looping	Pipe Capacity	New Distribution Pipe for Redundancy	8-inch new pipe in Ironwood Court east of Castlewood Drive	8-inch, 510 LF	0%	$239,000
CP-5	Murphy Road Redundant Looping	Pipe Capacity	New Transmission Pipe for Redundancy	12inch and 16-inch new pipe in Murphy Road Area between Brosterhous Road and 15th Street	12-inch to 16-inch, 7420 LF	0%	$0
FFCP-3	New Zone 4I pipe	Pipe Capacity	New Distribution Pipe for Fire Flow and Redundancy	8-inch new pipe connecting Village Office Court and Mt. Bachelor Drive and new PRV piping in Mt. Bachelor Drive to serve Zone 4I	8-inch, 520 LF	0%	$287,000
FFP-1	Transect Area New Development	Pipe Capacity	New and Upsize Transmission Pipe for Fire Flow	24-inch new pipe installed by developer between Sage Steppe Drive and McClain Drive and 8-inch upsized pipe in McClain Drive to Shevlin Meadow Drive	24-inch, 4920 LF	100%	$0
FFP-3	Clay Avenue and 3rd Street Looping Part 1	Pipe Capacity	New Distribution Pipe for Fire Flow	8-inch new pipe connecting dead-end on Clay Avenue to 3rd Street	8-inch, 140 LF	0%	$47,000
FFP-4	Builders Street Looping	Pipe Capacity	New and Upsize Distribution Pipe for Fire Flow	8-inch new and upsized pipe on Builders Street at Boyd Acres Road	8-inch, 850 LF	0%	$535,000
FFP-5	Adams Place Upsize	Pipe Capacity	Upsize Distribution Pipe for Fire Flow	8-inch upsized dead-end pipe on Adams Place and Delaware Avenue west of Broadway Street	8-inch, 860 LF	0%	$543,000
FFP-7	12th and Juniper Streets Improvements	Pipe Capacity	New and Upsize Distribution Pipe for Fire Flow	8-inch new pipe on Juniper Street between Trenton and Iowa Avenues and on 12th Street between Saginaw and Trenton Avenues. 8-inch upsized pipe in 12th Street between Trenton and West Hills Avenues and in Trenton Avenue between 12th and 10th Streets.	8-inch, 2770 LF	0%	$1,829,000
FFP-8	Quincy Avenue Upsize	Pipe Capacity	Upsize Distribution Pipe for Fire Flow	8-inch upsized pipe on Quincy Avenue to connect 8-inch pipe to west and 10-inch pipe to east in 12th Street	8-inch, 540 LF	0%	$341,000
FFP-9	4th Street Looping	Pipe Capacity	New Distribution Pipe for Fire Flow	8-inch new pipe connecting dead-end on 4th Street to Utica Avenue	8-inch, 220 LF	0%	$105,000
FFP-10	Awbrey Road and Portland Avenue	Pipe Capacity	New and Upsize Distribution Pipe for Fire Flow	8-inch new and upsized pipe in area between Awbrey Road and Vicksburg Avenue and Portland Avenue and NW 1st Street	8-inch, 2410 LF	0%	$1,788,000
FFP-11	Greenwood Avenue and 3rd Street Intersection New Pipe	Pipe Capacity	New Distribution Pipe for Fire Flow	12-inch new pipe connecting dead-end 6-inch pipe to intersection of Greenwood Avenue and 3rd Street	12-inch, 120 LF	0%	$145,000
FFP-12	River's Edge Golf Course Area Upsize	Pipe Capacity	Upsize Distribution Pipe for Fire Flow	8-inch and 12-inch upsized pipe in Golf Course Drive South and Rippling River Court	8-inch to 12-inch, 1000 LF	0%	$685,000
FFP-13	Riverhouse Resort Looping	Pipe Capacity	New Distribution Pipe for Fire Flow	8-inch new pipe connecting dead-end service lines around Riverhouse Resort and Shilo Inn near O B Riley Road	8-inch, 550 LF	0%	$345,000
FFP-14	Regency Street Upsize	Pipe Capacity	Upsize Distribution Pipe for Fire Flow	8-inch upsized dead-end in Regency Street west of College Way	8-inch, 500 LF	0%	$316,000
FFP-16	Zone 1 Dead-End Fire Flow Improvements	Pipe Capacity	Upsize Distribution Pipe for Fire Flow	8-inch and 12-inch upsized pipe in Gill Court, Elliot Court, Meldrum Court, and Moore Court dead-end streets in Zone 1	8-inch to 12-inch, 1520 LF	0%	$1,022,000
FFP-17	Highway 20 Looping	Pipe Capacity	New and Upsize Distribution Pipe for Fire Flow	8-inch new pipe connecting dead-ends near Highway 20 and Revere Avenue	8-inch, 950 LF	0%	$600,000
FFP-19	5th Street and Hawthorne Avenue Looping	Pipe Capacity	New Distribution Pipe for Fire Flow	8-inch new pipe on 5th Street between Greeley Avenue and Hawthorne Avenue	8-inch, 500 LF	0%	$316,000
FFP-20	8th Street and Bear Creek Road Looping and Upsize	Pipe Capacity	New and Upsize Distribution Pipe for Fire Flow	8-inch new pipe in 8th Street between Emerson Avenue and Dekalb Avenue and 8-inch upsized pipe in 10th Street and Bear Creek Road between Dekalb Avenue and Alden Avenue	8-inch, 1760 LF	0%	$1,463,000
FFP-21	Pilot Butte and Neff Road Upsize	Pipe Capacity	Upsize Distribution Pipe for Fire Flow	12-inch and 8-inch upsized pipe in Pilot Butte and Neff Road between 11th Street and Eastwood Drive	8-inch to 12-inch, 2680 LF	0%	$2,111,000
FFP-22	Cascade View Drive and Trenton Looping	Pipe Capacity	New and Upsize Distribution Pipe for Fire Flow	8-inch upsized pipe on Cascade View Drive and new 8-inch Zone 3 connection in Trenton Avenue	8-inch, 1400 LF	0%	$883,000
FFP-23	Foxwood Upsize	Pipe Capacity	Upsize Distribution Pipe for Fire Flow	8-inch upsized dead-end pipe in Foxwood	8-inch, 440 LF	0%	$276,000
FFP-24	Silver Buckle and Broken Arrow Road Upsize	Pipe Capacity	Upsize Distribution Pipe for Fire Flow	8-inch upsized pipe in Silver Buckle and in Broken Arrow Road east of Lower Village Road	8-inch, 1100 LF	0%	$689,000
FFP-25	Karena Court Upsize	Pipe Capacity	Upsize Distribution Pipe for Fire Flow	8-inch upsized pipe in dead-end on Karena Court at Craven Road	8-inch, 200 LF	0%	$128,000

Project ID	Project Name	Project Category	Type of Improvement	Description	Recommended Sizing	Growth Allocation	Cost (2020 $)
FFP-26	Wall Street and Harriman Street and Highway 20 Looping	Pipe Capacity	New and Upsize Distribution Pipe for Fire Flow	12-inch and 8-inch new pipe to connect dead-ends on Harriman Street and south of Revere Street to Wall Street	8-inch to 12-inch, 1040 LF	0%	$737,000
FFP-27	Xerxes Avenue and 4th Street Looping	Pipe Capacity	New Distribution Pipe for Fire Flow	8-inch new pipe connecting dead-end service line to 4th Street	8-inch, 320 LF	0%	$183,000
FFP-28	Sawyer Reach Lane Upsize	Pipe Capacity	Upsize Distribution Pipe for Fire Flow	8-inch upsized dead-end pipe north of Sawyer Reach Lane at O B Riley Road	8-inch, 300 LF	0%	$188,000
FFP-29	Peerless Court Looping	Pipe Capacity	New Distribution Pipe for Fire Flow	8-inch new pipe connecting dead-ends on Peerless Court at Brinson Boulevard	8-inch, 600 LF	0%	$375,000
FFP-30	Wilson Avenue and 15th Street Industrial Service Looping	Pipe Capacity	New Distribution Pipe for Fire Flow	8-inch new pipe connecting dead-end industrial services	8-inch, 390 LF	0%	$248,000
FFP-33	Bend River Promenade Looping	Pipe Capacity	New Distribution Pipe for Fire Flow	8-inch new pipe looping dead-end service at Bend River Mall Avenue near O B Riley Road	8-inch, 370 LF	0%	$233,000
FFP-34	High Desert Lane Looping	Pipe Capacity	New Distribution Pipe for Fire Flow	8-inch new pipe connecting dead-end lines south of High Desert Lane	8-inch, 120 LF	0%	$77,000
FFP-35	Addison Avenue Upsize	Pipe Capacity	Upsize Distribution Pipe for Fire Flow	12-inch upsized pipe at Highway 97 and Highway 20 near Addison Avenue	12-inch, 1050 LF	0%	$1,873,000
FFP-38	5th Street and Glenwood Drive Upsize	Pipe Capacity	Upsize Distribution Pipe for Fire Flow	8-inch upsized dead-end pipe off 5th Street south of Glenwood Drive	8-inch, 390 LF	0%	$248,000
FFP-40	Glassow Drive Looping	Pipe Capacity	New Distribution Pipe for Fire Flow	8-inch new pipe connecting Glassow Drive and Rimrock Road near College Reservoir 1	8-inch, 380 LF	0%	$237,000
FFP-42	Seward Avenue Upsize	Pipe Capacity	Upsize Distribution Pipe for Fire Flow	8-inch upsized dead-end pipe on Seward Avenue between 13th Street and 14th Street	8-inch, 260 LF	0%	$164,000
FFP-43	McClain Drive Upsize	Pipe Capacity	New and Upsize Transmission Pipe	Upsize existing 8-inch to 24-inch	24-inch, 770 LF	0%	$782,000
O-1	Outback Facility Plan	Planning/Conservation	-	Comprehensive assessment of Outback site	-	38%	$500,000
O-2	Conservation Program	Planning/Conservation	-	Implementation of conservation program	-	38%	$1,538,000
O-4	Hydropower Feasibility Study	Planning/Conservation	-	Analysis of addition of hydropower in the system, privately funded	-	38%	$0
O-5	Water System Master Plan Update #1	Planning/Conservation	-	First update to Water System Master Plan	-	38%	$1,000,000
O-6	Water Management and Conservation Plan Update #1	Planning/Conservation	-	10-year update to Water Management and Conservation Plan	-	38%	$200,000
O-10	Traffic Signal Improvements	Planning/Conservation	-	Coordination with transportation project	-	0%	$25,000
O-11	Outback Land Acquisition	Planning/Conservation	-	Land acquisition required for Outback Facility expansion	-	38%	$5,000,000
O-12	Standards & Specs Update	Planning/Conservation	-	Update to Standards and Specifications document	-	0%	$150,000
P-3	Discovery West Looping	Pipe Capacity	New Transmission Pipe for Hydraulic Performance	12-inch and 18-inch and 24-inch new pipe in new development connecting to North Outback Transmission Main, Sage Steppe Drive and Crossing Drive. Project funded primarily by developer.	12-inch to 24-inch, 5550 LF	100%	$0
P-13	New Awbrey Transmission	Pipe Capacity	New Transmission Pipe for Hydraulic Performance	30-inch new pipe in Shevlin Park Road, Utility ROW, and Trenton Avenue from Mt. Washington Avenue to Awbrey Reservoir. Includes trenched construction with rock excavation, fittings, valves, water meters, and surface restoration.	30-inch, 9040 LF	36%	$10,312,000
P-14	Upsize Pilot Butte Reservoir 1 Transmission Pipe	Pipe Capacity	Upsize Transmission Pipe for Hydraulic Performance	18-inch upsized pipe from Pilot Butte Reservoir 1 to Pilot Butte Well 4 Connection	18-inch, 270 LF	0%	$342,000
P-15	Newport Avenue Replacement	Pipe Capacity	Upsize Distribution Pipe for Hydraulic Performance	12-inch upsized pipe in Newport Avenue from College Way to 9th Street. 16-inch replacement pipe in Newport Avenue from 9th Street to the Deschutes River. Includes trenched construction with rock excavation, fittings, valves, and water meters.	12-inch to 16-inch, 4500 LF	43%	$3,984,000
P-17	Revere Division and Thurston Upsize Part 1	Pipe Capacity	Upsize Distribution Pipe for Hydraulic Performance	12-inch upsized pipe in Revere Avenue, Division Street, and Thurston Avenue between 4th Street and Wall Street	12-inch to 16-inch, 2920 LF	55%	$2,077,000
P-19	6th Street Upsize	Pipe Capacity	Upsize Transmission Pipe for Hydraulic Performance	16-inch upsized pipe in 6th Street from Lafayette Avenue to Innes Lane. 12-inch upsized pipe in 6th Street from Innes Lane to Stalker Court	12-inch to 16-inch, 4130 LF	78%	$3,625,000
P-23	Awbrey Reservoir Outlet Transmission Upsize	Pipe Capacity	Upsize Transmission Pipe for Hydraulic Performance	24-inch upsized pipe outlet from Awbrey Reservoir outlet to match 24-inch in 9th Street	24-inch, 320 LF	0%	$260,000
P-28	Neff and Purcell Intersection	Pipe Capacity	New and Upsize Distribution Pipe	Replace pipe in intersection of Neff Road and Purcell Boulevard while road is being resurfaced	16-inch, 20 LF	0%	$19,000

