



A place where families and businesses thrive.

CITY RECORDER USE ONLY:

AGENDA ITEM #: _____

MEETING DATE: _____

FINAL ACTION: _____

PLANNING COMMISSION STAFF REPORT

TO: *Planning Commission*

FROM: *Bryan Pohl, Community Development Director
Rich Blackmun, Engineering Division Manager
Dan Riordan, Senior Planner*

MEETING DATE: *April 18, 2022*

SUBJECT TITLE: *Water System Master Plan Update; File No. 311-22-000006-PLNG*

ACTION REQUESTED:

☐	Ordinance	☐	Order	☐	Resolution	☒	X Motion	☐	Informational
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X all that apply

ISSUE STATEMENT: City staff retained MurraySmith and Associates to update the City's 2010 Water System Master Plan (Plan). The review draft of the Water Master Plan is attached for Planning Commission review. MurraySmith has expertise preparing water master plans meeting state requirements. The Water Plan Master Plan update is attached for your review (Attachment A).

A water master plan is a type of facility plan that is addressed under Oregon Statewide Land Use Planning Goal 11 (Public Facilities) and the implementing Oregon Revised Statutes. Since Goal 11 pertains to a water master plan it is considered to be part of the local comprehensive plan. As such, the Planning Commission must review the plan for consistency with Goal 11 and the applicable policies in the comprehensive plan before adoption by City Council. Attachment B contains findings demonstrating compliance.

BACKGROUND: The Water Master Plan includes information about the City's water supply, distribution system, anticipated demand, and capital improvements required to serve anticipated development for the next twenty years. A local water system master plan must be consistent with the requirements of Oregon Administrative Rules, Oregon Statewide Land Use Planning 11 (Public Facilities) and the City's adopted Comprehensive Plan. As a supporting document to the City's Comprehensive Plan, the Planning Commission must review the Water Master Plan for consistency with applicable Comprehensive Plan goals and policies, conduct a public hearing and make a recommendation to City Council to adopt an ordinance adopting the Master Plan. Goal 11 requirements and applicable Comprehensive Plan goals and policies are briefly summarized below and described more fully in Attachment B.

Oregon Statewide Land Use Planning Goal 11 requires the City:

“To plan and develop a timely, orderly and efficient arrangement of public facilities and services to serve as a framework for urban and rural development.”

A timely, orderly and efficient arrangement of public facilities refers to a system or plan that coordinates the type, locations and delivery of public services to support existing and proposed land uses. Land uses are established by the City's Comprehensive Plan and implementing by the zoning map and Development Code.

The City's Comprehensive Plan includes three water service goals:

1. Water Facilities shall be designed and sized to serve the need of future land uses as designated on the Forest Grove Comprehensive Plan map.
2. Protect and restore the natural systems that underpin watershed health and hydrological integrity.
3. The Water Master Plan shall be incorporated as part of the Forest Grove Comprehensive Plan.

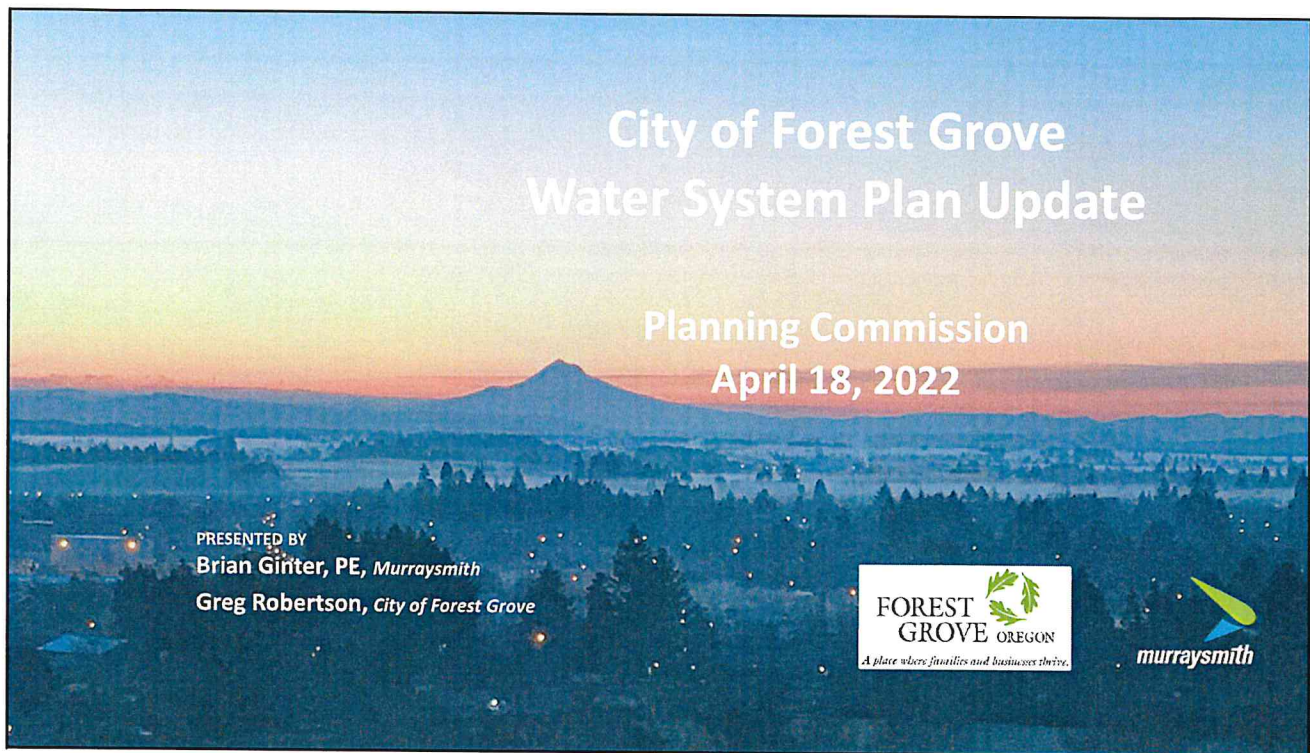
In addition to the goals above, the Comprehensive Plan includes several policies for the City's Water System. The policies most applicable to the Water Master Plan Update include:

1. A master plan including prioritized lists of capital improvement needs shall be adopted for provision of water services. This plan shall be based on future land use policies and needs.
2. The sizing of municipal water facilities shall follow land use plan designations and concentrate development close to the City Center.
3. The master plan element for water shall include design for adequate provision of these facilities for those areas designed in the land use plan for industrial use. The design requirements shall serve as the City standards for services to industrial areas.
4. The City of Forest Grove will develop a capital improvement program that will provide water for processing of agricultural products when economically feasible.
5. The Water Master Plan shall be designed for service to at least the year 2030 and be adopted as part of the Comprehensive Plan.