Project ID	Project Name	Project Category	Type of Improvement	Description	Recommended Sizing	Growth Allocation	Cost (2020 $)
PR-1A	Pipe Replacement Program Years 1 to 10	Pipe Replacement	-	Pipe replacement program	-	0%	$33,788,000
PR-P2	Awbrey Butte Distribution Improvements	Pipe Replacement	Replace Distribution Pipe	Phase 1 Awbrey Butte Distribution Improvements Pipe Replacement	24-inch, 2260 LF	0%	$2,737,000
PR-P3	Awbrey Butte Distribution Improvements	Pipe Replacement	Replace and Upsize Distribution Pipe	Phase 3 Awbrey Butte Distribution Improvements Pipe Replacement and Upsize Existing 6-inch pipe to 8-inch	8-inch to 18-inch, 3500 LF	0%	$3,346,000
PR-P4	Awbrey Butte Distribution Improvements	Pipe Replacement	Replace and Upsize Distribution Pipe	Phase 4 Awbrey Butte Distribution Improvements Pipe Replacement and Upsize Existing 6-inch pipe to 8-inch	8-inch, 1260 LF	0%	$1,104,000
PR-P5	Pilot Butte Distribution Improvements	Pipe Replacement	Replace Distribution Pipe	Phase 1 Pilot Butte Distribution Improvements Pipe Replacement	8-inch to 12-inch, 6650 LF	0%	$5,940,000
PR-P6	Pilot Butte Distribution Improvements	Pipe Replacement	Replace and Upsize Distribution Pipe	Phase 2 Pilot Butte Distribution Improvements Pipe Replacement and Upsize Existing 6-inch to 8-inch	8-inch to 12-inch, 2390 LF	0%	$2,314,000
PS-1	Awbrey Pump Station	Facility Condition	Pump Station Capital Maintenance	Condition Related Improvements to 3,900 Gallon Per Minute Pump Station (See Condition Assessment Project List for Additional Details)	-	0%	$3,459,000
PS-6	Replacement of Murphy Pump Station	Facility Condition and Capacity	Replace Pump Station	New pump station with 2,900 gpm capacity. Construction scheduled for Fall 2021. Cost is not included as it is already funded.	-	0%	$0
T-1	Outback Reservoir 1	Facility Condition	Reservoir Capital Maintenance	Condition Related Improvements (See Condition Assessment Project List for Additional Details)	-	0%	$1,585,000
T-4	Outback CT Basin	Facility Condition and Capacity	Decommission Reservoir	Decommission Existing Reservoir	-	0%	$500,000
T-5	Awbrey Reservoir	Facility Condition	Reservoir Capital Maintenance	Condition Related Improvements to 5.0 Million Gallon Reservoir (See Condition Assessment Project List for Additional Details)	-	0%	$3,547,000
T-17	Rock Bluff Reservoir Interior Coating	Facility Condition	Reservoir Capital Maintenance	Rock Bluff Reservoir Interior Coating	-	0%	$700,000
T-18	Outback Reservoir 2 Interior Coating	Facility Condition	Reservoir Capital Maintenance	Outback Reservoir 2 Interior Coating	-	0%	$1,300,000
TR-1	Pretreatment	Planning/Conservation	-	Design and construction of pretreatment at Water Filtration Facility	-	38%	$16,000,000
V-6	New Zone 4A to 4I PRV	Facility Capacity	New PRV	Zone 4A to 4I PRV on Mt. Bachelor Drive	-	0%	$155,000
W-1	Outback Well 1	Facility Condition	Well Capital Maintenance	Condition Related Improvements to 800 Gallon Per Minute Well (See Condition Assessment Project List for Additional Details)	-	0%	$1,223,000
W-2	Outback Well 2	Facility Condition	Well Capital Maintenance	Condition Related Improvements to 950 Gallon Per Minute Well (See Condition Assessment Project List for Additional Details)	-	0%	$1,531,000
W-10	River Well 1	Facility Condition	Well Capital Maintenance	Condition Related Improvements to 1,800 Gallon Per Minute Well (See Condition Assessment Project List for Additional Details)	-	0%	$2,198,000
W-11	River Well 2	Facility Condition	Well Capital Maintenance	Condition Related Improvements to 1,900 Gallon Per Minute Well (See Condition Assessment Project List for Additional Details)	-	0%	$2,928,000
						Total	$133,425,000

6.6 Projects Years 2031-2040

Projects planned for years 2031 to 2040 are displayed in **Figure 6-4**. The projects include additional piping improvements to address capacity related to fire flow and hydraulic performance deficiencies. Included in these projects is upsizing small diameter pipe in the Awbrey Meadows Development (6B Zone) and upsizing piping along 8th Street to 16-inch.

Capital maintenance projects include condition related improvements to the College Pump Station, Tetherow Pump Station, Murphy Pump Station, Pilot Butte Reservoirs 1, 2, and 3, Bear Creek Wells 1 and 2, Pilot Butte Wells 1 and 3, Rock Bluff Well 2, and Outback Wells 3, 4, and 5. A few facilities including the Westwood Pump Station, Overturf Reservoirs, and Westwood Reservoir are scheduled to be decommissioned. Additional new facilities to meet projected demand growth are also planned in the 20-year horizon. These facilities include a new Overturf Reservoir, Bear Creek Well, two new Zone 4 wells on Wilson Road, and three new PRVs.

Also planned is an update to the WSMP and WMCP as well as the continuation of the conservation program. A detailed list and description of the proposed projects for the 20-year horizon is in **Table 6-2** with project plates for each pipe and facility project in **Appendix 6D**.

6.7 Projects Beyond 2040

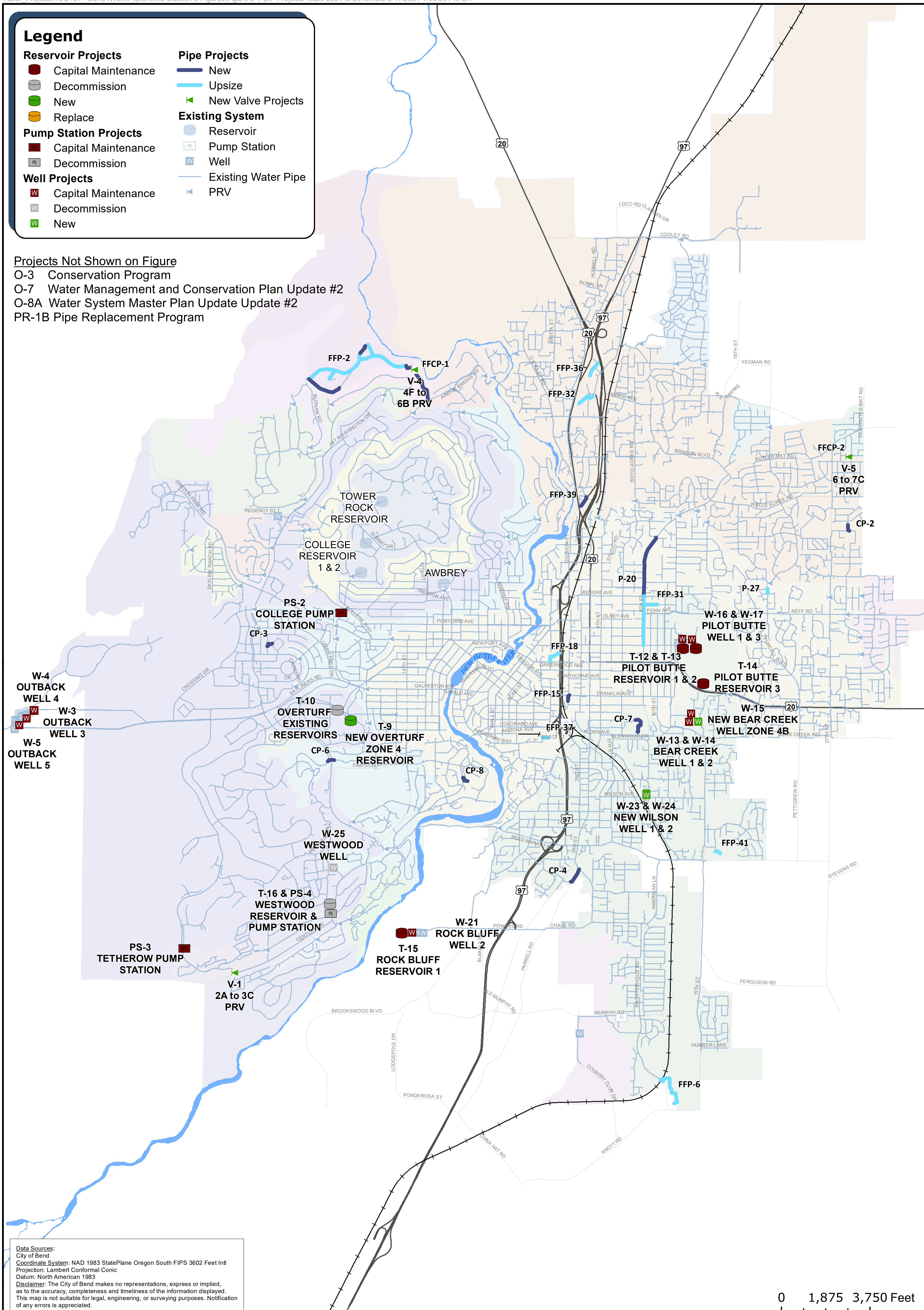
Projects planned for years beyond 2040 are displayed in **Figure 6-5**. These projects address improvements needed based on the 20-year demand projection requirements, however due to funding and staffing constraints are assumed for implementation over a longer period. The projects scheduled include the remaining pipe capacity projects to address distribution system deficiencies including two larger projects to convey flow from the Outback Facility and south to the Tetherow area.

Capital maintenance projects include condition related improvements to the Scott Street Pump Station, Outback Reservoir 3, College Reservoirs 1 and 2, Tower Rock Reservoir, Pilot Butte Well 4, Rock Bluff Wells 1 and 3, Shilo Well, Outback Wells 6 and 7, and Copperstone Well. Additionally, Outback Reservoir 2 is scheduled to be replaced with a larger volume reservoir.

New facilities intended to meet projected demands include a new Overturf Zone 5 Reservoir and well, two new Zone 5 wells near Purcell Boulevard and Paula Drive, a new Outback well, and two new PRVs. These facilities are required based on projected demands and their timing should be evaluated based on system demand thresholds as noted on the project plates in **Appendix 6D** and the requirements from **Section 4**.

An update to this iWSMP is also included. A detailed list and description of the proposed projects for beyond the 20-year horizon is in **Table 6-3** with project plates for each pipe and facility project in **Appendix 6D**.

I:\BOI_Projects\19\2484 - Bend IWSMP\GIS\MXD\Section 6 Figures\Figure 6-4 CIP Projects Years 2031 to 2040.mxd 9/17/2021 1:06:08 PM LH



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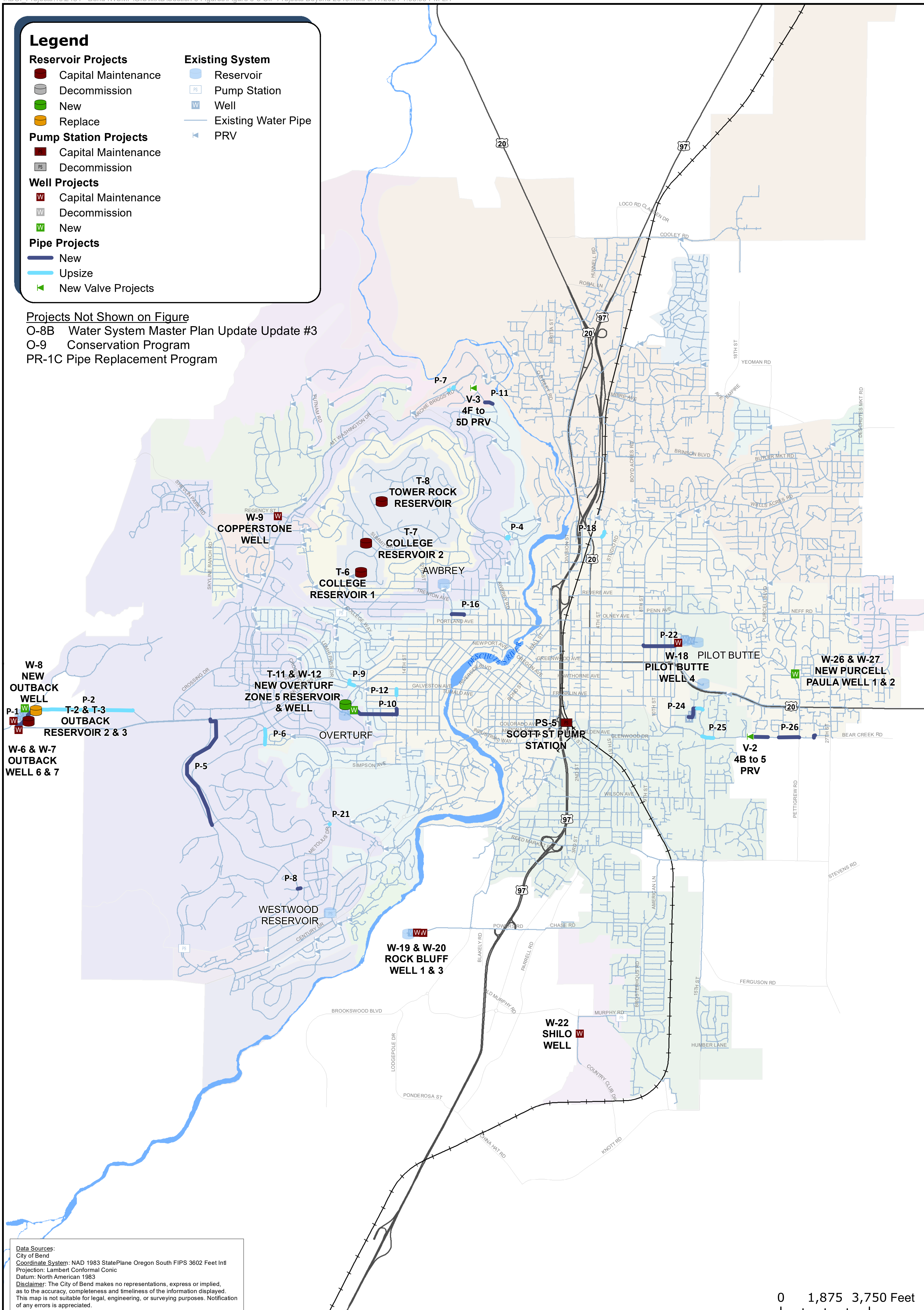
City of Bend
Integrated Water System
Master Plan

Figure 6-4
CIP Projects
Years 2031 to 2040

September 2021 19-2484

I:\BOI_Projects\19\2484 - Bend IWSMP\GIS\MXD\Section 6 Figures\Figure 6-5 CIP Projects Beyond 2040.mxd 9/17/2021 1:05:03 PM LH



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City of Bend
Integrated Water System
Master Plan