The goals and policies above are addressed in the adoption findings (Attachment B).

ATTACHMENT(s):

- A. Water System Master Plan Update (April 2022)
- B. Adoption Findings



1

Purpose of Water System Plan

-  Planning Resource for City Staff and Council
-  Document System History and Components
-  Outline plan for system improvements
-  Show financial impact of Capital Improvement Program
-  Meet Regulatory Requirements

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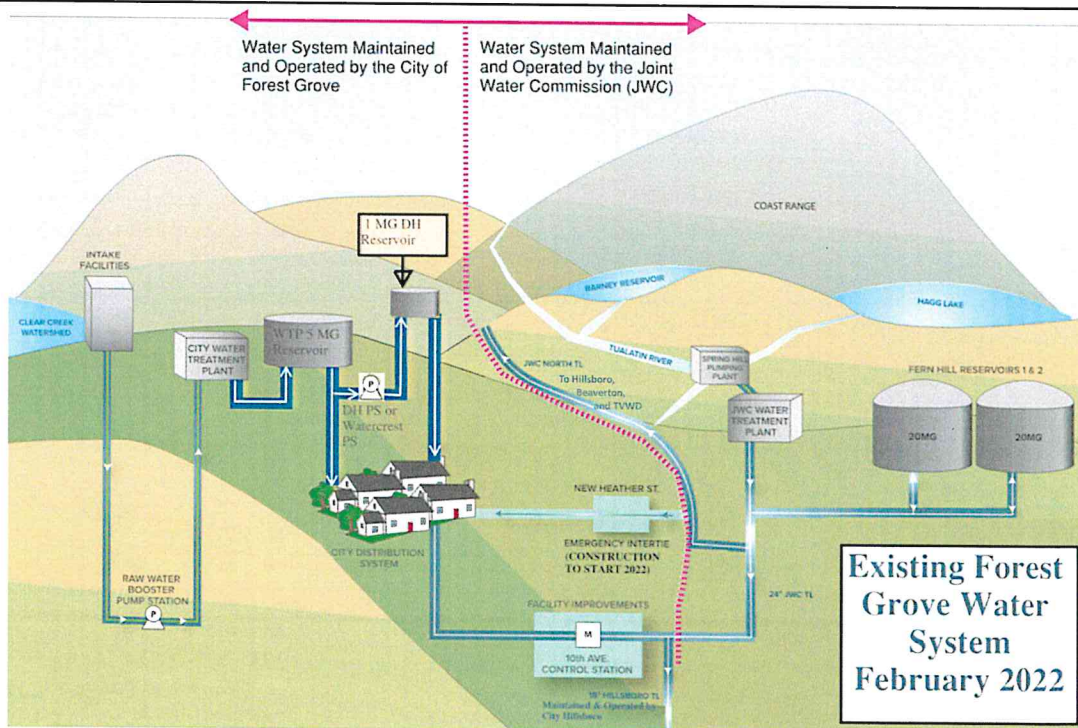
Water System Plan Contents



- Executive Summary
- 1 Introduction and Existing Water System
- 2 Water Requirements
- 3 Planning and Analysis Criteria
- 4 Water Supply Analysis
- 5 Distribution System Analysis
- 6 Seismic Resiliency Plan Summary
- 7 Capital Improvement Program

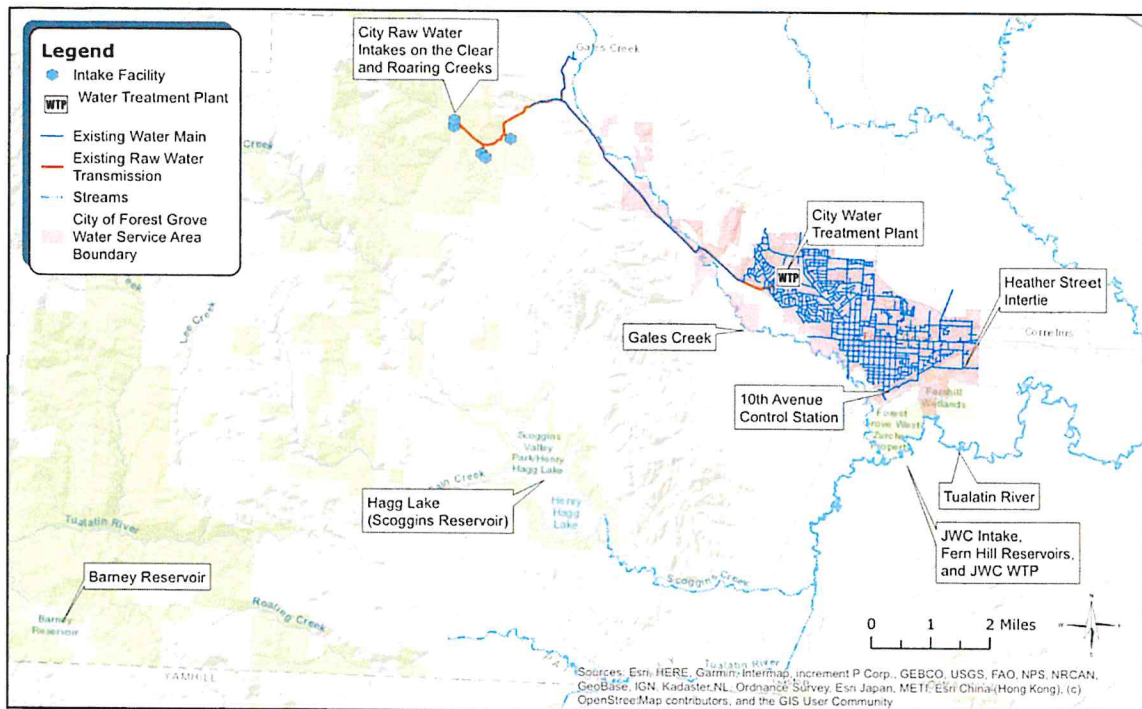
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Description of Water System