Figure 6-5
CIP Projects
Beyond 2040

September 2021

19-2484

Table 6-2 | Projects Years 2031-2040

Project ID	Project Name	Project Category	Type of Improvement	Description	Recommended Sizing	Growth Allocation	Cost (2020 $)
CP-2	Rainier Drive Redundant Looping	Pipe Capacity	New Distribution Pipe for Redundancy	8-inch new pipe connecting from Catholic School to the south to Rainier Drive	8-inch, 280 LF	0%	$176,000
CP-3	High Lakes Elementary Redundant Looping	Pipe Capacity	New Distribution Pipe for Redundancy	12-inch new pipe serving High Lakes Elementary School from John Fremont Street	12-inch, 290 LF	0%	$210,000
CP-4	Fred Meyer Redundant Looping	Pipe Capacity	New Distribution Pipe for Redundancy	8-inch new pipe serving commercial area	12-inch, 660 LF	0%	$776,000
CP-6	Forest Ridge Avenue and Mt. Washington Drive Crossing	Pipe Capacity	New Distribution Pipe for Redundancy	12-inch new pipe crossing Mt. Washington Drive between Forest Ridge Avenue and Green Lakes Loop	8-inch, 310 LF	0%	$359,000
CP-7	Bend High School Redundant Looping	Pipe Capacity	New Distribution Pipe for Redundancy	8-inch new pipe along High School perimeter to connect to existing 6-inch service line	8-inch, 790 LF	0%	$497,000
CP-8	Deschutes Brewery Redundant Looping	Pipe Capacity	New Distribution Pipe for Redundancy	8-inch new pipe connecting to Colorado Avenue north of Emkay Drive	8-inch, 310 LF	0%	$195,000
FFCP-1	Awbrey Meadows pipe	Pipe Capacity	New Distribution Pipe for Fire Flow and Redundancy	8-inch new PRV piping between Archie Briggs Road and Putnam Road to serve Awbrey Meadows	8-inch, 1950 LF	0%	$1,226,000
FFCP-2	New Zone 7C pipe	Pipe Capacity	New Distribution Pipe for Fire Flow and Redundancy	8-inch new PRV piping in Marea Drive at Sandalwood Drive to serve Zone 7C	8-inch, 220 LF	0%	$137,000
FFP-2	Awbrey Meadows	Pipe Capacity	New and Upsize Distribution Pipe for Fire Flow	8-inch new and upsized pipe in Zone 6B	8-inch, 8000 LF	0%	$5,030,000
FFP-3	Clay Avenue and 3rd Street Looping Part 2	Pipe Capacity	New Distribution Pipe for Fire Flow	8-inch new pipe connecting dead-end on Clay Avenue to 3rd Street	8-inch, 140 LF	0%	$100,000
FFP-6	Brosterhous Road Fire Service Upsize	Pipe Capacity	Upsize Distribution Pipe for Fire Flow	8-inch upsized dead-end pipe east of Brosterhous Road at Knott Road	8-inch, 1860 LF	0%	$898,000
FFP-15	Franklin Avenue and 1st Street Looping	Pipe Capacity	New Distribution Pipe for Fire Flow	8-inch new pipe connecting dead-end pipes north and south of Franklin Avenue on 1st Street	8-inch, 280 LF	0	$299,000
FFP-18	Greenwood Avenue and Hill Street Upsize	Pipe Capacity	Upsize Distribution Pipe for Fire Flow	12-inch upsized pipe on Hill Street at Greenwood Avenue	12-inch, 660 LF	0%	$482,000
FFP-31	Quimby Avenue Upsize	Pipe Capacity	Upsize Distribution Pipe for Fire Flow	8-inch upsized dead-end pipe in Quimby Avenue at 8th Street	8-inch, 590 LF	0%	$372,000
FFP-32	Nels Anderson Road Upsize	Pipe Capacity	Upsize Distribution Pipe for Fire Flow	8-inch upsized dead-end service lines in Nels Anderson Road Upsize	8-inch, 710 LF	0%	$463,000
FFP-36	Cady Way Upsize	Pipe Capacity	Upsize Distribution Pipe for Fire Flow	12-inch upsized dead-end industrial service lines at Cady Way	12-inch, 640 LF	0%	$468,000
FFP-37	Industrial Way Upsize	Pipe Capacity	Upsize Distribution Pipe for Fire Flow	8-inch upsized dead-end near Industrial Way near Highway 97	8-inch, 250 LF	0%	$159,000
FFP-39	Red Lion Inn Looping	Pipe Capacity	New Distribution Pipe for Fire Flow	12-inch new pipe connecting dead-end service line around Red Lion Inn on Buter Market Road at Division Street	12-inch, 460 LF	0%	$336,000
FFP-41	Castlewood Drive Upsize	Pipe Capacity	Upsize Distribution Pipe for Fire Flow	8-inch upsized dead-end pipes off Castlewood Drive south of Ironwood Drive	8-inch, 230 LF	0%	$144,000
O-3	Conservation Program	Planning/Conservation	-	Continuation of conservation program	-	38%	$1,538,000
O-7	Water Management and Conservation Plan Update #2	Planning/Conservation	-	20-year update Water Management and Conservation Plan	-	38%	$200,000
O-8A	Water System Master Plan Update #2	Planning/Conservation	-	Second update to Water System Master Plan	-	38%	$1,000,000
P-17	Revere Division and Thurston Upsize Part 2	Pipe Capacity	Upsize Distribution Pipe for Hydraulic Performance	12-inch upsized pipe in Revere Avenue, Division Street, and Thurston Avenue between 4th Street and Wall Street	12-inch to 16-inch, 2920 LF	55%	$2,077,000
P-20	8th Street Upsize and Parallel Transmission	Pipe Capacity	New and Upsize Transmission Pipe for Hydraulic Performance	16-inch upsized pipe in 8th Street between Lafayette Avenue and Revere Avenue. 16-inch new pipe in 8th Street between Revere Avenue and Ravenwood Drive.	16-inch, 4740 LF	86%	$5,985,000
P-27	Upsize 6-inch pipe on Purcell Boulevard	Pipe Capacity	Upsize Distribution Pipe for Hydraulic Performance	12-inch upsized pipe in Purcell Boulevard at Loop Road near Full Moon Drive	12-inch, 190 LF	75%	$185,000
PR-1B	Pipe Replacement Program Years 11 to 20	Pipe Replacement	-	Pipe replacement program	-	0%	$66,970,000
PS-2	College Pump Station	Facility Condition	Pump Station Capital Maintenance	Condition Related Improvements to 2,200 Gallon Per Minute Pump Station (See Condition Assessment Project List for Additional Details)	-	0%	$1,276,000
PS-3	Tetherow Pump Station	Facility Condition	Pump Station Capital Maintenance	Condition Related Improvements to 3,200 Gallon Per Minute Pump Station (See Condition Assessment Project List for Additional Details)	-	0%	$1,967,000

Project ID	Project Name	Project Category	Type of Improvement	Description	Recommended Sizing	Growth Allocation	Cost (2020 $)
PS-4	Westwood Pump Station	Facility Condition and Capacity	Decommission Pump Station	Decommission 2,300 Gallon Per Minute Existing Pump Station	-	0%	$160,000
T-9	New Overturf Zone 4 Reservoir	Facility Capacity	New Reservoir	New 4.0 million gallon prestressed concrete reservoir. Includes site development, mechanical, electrical, instrumentation and controls.	-	50%	$11,219,000
T-10	Existing Overturf Reservoirs	Facility Condition and Capacity	Decommission Reservoirs	Decommission Existing Reservoirs	-	0%	$1,100,000
T-12	Pilot Butte Reservoir 1	Facility Condition	Reservoir Capital Maintenance	Condition Related Improvements to 1.5 Million Gallon Reservoir (See Condition Assessment Project List for Additional Details)	-	0%	$1,454,000
T-13	Pilot Butte Reservoir 2	Facility Condition	Reservoir Capital Maintenance	Condition Related Improvements to 1.0 Million Gallon Reservoir (See Condition Assessment Project List for Additional Details)	-	0%	$1,533,000
T-14	Pilot Butte Reservoir 3	Facility Condition	Reservoir Capital Maintenance	Condition Related Improvements to 5.0 Million Gallon Reservoir (See Condition Assessment Project List for Additional Details)	-	0%	$904,000
T-15	Rock Bluff Reservoir 1	Facility Condition	Reservoir Capital Maintenance	Condition Related Improvements to 1.5 Million Gallon Reservoir (See Condition Assessment Project List for Additional Details)	-	0%	$1,429,000
T-16	Westwood Reservoir	Facility Condition and Capacity	Decommission Reservoir	Decommission 0.5 Million Gallon Reservoir Existing Reservoir	-	0%	$340,000
V-1	New Zone 2A to 3C PRV	Facility Capacity	New PRV	Zone 2A to 3C PRV Skyline Ranch Road and Century Drive	-	0%	$155,000
V-4	New Zone 4F to 6B PRV	Facility Capacity	New PRV	New Zone 4F to 6B PRV between Archie Briggs Road and Putnam Road	-	0%	$155,000
V-5	New Zone 6 to 7C PRV	Facility Capacity	New PRV	New Zone 6 to 7C PRV on Marea Drive at Sandalwood Drive	-	0%	$155,000
W-3	Outback Well 3	Facility Condition	Well Capital Maintenance	Condition Related Improvements to 1,050 Gallon Per Minute Well (See Condition Assessment Project List for Additional Details)	-	38%	$1,633,000
W-4	Outback Well 4	Facility Condition	Well Capital Maintenance	Condition Related Improvements to 1,150 Gallon Per Minute Well (See Condition Assessment Project List for Additional Details)	-	38%	$954,000
W-5	Outback Well 5	Facility Condition	Well Capital Maintenance	Condition Related Improvements to 1,050 Gallon Per Minute Well (See Condition Assessment Project List for Additional Details)	-	38%	$912,000
W-13	Bear Creek Well 1	Facility Condition	Well Capital Maintenance	Condition Related Improvements to 1,100 Gallon Per Minute Well (See Condition Assessment Project List for Additional Details)	-	0%	$2,116,000
W-14	Bear Creek Well 2	Facility Condition	Well Capital Maintenance	Condition Related Improvements to 1,050 Gallon Per Minute Well (See Condition Assessment Project List for Additional Details)	-	0%	$1,160,000
W-15	New Bear Creek Zone 4 Well	Facility Capacity	New Well	1 New 300 horsepower deep well. Includes well drilling, casing, and pump and standby power generator. Also includes site development, building systems, mechanical, electrical, instrumentation and controls.	-	100%	$4,049,000
W-16	Pilot Butte Well 1	Facility Condition	Well Capital Maintenance	Condition Related Improvements to 750 Gallon Per Minute Well (See Condition Assessment Project List for Additional Details)	-	0%	$853,000
W-17	Pilot Butte Well 3	Facility Condition	Well Capital Maintenance	Condition Related Improvements to 900 Gallon Per Minute Well (See Condition Assessment Project List for Additional Details)	-	0%	$1,645,000
W-21	Rock Bluff Well 2	Facility Condition	Well Capital Maintenance	Condition Related Improvements to 800 Gallon Per Minute Well (See Condition Assessment Project List for Additional Details)	-	0%	$2,382,000
W-23	New Wilson Zone 4 Well 1	Facility Capacity	New Well	New 300 horsepower mid depth wells. Includes well drilling, casing, and pump and standby power generator. Also includes site development, building systems, mechanical, electrical, instrumentation and controls.	-	100%	$4,358,000
W-24	New Wilson Zone 4 Well 2	Facility Capacity	New Well	New 300 horsepower mid depth wells. Includes well drilling, casing, and pump and standby power generator. Also includes site development, building systems, mechanical, electrical, instrumentation and controls.	-	100%	$4,358,000
W-25	Westwood Well	Facility Condition and Capacity	Decommission Well	Decommission 700 Gallon Per Minute Existing Well	-	0%	$180,000
						Total	$136,729,000

Table 6-3 | Projects Beyond 2040

Project ID	Project Name	Project Category	Type of Improvement	Description	Recommended Sizing	Growth Allocation	Cost (2020 $)
P-1	Outback Site Transmission	Pipe Capacity	New Transmission Pipe for Hydraulic Performance	16-inch and 30-inch pipe parallel to connect North and South Outback Transmission Mains	16-inch to 30-inch, 1070 LF	100%	$815,000
P-2	Outback North Transmission Replacement	Pipe Capacity	Upsize Transmission Pipe for Hydraulic Performance	30-inch new pipe to replace existing 14-inch and 16-inch parallel pipe that is in poor condition.	30-inch, 4320 LF	38%	$3,927,000
P-4	Zone 3 to 4A Mt. Washington Drive and Rivers Edge PRV Pipe Upsize	Pipe Capacity	Upsize Transmission and Distribution Pipe for Hydraulic Performance	12-inch and 16-inch upsized pipe crossing Mt. Washington Drive at Pro Shop Drive	12-inch to 16-inch, 200 LF	100%	$246,000
P-5	Skyline Ranch Road Parallel	Pipe Capacity	New Transmission Pipe for Hydraulic Performance	18-inch parallel pipe in Skyline Ranch Road from Skyliners Road to Broken Top Road.	18-inch, 5590 LF	100%	$5,923,000
P-6	Niagara Court Upsize	Pipe Capacity	Upsize Distribution Pipe for Hydraulic Performance	12-inch upsized pipe in Niagara Court from Hosmer Lake Drive to Green Lakes Loop	12-inch, 650 LF	100%	$477,000
P-7	Archie Briggs and Falcon Ridge Upsize	Pipe Capacity	Upsize Transmission Pipe for Hydraulic Performance	16-inch upsized pipe crossing Archie Briggs Road and Falcon Ridge	16-inch, 90 LF	75%	$94,000
P-8	Mirror Lake Place Looping	Pipe Capacity	New Distribution Pipe for Hydraulic Performance	8-inch new pipe on Mirror Lake Place from dead-end east of Fisher Lake Lane to Meeks Trail	8-inch, 130 LF	0%	$79,000
P-9	Skyliners Road and Flagline Drive Upsize	Pipe Capacity	Upsize Distribution Pipe for Hydraulic Performance	12-inch upsized pipe in Skyliners Road and Flagline Drive	12-inch, 380 LF	100%	$385,000
P-10	New Zone 5 Overturf Reservoir and Well Transmission	Pipe Capacity	New Transmission Pipe for Hydraulic Performance	16-inch pipe in Cumberland Avenue from New Overturf Zone 5 Reservoir to 15th Street. Includes trenched construction with rock excavation, fittings, valves, water meters, and surface restoration.	16-inch, 2040 LF	100%	$1,564,000
P-11	Zone 4F and Zone 4A Distribution Connection	Pipe Capacity	New and Upsize Distribution Pipe for Hydraulic Performance	8-inch upsized pipe Zone 4F pipe at Archie Briggs Road and NW Stoneridge and new 8-inch Zone 4F to 4A connection	8-inch, 370 LF	100%	$257,000
P-12	15th Street Upsize	Pipe Capacity	Upsize Distribution Pipe for Hydraulic Performance	12-inch upsized pipe in 15th Street from Galveston Avenue to Fresno Avenue	12-inch, 260 LF	56%	$192,000
P-16	Roanoke Avenue Looping	Pipe Capacity	New Distribution Pipe for Hydraulic Performance	8-inch new pipe in Roanoke Avenue from dead-end west of 7th Street to 9th Street	8-inch, 540 LF	44%	$340,000
P-18	4th Street Upsize	Pipe Capacity	Upsize Distribution Pipe for Hydraulic Performance	12-inch upsized pipe in 4th Street north of Yale Avenue	12-inch, 250 LF	100%	$297,000
P-21	Metolius Drive Upsize	Pipe Capacity	Upsize Distribution Pipe for Hydraulic Performance	12-inch upsized pipe in Metolius Drive at Bridge Creek Drive	12-inch, 20 LF	56%	$19,000
P-22	Pilot Butte Parallel Transmission on Lafayette Avenue	Pipe Capacity	New Transmission Pipe for Hydraulic Performance	24-inch parallel new pipe in Lafayette Avenue between east of 12th Street and 8th Street	24-inch, 1400 LF	100%	$1,344,000
P-24	New and Upsize Bear Creek Well Transmission	Pipe Capacity	New and Upsize Transmission Pipe for Hydraulic Performance	18-inch new and upsized pipe to connect Bear Creek Wells Transmission to 15th Street	18-inch, 940 LF	100%	$894,000
P-25	Bear Creek Road Upsize 15th Street to McCartney Drive	Pipe Capacity	Upsize Transmission Pipe for Hydraulic Performance	12-inch upsized pipe in Bear Creek Road between McCartney Drive and 15th Street	12-inch, 490 LF	100%	$573,000
P-26	Bear Creek Road Connections	Pipe Capacity	New Distribution Pipe for Hydraulic Performance	12-inch and 8-inch new connections on Bear Creek Road between Cessna Drive and Janalee Place	8-inch to 12-inch, 1640 LF	38%	$786,000
PR-1C	Pipe Replacement Program Years 21 to 30	Pipe Replacement	-	Pipe replacement program	-	0%	$35,620,000
PS-5	Scott Pump Station	Facility Condition and Capacity	Pump Station Capital Maintenance	Condition Related Improvements to 3,000 Gallon Per Minute Pump Station (See Condition Assessment Project List for Additional Details)	-	0%	$1,465,000
T-2	Replacement Outback Reservoir 2	Facility Condition and Capacity	Replace Reservoir	New 7.0 million gallon prestressed concrete reservoir. Includes site development, mechanical, electrical, instrumentation and controls.	-	43%	$17,866,000
T-3	Outback Reservoir 3	Facility Condition	Reservoir Capital Maintenance	Condition Related Improvements to 3.6 Million Gallon Reservoir (See Condition Assessment Project List for Additional Details)	-	0%	$2,284,000

Project ID	Project Name	Project Category	Type of Improvement	Description	Recommended Sizing	Growth Allocation	Cost (2020 $)
T-6	College Reservoir 1	Facility Condition	Reservoir Capital Maintenance	Condition Related Improvements to 0.5 Million Gallon Reservoir (See Condition Assessment Project List for Additional Details)	-	0%	$987,000
T-7	College Reservoir 2	Facility Condition	Reservoir Capital Maintenance	Condition Related Improvements to 1.0 Million Gallon Reservoir (See Condition Assessment Project List for Additional Details)	-	0%	$944,000
T-8	Tower Rock Reservoir	Facility Condition	Reservoir Capital Maintenance	Condition Related Improvements to 1.0 Million Gallon Reservoir (See Condition Assessment Project List for Additional Details)	-	0%	$1,257,000
T-11	New Overturf Zone 5 Reservoir	Facility Capacity	New Reservoir	New 3.0 million gallon prestressed concrete reservoir. Includes site development, mechanical, electrical, instrumentation and controls.	-	100%	$9,009,000
V-2	New Zone 4B to 5 PRV	Facility Capacity	New PRV	Zone 4B to 5 PRV Bear Creek Road	-	38%	$155,000
V-3	New Zone 4F to 5D PRV	Facility Capacity	New PRV	Zone 4F to 5D PRV Summerfield Road	-	38%	$155,000
W-6	Outback Well 6	Facility Condition	Well Capital Maintenance	Condition Related Improvements to 1,100 Gallon Per Minute Well (See Condition Assessment Project List for Additional Details)	-	38%	$2,660,000
W-7	Outback Well 7	Facility Condition	Well Capital Maintenance	Condition Related Improvements to 1,300 Gallon Per Minute Well (See Condition Assessment Project List for Additional Details)	-	0%	$730,000
W-8	New Outback Well	Facility Capacity	New Well	1 New 185 horsepower shallow well. Includes well drilling, casing, and pump and standby power generator. Also includes site development, building systems, mechanical, electrical, instrumentation and controls.	-	100%	$2,711,000
W-9	Copperstone Well	Facility Condition	Well Capital Maintenance	Condition Related Improvements to 950 Gallon Per Minute Well (See Condition Assessment Project List for Additional Details)	-	0%	$1,676,000
W-12	New Overturf Zone 5 Well	Facility Capacity	New Well	1 New 200 horsepower mid depth well. Includes well drilling, casing, and pump and standby power generator. Also includes site development, building systems, mechanical, electrical, instrumentation and controls.	-	100%	$3,386,000
W-18	Pilot Butte Well 4	Facility Condition	Well Capital Maintenance	Condition Related Improvements to 1,150 Gallon Per Minute Well (See Condition Assessment Project List for Additional Details)	-	0%	$774,000
W-19	Rock Bluff Well 1	Facility Condition	Well Capital Maintenance	Condition Related Improvements to 750 Gallon Per Minute Well (See Condition Assessment Project List for Additional Details)	-	0%	$812,000
W-20	Rock Bluff Well 3	Facility Condition	Well Capital Maintenance	Condition Related Improvements to 800 Gallon Per Minute Well (See Condition Assessment Project List for Additional Details)	-	0%	$830,000
W-22	Shilo Well	Facility Condition	Well Capital Maintenance	Condition Related Improvements to 1,200 Gallon Per Minute Well (See Condition Assessment Project List for Additional Details)	-	0%	$1,926,000
W-26	New Purcell Paula Zone 5 Well 1	Facility Capacity	New Well	New 300 horsepower mid depth well. Includes well drilling, casing, and pump and standby power generator. Also includes site development, building systems, mechanical, electrical, instrumentation and controls.	-	100%	$4,321,000
W-27	New Purcell Paula Zone 5 Well 2	Facility Capacity	New Well	New 300 horsepower mid depth well. Includes well drilling, casing, and pump and standby power generator. Also includes site development, building systems, mechanical, electrical, instrumentation and controls.	-	100%	$4,321,000
O-8B	Water System Master Plan Update #3	Planning/Conservation	-	Third update to Water System Master Plan	-	38%	$1,000,000
O-9	Beyond 2040 Conservation Program	Planning/Conservation	-	Continuation of conservation program	-	38%	$7,998,000
						Total	$121,099,000

6.8 Summary

The Capital Improvement Plan identifies projects to address existing system condition and hydraulic capacity deficiencies and serve future growth. It includes recommendations to provide capacity through the 20-year growth projections, which are based on historic demands. However, the improvement timeline is spread beyond 20 years due to constraints in funding and staff resource availability to implement the plan. Recommended projects are divided across three timeframes, those within the 10-year, 20-year, and beyond 20-year horizon.

Some of the projects, such as new supply and storage may need to be accelerated to meet demands and other improvements deferred to stay within budget. Or projects may be delayed if demands are lower than projected, for example due to the continuing trend of decreasing per capita demands, or success in implementation of increased conservation program efforts. Projects should be evaluated annually through City reviews of demand growth, available budget, and where development is occurring.

The projects prioritized over the next 10 years are intended to address facility condition and piping condition and capacity deficiencies. There are several condition projects at current facilities that include the Awbrey Pump Station, Outback Reservoir 1, Awbrey Reservoir, Outback Wells 1 and 2, and the River Wells. Included in facility condition projects is the decommissioning of the Outback Contact Time (CT) Basin. The intent is that the contact time requirements can be met by Outback Reservoir 1, or the Outback Facility Plan will identify another configuration to meet contact time. Additionally, interior coating is slated for the Rock Bluff Reservoir and Outback Reservoir 2.