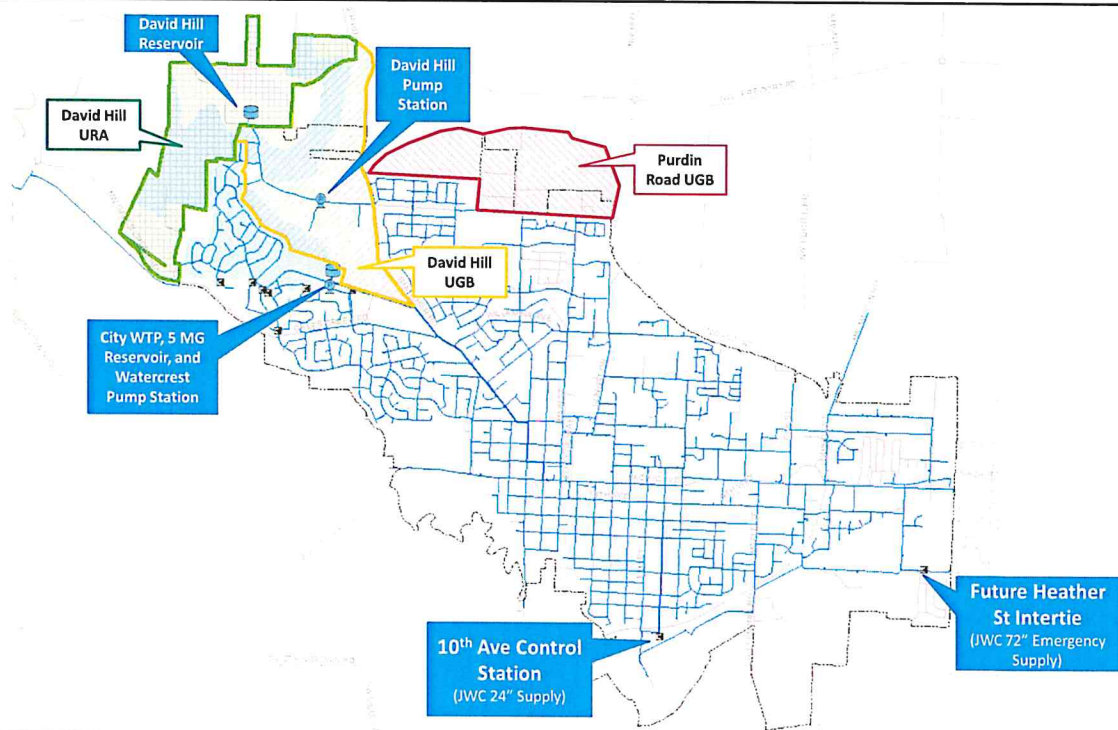
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Description of Water System



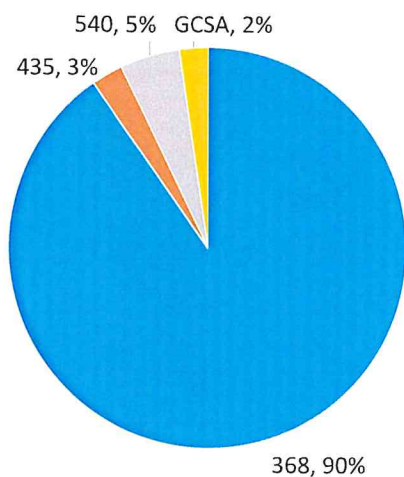
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Description of Water System



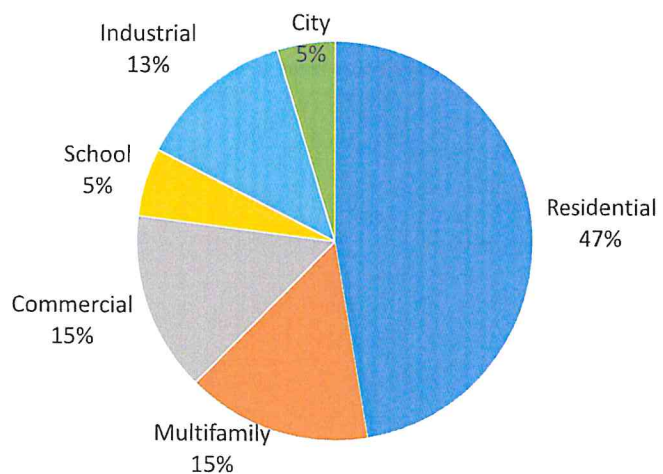
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Historical Demands (2018-2020)