Also included in the 10-year horizon are some major piping projects including a new 30-inch Awbrey transmission main, and upsizing portions of piping along Newport Avenue. Many smaller pipe projects to address fire flow deficiencies and a yearly pipe replacement program are planned. Planning projects include updates to this iWSMP and the WMCP and an Outback Facility Plan along with additional improvements at Outback including pretreatment that would allow the City to continue operating in the event of a wildfire or other water quality event, incorporation of required federal security recommendations, and land acquisition for the recommended facilities. Future planning projects could include an analysis and possible implementation of hydropower generation that would work in conjunction with pretreatment. Implementation of the expanded conservation program and Standards and Specifications document are planned for the 2021-2030 timeframe as well.

Projects focus on replacing and installing new pipe to address distribution system deficiencies and work towards a greater annual pipe replacement rate to attain a program more consistent with expected pipe replacement life cycles. Considerable investment in existing infrastructure will be required at most existing facilities to address deferred maintenance and extend useful life. New facilities will serve growth and be required as demands increase. The total CIP cost is approximately $391 million (in 2020 dollars), with $133 million scheduled for 2021-2030, $137 million in years 2031-2040 and $121 million beyond 2040.


FIGURE 6-1
City of Bend
Integrated
Water System Master Plan
CIP Projects
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Legend
Reservoir Projects
2021 - 2030
2031 - 2040
Beyond 2040
Pump Station Projects
2021 - 2030
2031 - 2040
Beyond 2040
Well Projects
2021 - 2030
2031 - 2040
Beyond 2040
Pipe Projects
2021-2030
2031-2040
Beyond 2040
Pipe Replacement
Replacement Score of 3.5 - 7.5
Replacement Score of 3
Valve Projects
2021 - 2030
2031-2040
Beyond 2040
Existing Water Pipe Diameter
<= 12"
>= 14"
Existing PRV
2021-2030 Projects Not Shown on Figure
O-1 Outback Facility Plan
O-2 Conservation Program
O-4 Hydropower Feasibility Study
O-5 Water System Master Plan Update #1
O-6 Water Management and Conservation Plan Update #1
O-10 Traffic Signal Improvements
O-11 Outback Land Acquistion
O-12 Standards and Specs Update
PR-1A Pipe Replacement Program
TR-1 Pretreatment
2031-2040 Projects Not Shown on Figure
O-3 Conservation Program
O-7 Water Management and Conservation Plan Update #2
O-8A Water System Master Plan Update #2
PR-1B Pipe Replacement Program
Beyond 2040 Projects Not Shown on Figure
O-8B Water System Master Plan Update Update #3
O-9 Conservation Program
PR-1C Pipe Replacement Program
T-8 TOWER ROCK RESERVOIR
W-9 COPPERSTONE WELL
T-7 COLLEGE RESERVOIR 2
T-6 COLLEGE RESERVOIR 1
T-5 AWBREY RESERVOIR
PS-1 AWBREY PUMP STATION
PS-2 COLLEGE PUMP STATION
T-11 & W-12 NEW ZONE 5 RESERVOIR & WELL
T-10 EXISTING RESERVOIRS
T-9 NEW ZONE 4 RESERVOIR
OVERTURF
OUTBACK SITE
T-2 & T-18
PS-5 SCOTT ST PUMP STATION
W-11 RIVER WELL 2
W-10 RIVER WELL 1
W-23 & W-24 NEW WILSON WELLS
W-25 WESTWOOD WELL
V-6 4A to 4I PRV
T-16 & PS-4 WESTWOOD RESERVOIR & PUMP STATION
PS-3 TETHEROW PUMP STATION
W-21 W-19 W-20
T-15 & T-17
ROCK BLUFF
V-1 2A to 3C PRV
PS-6 MURPHY PUMP STATION
W-22 SHILO WELL
PILOT BUTTE
W-16 W-17 T-13 T-12 W-18 T-14
W-26 & W-27 NEW PURCELL PAULA WELLS
W-15 NEW BEAR CREEK WELL ZONE 4B
W-13 & W-14 BEAR CREEK WELL 1 & 2
V-2 4B to 5 PRV
V-3 4F to 5D PRV
V-4 4F to 6B PRV
V-5 6 to 7C PRV
Data Sources:
City of Bend
Coordinate System: NAD 1983 StatePlane Oregon South FIPS 3602 Feet Intl
Projection: Lambert Conformal Conic
Datum: North American 1983
Disclaimer: The City of Bend makes no representations, express or implied, as to the accuracy, completeness and timeliness of the information displayed. This map is not suitable for legal, engineering, or surveying purposes. Notification of any errors is appreciated.
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September 2021
19-2484

Section **7**

Section 7

Financial Plan

7.1 Introduction

This financial plan was prepared by FCS Group to determine the funding requirements to provide water service to the City of Bend (City) customers. The purpose of this section is to document the City's financial plan to fund ongoing system operations and the escalated costs of the capital improvement plan (CIP) recommended in Section 6. The plan demonstrates the ability of the water utility to maintain sufficient funds to construct, operate, and manage the system on a continuing basis based on a 30-year implementation timeframe of the CIP.

7.2 Financial Structure

This section summarizes the current financial structure used as the baseline for the capital financing strategy and financial forecast developed for this iWSMP.

7.2.1 Elements of a Financial Plan

The water utility is responsible for funding all of its costs. The primary source of funding is derived from ongoing monthly charges for service, with additional revenues coming from system development charges, installation fees, reconnect fees, and other miscellaneous revenue. The City controls the level of user charges and, subject to the City Council, can adjust user charges as needed to meet financial objectives.

The financial plan can only provide a qualified assurance of financial feasibility if it considers the total system costs of providing water services, both operating and capital. To meet these objectives, the following elements have been completed.

7.2.1.1 Capital Funding Plan

The Capital Funding Plan identifies the total CIP obligations of the planning period. The plan defines a strategy for funding the CIP, including an analysis of available resources from rate revenues, existing reserves, connection charges, debt financing, and any special resources that may be readily available (e.g., grants, developer contributions, etc.). The capital funding plan impacts the financial plan through the capital financing strategy, which incorporates the use of debt financing (resulting in annual debt service) and assumed rate revenue available for capital funding.

7.2.1.2 Financial Forecast

The Financial Forecast identifies future annual non-capital costs associated with the operation, maintenance, and administration of the water system. Included in the financial plan is a reserve analysis that forecasts cash flow and fund balance activity, along with testing for satisfaction of actual or recommended minimum fund balance policies. The financial plan ultimately evaluates the sufficiency of utility revenues in meeting all obligations, including cash uses such as operating expenses, debt service, capital outlays, and reserve contributions, as well as any coverage requirements associated with long-term debt. The plan also identifies the future adjustments required to fully fund all utility obligations in the planning period.

7.3 Capital Funding Plan

The CIP and operating project costs total approximately$164 million (escalated) over the 10-year planning horizon. The full CIP in **Section 6** plus some additional operating project costs is $581 million (escalated) and assumed over a 30-year implementation period in this financial plan. The historical 10-year average of the engineering news record (ENR) construction cost index (2.7 percent annually) has been applied to capital costs to estimate the project cost at the year of planned spending. The ENR is an index that tracks how the cost of material, labor and other factors have changed over time. Applying an ENR index is common practice to estimate the anticipated capital spending during the year of planned construction to determine total resource needs in any given year. It should be noted that the demand projections in **Section 2** and analysis in **Section 4** assume a 20-year planning period through 2040. However, due to funding and staffing constraints the CIP and financial plan are assumed for implementation over a longer, 30-year period.

A summary of the 10-year and 30-year CIP is shown in **Table 7-1.** As shown, each year has varied capital cost obligations depending on construction schedules and infrastructure planning needs. Approximately 28 percent of the escalated capital costs are included in the 10-year planning period. **Table 7-2** provides more detail for each fiscal year (FY) of the 10-year CIP.

Table 7-1|10- and 30-Year CIP (Escalated $ in millions)

Fiscal Year (FY)	Capital Expenditures
FY 2021	$5.3
FY 2022	$11.5
FY 2023	$13.9
FY 2024	$18.4
FY 2025	$32.1
FY 2026	$24.6
FY 2027	$11.5
FY 2028	$8.6
FY 2029	$16.2
FY 2030	$21.8
10-Year Total	**$163.9**
FY 2031 - FY 2050	$416.9
30-Year Total	**$580.8**

Table 7-2|10 Year CIP (Escalated $ in millions)

Project Type	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027	FY 2028	FY 2029	FY 2030	Total
Capacity	$0	$0	$0.1	$0.1	$0.8	$0	$0.8	$0.4	$7.9	$9.9	$20.0
Condition	$0.5	$5.0	$10.1	$16.3	$29.3	$22.5	$10.1	$7.6	$7.7	$7.8	$116.9
Planning/Conservation	$4.8	$6.5	$3.7	$2.0	$2.0	$2.1	$0.6	$0.6	$0.6	$4.1	$27.0
Total	**$5.3**	**$11.5**	**$13.9**	**$18.4**	**$32.1**	**$24.6**	**$11.5**	**$8.6**	**$16.2**	**$21.8**	**$163.9**

Hydraulic capacity projects are investments in the system to address existing fire flow, velocity, and pressure deficiencies as well as future improvements to provide capacity for growth. Condition projects address the changes to safety, structural and security standards over time as well as targeting undersized and substandard pipe to avoid failures and maintain consistent service. Additional detail related to the capital improvement program can be found in **Section 6** of this iWSMP.

7.3.1 Capital Financing Strategy

An ideal capital financing strategy would include the use of grants and low-cost loans when a debt issuance is required. However, these resources are very limited and competitive in nature and do not provide a reliable source of funding for planning purposes. It is recommended that the City pursue these funding avenues but assume bond financing to meet the needs for which the City's available cash resources are insufficient. Revenue bonds have been used as the debt funding instrument in this analysis. The capital financing strategy developed to fund the CIP identified in this iWSMP assumes the following funding resources:

- Accumulated cash reserves – The total amount of available operating and capital cash resources
- Transfers of excess cash (over minimum balance targets) from the Operating Fund – The total amount of annual cash contributions available to transfer to the capital fund after all operating and debt service obligations are met;
- System development charge revenues - A connection charge such as the City's system development charge refers to a one-time charge imposed on new customers as a condition of connecting to the water system.;
- Interest earned on capital fund balances and other miscellaneous capital resources; and
- Bond financing - Revenue bonds are commonly used to fund utility capital improvements. The debt is secured by the revenues of the issuing utility. With this limited commitment, revenue bonds typically bear higher interest rates than FFC loans and may require security conditions related to the maintenance of dedicated reserves (a bond reserve) and/or financial performance (added bond debt service coverage). The City agrees to satisfy these requirements as a condition of bond sale.

- Based on information provided by the City, the water utility began FY 2021 with $58.3M in total funds.

The cash resources described above are anticipated to fund 65 percent of the 10-year CIP and 75 percent of the 30-year CIP. The remaining funding will come from new debt obligations of nearly $58 million in the initial 10-year period, followed by an additional $86.4 million through FY 2050.

Table 7-3 presents the corresponding 30-year capital financing strategy.

Table 7-3|30-Year Capital Funding Strategy (Escalated $ in millions)

Year	Capital Expenditures	Revenue Bond Financing	Cash Funding	Total Financial Resources
FY 2021	$5.3	$0	$5.3	$5.3
FY 2022	$11.5	$0	$11.5	$11.5
FY 2023	$13.9	$0	$13.9	$13.9
FY 2024	$18.4	$0	$18.4	$18.4
FY 2025	$32.1	$0	$32.1	$32.1
FY 2026	$24.6	$23.9	$0.7	$24.6
FY 2027	$11.5	$0	$11.5	$11.5
FY 2028	$8.6	$0	$8.6	$8.6
FY 2029	$16.2	$16.2	$0	$16.2
FY 2030	$21.8	$17.7	$4.1	$21.8
Subtotal	**$163.9**	**$57.8**	**$106.1**	**$163.9**
FY 2031 – FY 2050	$416.9	$86.4	$330.6	$416.9
Total	**$580.8**	**$144.2**	**$436.7**	**$580.8**

7.3.2 Other Alternative Financing Resources

This section outlines various grant and low-cost loan opportunities available to the City through federal and state agencies to fund the CIP identified in the iWSMP.

7.3.2.1 Grants and Low-Cost Loans

Historically, federal and state grant programs were available to local utilities for capital funding assistance. However, these assistance programs have been mostly eliminated, substantially reduced in scope and amount, or replaced by loan programs. Remaining miscellaneous grant programs are generally lightly funded and heavily subscribed. Nonetheless, even the benefit of low-interest loans makes the effort of applying worthwhile. Grants and low-cost loans for Oregon utilities are available from the Department of Environmental Quality's Clean Water State Revolving Fund Program (CWSRF). This program supports communities by funding projects that improve water quality and environmental outcomes for the State of Oregon. CWSRF has three application deadlines in 2021 with applications available online.

In addition, federal assistance is available through the Water Infrastructure Funding Innovation Act (WIFIA). WIFIA was established in 2014 as a federal credit program administered by the Federal Environmental Protection Agency for eligible water and wastewater infrastructure projects. Additional information regarding funding availability and the application process can be found online.

7.4 Financial Forecast

The financial forecast, or revenue requirement analysis, forecasts the amount of annual revenue that needs to be generated by user rates. The analysis incorporates operating revenues, O&M expenses, debt service payments, rate-funded capital needs, and any other identified revenues or expenses related to operations. The objective of the financial forecast is to evaluate the sufficiency of the current level of rates. In addition to annual operating costs, the revenue needs also include debt covenant requirements and specific fiscal policies and financial goals of the City.

The analysis determines the amount of revenue needed in a given year to meet that year's expected financial obligations. For this analysis, two revenue sufficiency tests have been developed to reflect the financial goals and constraints of the City: cash needs must be met; and debt service coverage requirements must be realized. In order to operate successfully with respect to these goals, both tests of revenue sufficiency must be met.

7.4.1 Cash Test

The cash flow test identifies all known cash requirements for the City in each year of the planning period. Typically, these include O&M expenses, debt service payments, rate-funded system reinvestment funding or directly funded capital outlays, and any additions to specified reserve balances. The total annual cash needs of the City are then compared to projected cash revenues using the current rate structure. Any projected revenue shortfalls are identified, and the rate increases necessary to make up the shortfalls are established.

7.4.2 Coverage Test

The coverage test is based on a commitment made by the City when issuing revenue bonds and some other forms of long-term debt. For the purposes of this analysis, revenue bond debt is assumed for any needed debt issuance. As a security condition of issuance, the City would be required per covenant to agree that the revenue bond debt would have a higher priority for payment (a senior lien) compared to most other expenditures; the only outlays that are higher in the bond declaration flow of funds payment order are O&M expenses. Debt service coverage is expressed as a multiplier of the annual revenue bond debt service payment. The current rate covenant for the City's current outstanding bonds states the net revenue generated in any fiscal year must at least equal:

a) 1.25 times annual bond debt service due in that fiscal year,

b) 1.15 times annual bond debt service due in that fiscal year, excluding SDC fees,

c) 1.0 times the annual bond debt service due in that fiscal year for any subordinated obligations (e.g., low interest loans) and d) any amounts owed by the City to a credit provider for surety premium payments. The excess cash flow derived from the added coverage, if any, can be used for any purpose, including funding capital projects.

The City has a fiscal policy for the water fund of maintaining a minimum debt coverage ratio of 1.50 or "at a level sufficient to protect the credit rating of the water…system." Along with monitoring the required debt ratios identified in the bond covenant, the financial analysis uses and satisfies the higher 1.50 minimum city policy target.

In determining the annual revenue requirement, both the cash and coverage sufficiency test must be met, and the test with the greatest deficiency drives the level of needed rate increase in any given year.

7.4.3 Current Financial Structure

The City maintains a fund structure and implements financial policies that target management of a financially viable and fiscally responsible water system.

7.4.3.1 Fiscal Policies

The fiscal policies of the City include reserve policies specifically for the water, water reclamation and stormwater funds. A brief summary of the City's water ending fund balance and reserve requirement policies are discussed below. Fiscal policies are adopted by City Council and reviewed and amended as needed.

7.4.3.1.1 Operating Undesignated Reserves

Operating undesignated reserves are designed to provide a liquidity cushion to ensure that adequate cash working capital will be maintained to deal with significant cash balance fluctuations, such as seasonal fluctuations in billings and receipts, unanticipated cash expenses, or lower than expected revenue collections. Like other types of reserves, operating reserves also serve another purpose: they help smooth rate increases over time. Target funding levels for an operating reserve are generally expressed as a certain number of days of O&M expenses, with the minimum requirement varying with the expected revenue volatility. Industry practice for utility operating reserves ranges from 30 days to 120 days of O&M expenses, with the lower end more appropriate for utilities with stable revenue streams and the higher end more appropriate for utilities with significant seasonal or consumption-based fluctuations. The City's current policy is to maintain operating undesignated reserves of at least 25 percent or 3 months (90 days) of the operating budget for the water fund.

7.4.3.1.2 Rate Stabilization Reserves

Rate stabilization reserves are cash reserves that can mitigate the impacts of occasional revenue shortfalls. Revenue shortfalls can occur because of several factors, including weather factors economic conditions, increased water conservation, or other unforeseen circumstances. Rate stabilization reserves can protect against or help smooth out revenue volatility resulting from these factors and help ensure adequate fiscal resources during such times that could otherwise require large rate spikes. The City's current water fund policy is to maintain this reserve at no less than $1.5 million.

7.4.3.1.3 Capital Fund

A capital contingency reserve is an amount of cash set aside in case of an emergency should a piece of equipment or a portion of the utility's infrastructure fail unexpectedly. The reserve also could be used for other unanticipated capital needs, including capital project cost overruns. Industry practices range from maintaining a balance equal to 1.00 to 2.00 percent of fixed assets, an amount equal to a 5-year rolling average of CIP costs, or an amount determined sufficient to fund equipment failure (other than catastrophic failure). The final target level should balance industry standards with the risk level of the City. The City currently aims to maintain a residual capital balance of $5.0 million. This value was determined to be sufficient in the event of an equipment failure by the City.

7.4.3.1.4 Debt Service Reserves

Debt service reserves are reserves used to pay debt service if revenues are insufficient to satisfy annual debt service requirements. Most often, this reserve is established as a legal covenant of a debt issuance and is used in whole or in part to pay debt service in the event of a revenue shortfall. A debt service reserve is most common for revenue bond issues but may be required or voluntarily established by the City for other types of subordinate indebtedness. The City currently does not have any required debt service reserves.

The City's fiscal policies for the water fund note that the ending fund balance and reserves will be prioritized as follows:

- Required debt service reserves
- Operating reserves
- Rate stabilization reserves and
- Repair and replacement reserves

In the event that reserve funds decrease to levels below the levels established by policy, the City will develop a plan to restore reserves to the required levels. Ideally, the minimum reserve balances shall be replenished in the following year with replenishment no longer than five years.

7.4.3.1.5 System Reinvestment

System reinvestment funding promotes system integrity through reinvestment in the system. Target system reinvestment funding levels are commonly linked to annual depreciation expense as a measure of the decline in asset value associated with routine use of the system. Particularly for utilities that do not already have an explicit system reinvestment policy in place, implementing a funding level based on full depreciation expense could significantly impact rates. A common alternative benchmark is annual depreciation expense net of debt principal payments on outstanding debt. This approach recognizes that customers are still paying for certain assets through the debt component of their rate and intends to avoid simultaneously charging customers for an asset and its future replacement. The specific benchmark used to set system reinvestment funding targets is a matter of policy that must balance various objectives, including managing rate impacts, keeping long-term costs down, and promoting "generational equity" (i.e., not excessively burdening current customers with paying for facilities that will serve a larger group of customers in the future).

The utility is not currently funding a dedicated annual budget account line item for system reinvestment, nor has a specified funding amount been included for system reinvestment in this analysis. Rather, the City directs the remaining revenues after the O&M and debt service expenses have been satisfied to first fund the operating fund target and then capital needs. As a result, rate revenues do contribute to the funding of capital projects, but the level of funding is not consistent from year to year. Over the ten-year rate setting period, capital funding from rates varies from $3.8 million to $6.1 million depending on the year. While the City does not have a dedicated annual budget line-item funding provision targeted, they do aim to cash fund all projects that are repairing or replacing existing infrastructure. It is recommended that the City consider a dedicated rate funding system reinvestment strategy in the future to smooth rate impacts of cash-funding repair and replacement projects over the long-term.