ADD by Pressure Zone

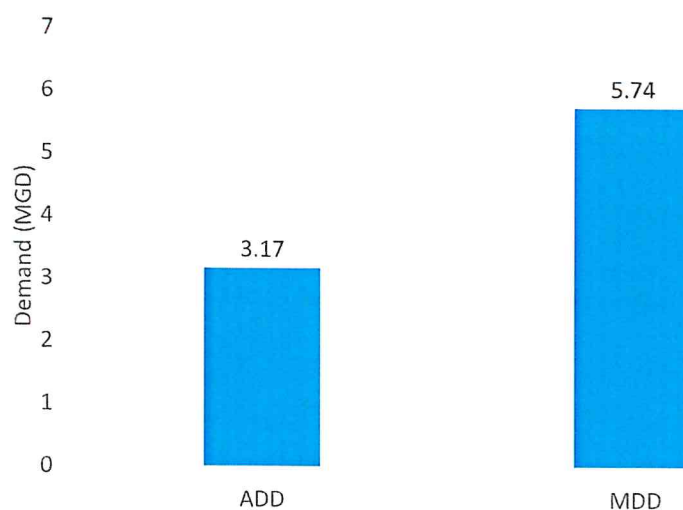
ADD= Average Day Demand



ADD by Customer Type

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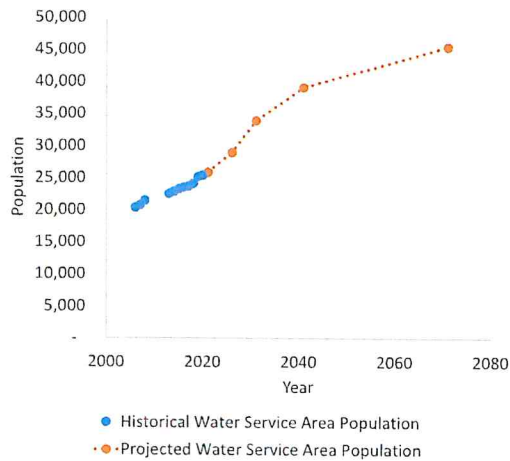
Historical Demands (2018-2020)



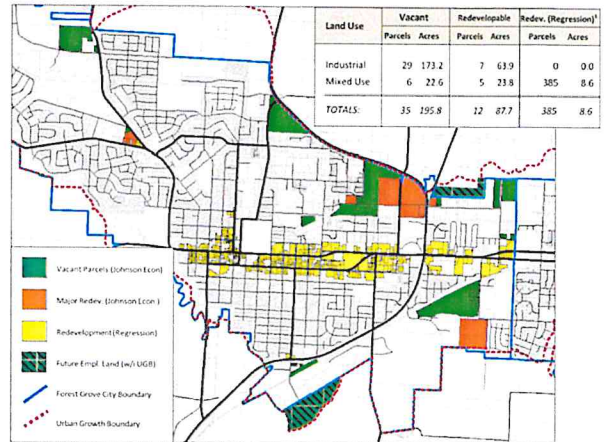
ADD= Average Day Demand
MDD = Max Day Demand

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Planning Data and Projections



Population Projections



Non-Residential Projections

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Water Conservation

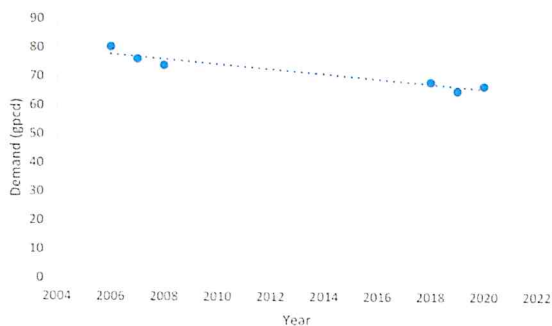


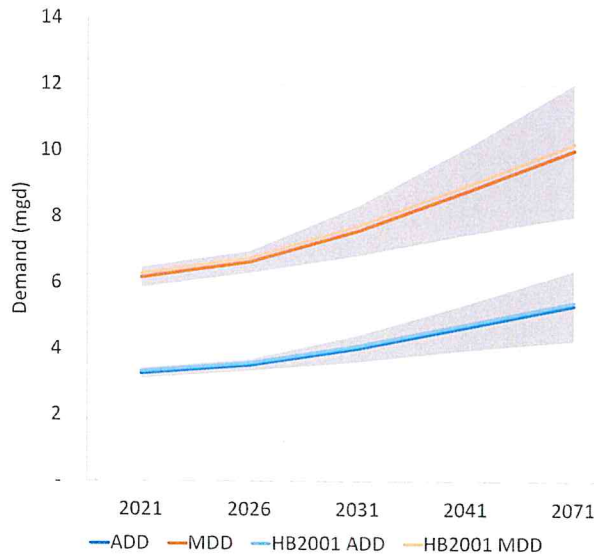
Figure 2-6 | Historical Residential Demand per Capita

JWC Water Management and Conservation Plan

- Distributes indoor and outdoor conservation items (low flow showerheads, hose nozzles, faucet aerators)
- Expanded water-efficient toilet rebate program
- Customer billing with water conservation messages
- Progressive tiered billing

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Middle Housing (HB2001) and Demand Uncertainty



Impact of HB2001:

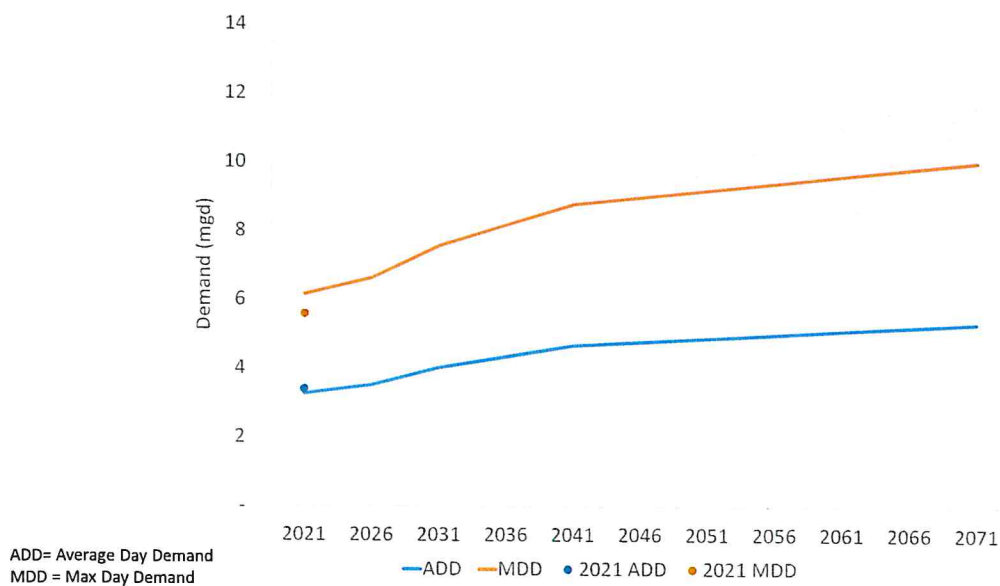
- Assumes 3% increase in density (increase in population)
- Only affects residential demands

Demand Uncertainty:

- +/- 5% for 5 year projections
- +/- 10% for 10 year projections
- +/- 15% for 20 year projections
- +/- 20% for 50 year projections

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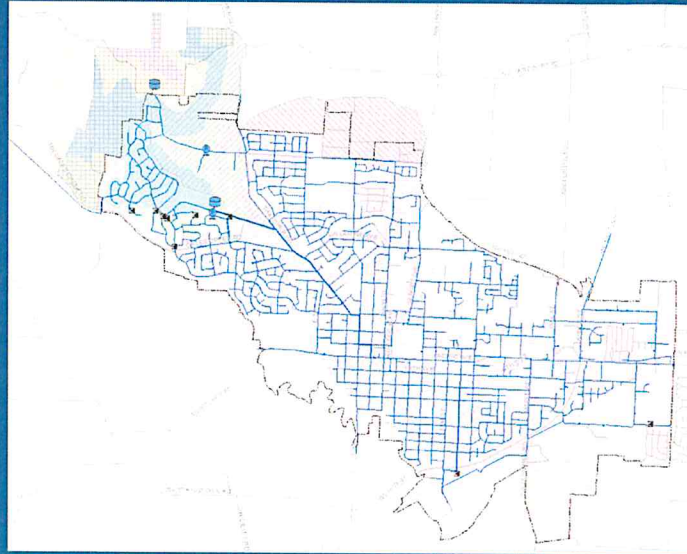
Demand Projections



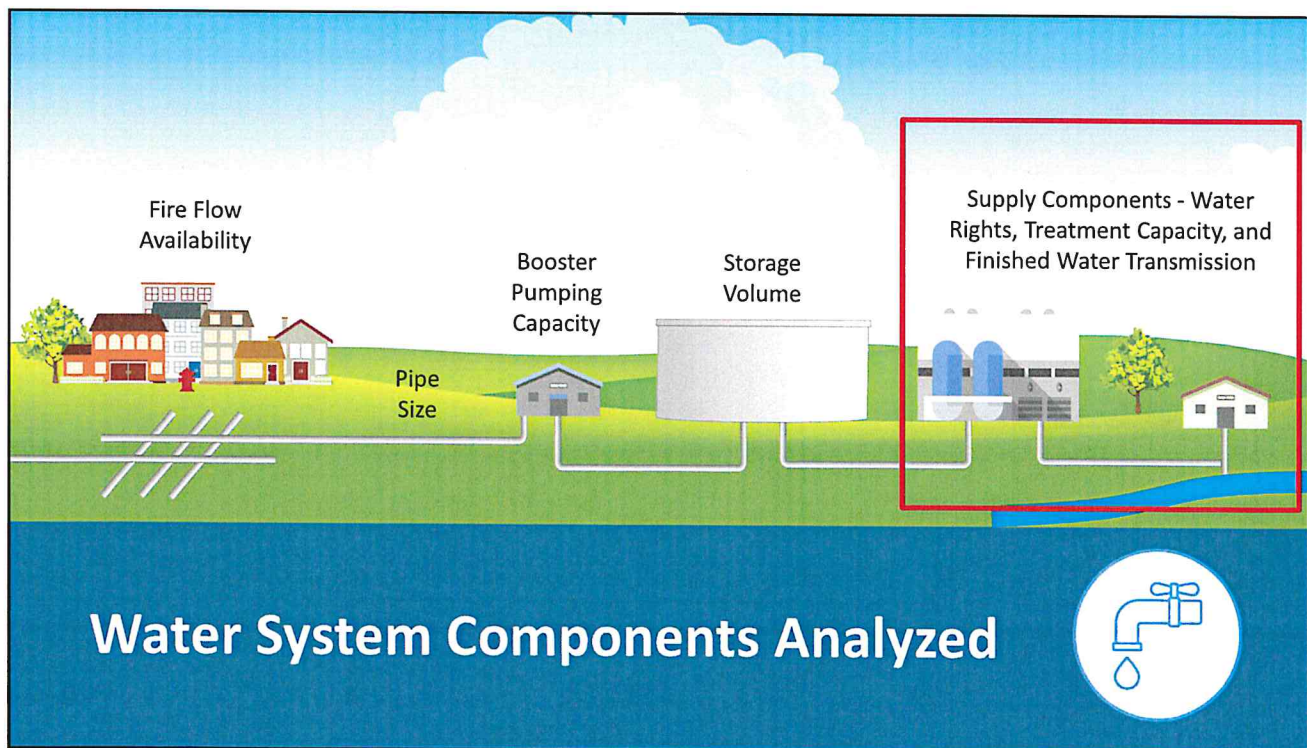
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System Analysis

- Supply
 - City
 - Water Rights
 - Raw Water Transmission
 - WTP Capacity
 - JWC
 - Water Rights
 - WTP Capacity
 - Finished Water Transmission
- Distribution
 - 3 Main Pressure Zones
 - 2 Storage Reservoirs
 - 2 Pump Stations