7.4.3.2 Financial Plan

The financial plan is established from the 2021-2023 biennial budget documents along with other key factors and assumptions to develop a complete portrayal of the City's annual financial obligations for the water utility. The following is a list of the key revenue and expense factors and assumptions used to develop the financial forecast.

- Operational Revenue – The City has two main revenue sources: 1) water service charges (rate revenue); and 2) miscellaneous (non-rate) revenue. FY 2021 rate revenues are based on the City's year-end estimate utilizing the trends of year-to-date actuals with customer growth added for future years. In the event of a forecasted annual shortfall, rate revenue can be increased to meet the annual revenue requirement. For the purpose of this financial forecast, non-rate revenues are forecast to increase with customer growth or not escalate depending on the nature of the revenue.

- System Development Charge Revenue – the existing connection charges are applied to the projected new connections to forecast revenue. Based on the growth assumptions described above, the connection charge will generate an average of $3.5 million annually from FY 2021-FY 2030. This equates to an average of 572 new connections per year. Connection charge revenue is directed towards annual capital needs.

- **Growth** – Rate revenue is escalated based on the population growth rates developed by the City in their ten-year outlook. The annual growth rate is projected to be 1.42 percent from FY 2021-FY 2025 before dropping to 1.00 percent annually for the remainder of the forecast. It should be noted that the population growth rate assumed for the financial analysis is projected at lower rates than the water system growth discussed in **Section 2**. Growth rates for the financial projections are lower than those used for future water demand to be conservative from a revenue generation perspective and not overestimate financial revenues.

- **Expenses** – O&M expense projections are based on the 2021-2023 biennial budget and forecasted to increase with general cost inflation of 2.20 percent, labor cost inflation of 4.31 percent, average benefit cost inflation of 6.85 percent, electricity cost inflation of 3.40 percent, chemical cost inflation of 4.40 percent and internal transfer cost inflation averaging 6.47 percent.

- **Existing Debt** – The City currently has one outstanding 2016 Series revenue bond with full repayment planned for FY 2037 and three full faith and credit loans (FF&C), one with full repayment in FY 2021, the second with full repayment in FY 2031 and the third planned for full repayment by FY 2040. Annual debt service payments on existing debt average $4.2 million annually through FY 2037 when they drop to $93,000 annually for the remaining term on the final FF&C loan.

- **Future Debt** – The capital funding strategy developed for this iWSMP forecasts the need for two debt issuances within the ten-year rate setting period: $23.9 million in new debt proceeds in FY 2026, followed by $33.9 million in FY 2029. In order to fully fund the capital program identified in this iWSMP, $86.4 million in additional debt issuances are required from FY 2031-FY 2050. Annual new debt service payments are forecast to increase from $2.0 million with the first issuance to a maximum of $11.3 million in FY 2045. The analysis performed assumes revenue bond financing.

- **Revenue Bond Assumptions** – Future debt is assumed to be revenue bonds each with a 20-year term, a 5.00 percent interest rate and a 2.00 percent issuance cost.

- **Transfer to Capital** – Any Operating Fund balance above the minimum requirement is assumed to be available to fund capital projects and projected to be transferred to the Capital Fund each year. The FY 2021 Operating Fund balance is expected to end the year at 90 days of O&M expenses, or $3.2 million. The Capital Fund balance is expected to end the year at $57.3 million.

Although the financial plan is completed for the 30-year time horizon of this iWSMP, the rate strategy focuses on the shorter-term planning period of FY 2021 through FY 2030. As is the current practice, the City will revisit the proposed rates each year to ensure that the rate projections developed remain adequate. Any significant changes should be incorporated into the financial plan and future rates should be adjusted as needed.

Table 7-4 summarizes the annual revenue requirements based on the forecast of revenues, expenditures, fund balances, and fiscal policies.

Table 7-4 | 10-Year Financial Forecast ($ in millions)

Revenue Requirement	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027	FY 2028	FY 2029	FY 2030
Revenues										
Rate Revenues (existing rates)	$20.6	$20.9	$21.2	$21.5	$21.8	$22.0	$22.2	$22.5	$22.7	$22.9
Non-Rate Revenues	$1.9	$1.6	$1.6	$1.6	$1.9	$1.8	$1.4	$1.3	$2.0	$1.6
Total Revenues	**$22.5**	**$22.5**	**$22.8**	**$23.1**	**$23.7**	**$23.8**	**$23.6**	**$23.8**	**$24.7**	**$24.5**
Expenses										
Cash Operating Expenses	$12.9	$14.7	$15.1	$16.9	$17.1	$18.6	$18.9	$19.7	$21.1	$21.2
Existing Debt Service	$5.6	$4.2	$4.2	$4.2	$4.2	$4.2	$4.2	$4.2	$4.2	$4.2
New Debt Service	$0	$0	$0	$0	$0	$1.3	$2.0	$2.0	$3.9	$4.7
Total Expenses	**$18.5**	**$18.9**	**$19.3**	**$21.1**	**$21.3**	**$24.1**	**$25.1**	**$25.9**	**$29.2**	**$30.1**
Total Surplus (Deficiency)	**$4.0**	**$3.6**	**$3.5**	**$2.0**	**$2.4**	**($0.3)**	**($1.5)**	**($2.1)**	**($4.5)**	**($5.6)**
Proposed Rate Strategy	**0.0%**	**3.0%**	**3.0%**	**4.0%**	**4.0%**	**4.0%**	**4.5%**	**4.5%**	**4.5%**	**4.5%**
Cash Flow after Rate Increase	**$4.0**	**$4.2**	**$4.8**	**$4.2**	**$5.6**	**$3.9**	**$4.0**	**$4.7**	**$3.8**	**$4.1**

The financial forecast indicates that the utility is currently covering all financial obligations under existing rates, however as the City prepares to fund the needed capital improvements identified in the iWSMP, rates will need to increase annually to support the capital funding plan. The financial plan proposes the following rate increases and debt issuances to satisfy the identified future obligations of the utility:

- 3.0 percent in FY 2022 & FY 2023, 4.0 percent from FY 2024 – FY 2026, followed by 4.5 percent through FY 2030
- Two new revenue bonds proposed in the ten-year planning period:
  - $23.9M revenue bond in FY 2026 and $33.9M revenue bond in FY 2029.
  - Annual new debt service payments are forecast to increase from $2.0 million with the first issuance to $4.7 million by the second new debt issuance. Including this new debt, total debt service will increase from $5.6 million in FY 2021 to $8.9 million by FY 2030.

7.4.3.3 City Reserves

Table 7-5 shows a summary of the projected Undesignated Operating Reserve and residual Capital Reserve ending balances through FY 2030 based on the rate forecasts presented above. The undesignated operating reserve is maintained at a minimum of 3 months of O&M expenses, and the capital reserve balance fluctuates depending on the level of CIP funded; however, it never falls below the minimum target of $5.0 million.

Table 7-5|Ending Reserve Balance Summary ($ in millions)

Ending Reserve Balances	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027	FY 2028	FY 2029	FY 2030
Undesignated Operating	$3.2	$3.6	$3.7	$4.2	$4.2	$4.6	$4.7	$4.9	$5.2	$5.2
Capital	$57.3	$53.2	$47.8	$37.1	$14.7	$20.5	$16.1	$15.3	$39.7	$25.5
Total	**$60.5**	**$56.8**	**$51.5**	**$41.3**	**$18.9**	**$25.1**	**$20.8**	**$20.2**	**$44.9**	**$30.7**

7.5 Current and Projected Rates

The existing water rates include one rate structure that is applied to all customers. The minimum monthly charge is applied by meter size and does not include any water allowance. All water use is charged on a per 100 cubic foot basis.

The financial forecast discussed above indicates that the utility is currently covering all financial obligations under existing rates, however as the City prepares to fund the needed capital improvements identified in the iWSMP, rates will need to increase annually to support the capital funding plan. Rates are forecast to increase 3.0 percent in FY 2022 & FY 2023, 4.0 percent in FY 2024 – FY 2026, followed by 4.5 percent thereafter. **Table 7-6** shows the existing rates schedule and projected rates with increases applied uniformly to all rate components for all meter sizes.

Table 7-6|Current and Projected Schedule of Rates

Inside City	Existing Rates	Proposed Rates								
	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027	FY 2028	FY 2029	FY 2030
Annual Rate Increase		***3.0%***	***3.0%***	***4.0%***	***4.0%***	***4.0%***	***4.5%***	***4.5%***	***4.5%***	***4.5%***
3/4”	$23.60	$24.31	$25.04	$26.04	$27.08	$28.16	$29.43	$30.76	$32.14	$33.59
1”	$27.15	$27.96	$28.80	$29.96	$31.15	$32.40	$33.86	$35.38	$36.97	$38.64
1-1/2”	$35.93	$37.01	$38.12	$39.64	$41.23	$42.88	$44.81	$46.82	$48.93	$51.13
2”	$46.50	$47.90	$49.33	$51.31	$53.36	$55.49	$57.99	$60.60	$63.33	$66.17
3”	$74.74	$76.98	$79.29	$82.46	$85.76	$89.19	$93.21	$97.40	$101.78	$106.36
4”	$106.46	$109.65	$112.94	$117.46	$122.16	$127.05	$132.76	$138.74	$144.98	$151.50
6”	$194.57	$200.41	$206.42	$214.68	$223.26	$232.19	$242.64	$253.56	$264.97	$276.90
8”	$300.32	$309.33	$318.61	$331.35	$344.61	$358.39	$374.52	$391.37	$408.99	$427.39
10”	$423.75	$436.46	$449.56	$467.54	$486.24	$505.69	$528.45	$552.23	$577.08	$603.04
12”	$568.27	$585.32	$602.88	$626.99	$652.07	$678.16	$708.67	$740.56	$773.89	$808.71
All Water Use (per 100 cu. ft.)	$1.96	$2.02	$2.08	$2.16	$2.25	$2.34	$2.44	$2.55	$2.67	$2.79

7.6 Summary

The results of this analysis indicate that annual rate increases are needed to provide revenue sufficient to cover all financial obligations of the utility. Rate increases are proposed at 3.0 percent in FY 2022 & FY 2023, 4.0 percent from FY 2024 to FY 2026, followed by 4.5 percent through FY 2030.

The analysis performed in this section assumes revenue growth and expense inflationary factors discussed previously. If the forecasting factors change significantly, the existing rate strategy may need to be updated and revised.

The City will continue to review and update the key underlying assumptions that compose the multi-year financial plan at least annually, to ensure that adequate revenues are collected to meet the City’s total financial obligations.

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