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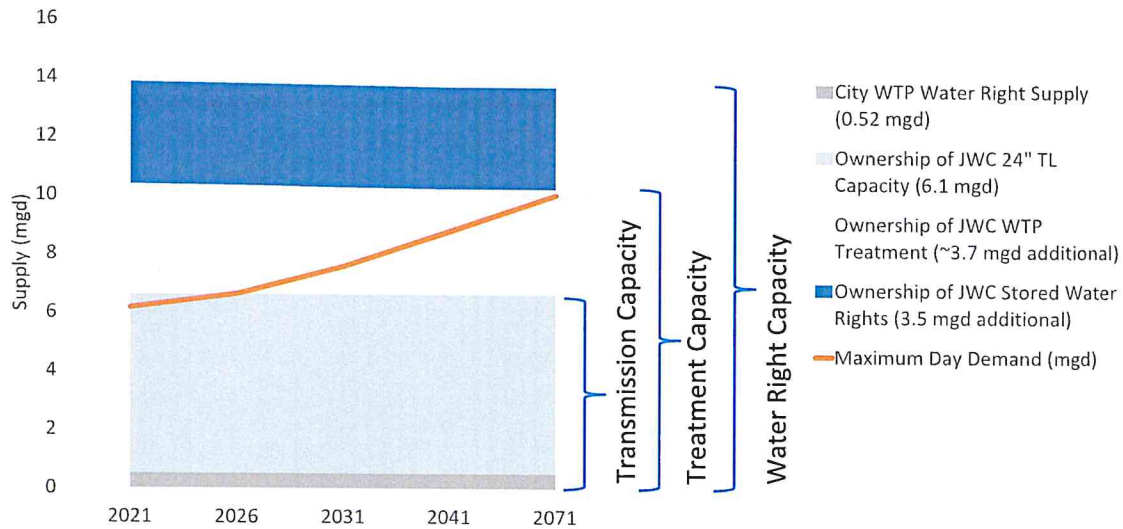


Water System Components Analyzed



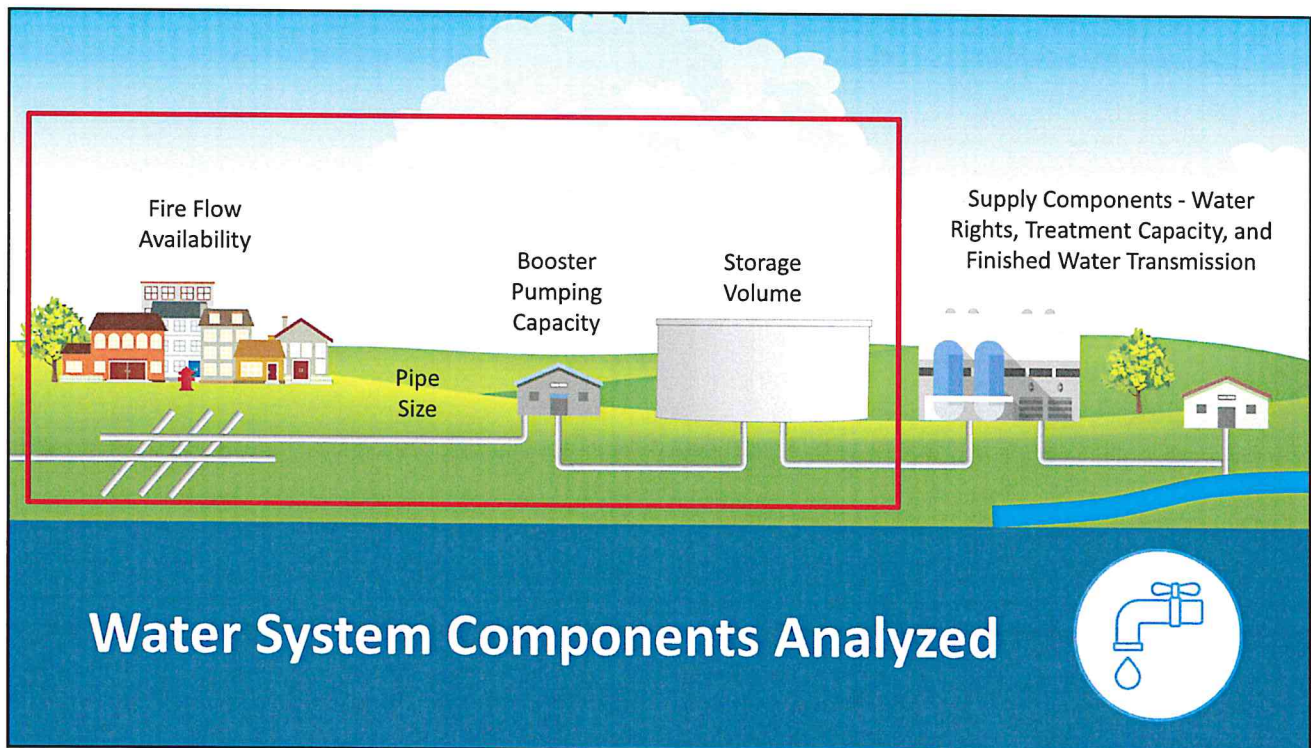
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Water Supply Analysis – Max Demand



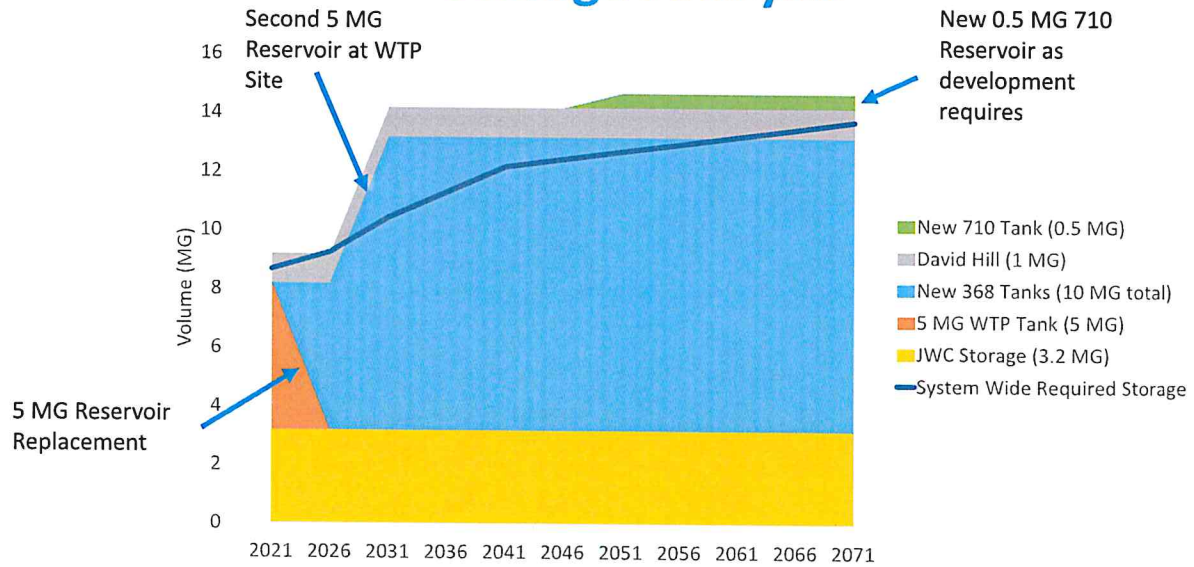
MGD = Million Gallons per Day

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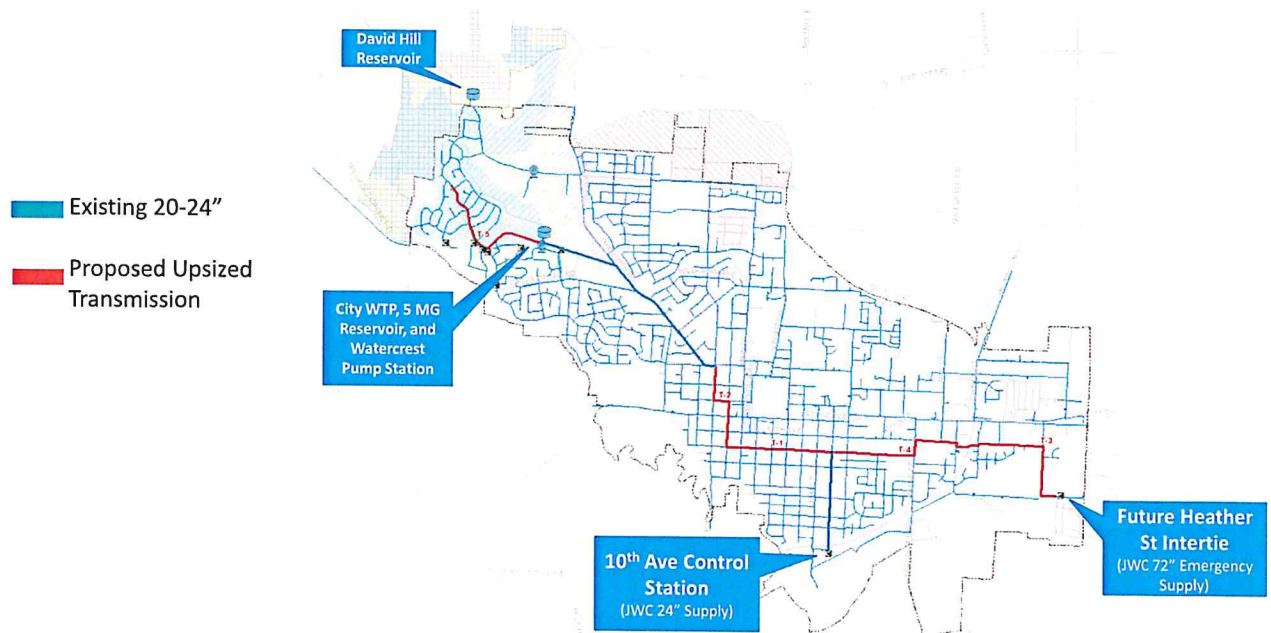
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Storage Analysis



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System Transmission



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Seismic Analysis

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Seismic Analysis

Proposed Seismic Improvements

Proposed Upsized Transmission (may also be concurrent with proposed seismic improvements)

David Hill Reservoir

City WTP, 5 MG Reservoir, and Watercrest Pump Station

10th Ave Control Station (JWC 24" Supply)

Future Heather St Intertie (JWC 72" Emergency Supply)

E2-5 (JWC 24" TL) needed for both increased transmission and seismic resilience

- Proposed Seismic Improvements
- Proposed Upsized Transmission (may also be concurrent with proposed seismic improvements)

Proposed Upsized Transmission (may also be concurrent with proposed seismic improvements)

- Proposed Seismic Improvements
- Proposed Upsized Transmission (may also be concurrent with seismic improvements)

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Capital Improvement Program Goals



Improve Existing System



Provide for Development



Seismic Preparation

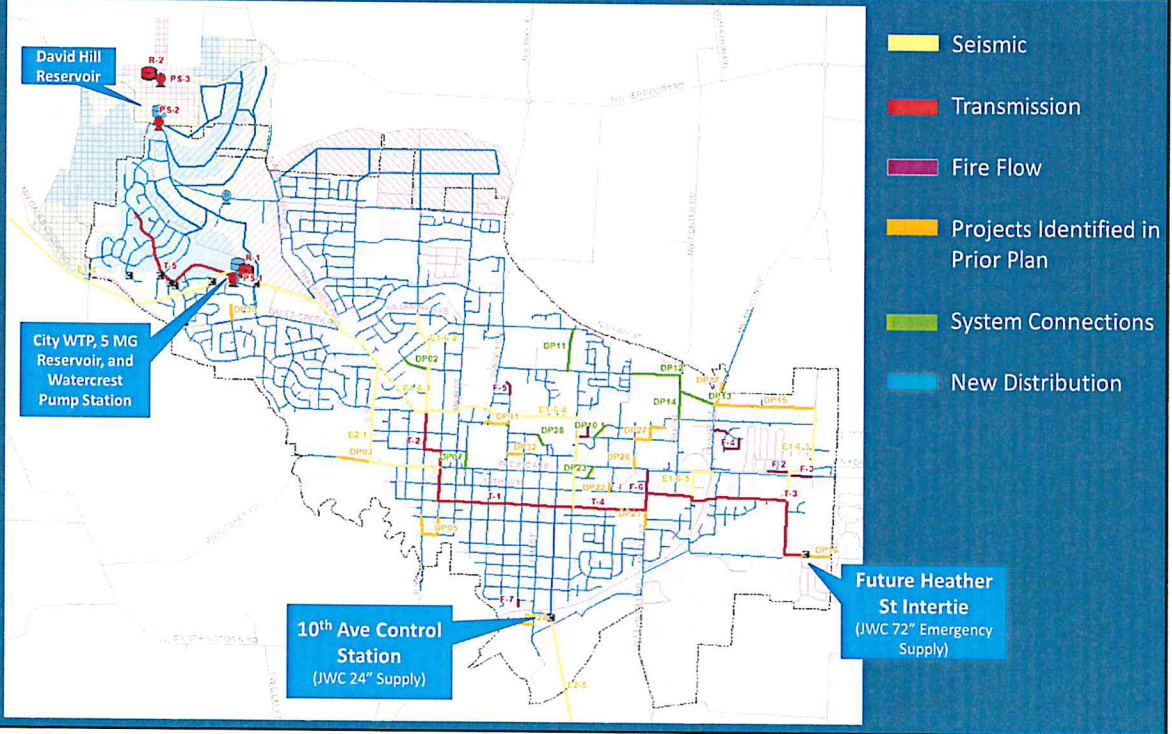
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Capital Improvement Program Areas of Focus

Project Type	0-5 Years	6-10 Years	11-20 Years	20-Year Total
Supply	\$2,595,000	\$-	\$7,640,000	\$10,235,000
Storage Reservoirs	\$11,300,000	\$11,300,000	\$1,000,000	\$23,600,000
Pump Stations	\$2,100,000	\$-	\$850,000	\$2,950,000
Piping Improvements	\$7,840,000	\$5,040,000	\$8,210,000	\$21,090,000
Seismic Improvements	\$22,047,500	\$50,000	\$4,100,000	\$26,197,500
Planning	\$50,000	\$300,000	\$300,000	\$650,000
TOTAL	\$45,932,500	\$16,690,000	\$22,100,000	\$84,722,500

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Capital Improvement Program



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Replace 5 MG Reservoir

Replace aging infrastructure, increase storage capacity, improve seismic resiliency



Increase Transmission of Finished Water from JWC

Increase capacity, improve seismic resiliency



Improve System Transmission

Increase capacity and system resiliency, improve fire flow deficiencies, improve seismic resiliency

Key CIP Projects

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Summary



System currently adequately provides for existing residential, commercial, and industrial customers.



Investment is required to provide for future growth.



Additional investment is important to plan for seismic and emergency conditions



The proposed CIP will help the City build a more resilient system.

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NEXT STEPS

- Legislative process:
 - Submit Draft for State Approval
 - Meet with Planning Commission
 - First/Second Reading at City Council
 - Approve Water Master Plan and Include in City Comprehensive Plan
- Begin Water Rate/SDC Update

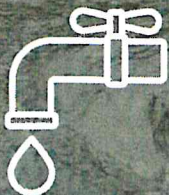
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Questions?



FINAL REVIEW



CITY OF FOREST GROVE

Water System Master Plan

February 2022

Water System Master Plan

City of Forest Grove

February 2022

FINAL REVIEW DRAFT

Murraysmith

888 SW 5th Avenue
Suite 1170
Portland, OR 97204

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Acronyms & Abbreviations

A	
AACE	Association for the Advancement of Cost Engineering International
AAGR	average annual growth rate
AC	asbestos cement
ADD	average daily demand
AWWA	American Water Works Association
C	
CCI	Construction Cost Index
CCP	concrete cylindrical pipe
Census	United States Census Bureau
CIP	Capital Improvement Program
City	City of Forest Grove
CSZ	Cascadia Subduction Zone
CSZE	Cascadia Subduction Zone Earthquake
CWS	Clean Water Services
D	
D/DBPR	Disinfectants and Disinfection Byproducts Rule
DBP	Disinfection Byproducts
DOGAMI	Department of Geology and Mineral Industries
DWS	Drinking Water Services
E	
EMAC	Emergency Management Assistance Compact
ENR	Engineering News-Record
EPA	Environmental Protection Agency
ES	emergency storage
F	
FEMA	Federal Emergency Management Agency
FS	fire storage
G	
GCSA	Gales Creek Service Area
GIS	geographic information system
Gpcd	gallons per capita per day
Gpm	gallons per minute
GSI	GSI Water Solutions, Inc.
H	
HAA5	Haloacetic Acids
HB	(Oregon) House Bill

HGL	hydraulic grade line
I	
IGA	intergovernmental agreement
ISO	Insurance Services Office
J	
JWC	Joint Water Commission
L	
LF	linear feet
LOS	level of service
M	
M9	Magnitude 9.0
MCL	maximum annual average level
MDD	maximum day demand
mgd	million gallons per day
MG	million gallons
mg/L	milligrams per liter
N	
NMU	neighborhood mixed-use (zoning)
NTL	North Transmission Line
O	
OAR	Oregon Administrative Rule
ODOT	Oregon Department of Transportation
OFC	Oregon Fire Code
OHA	Oregon Health Authority
OPSC	Oregon Plumbing Specialty Code
ORP	Oregon Resilience Plan
ORWARN	Oregon Water/Wastewater Agency Response Network
OS	operational storage
OSSPAC	Oregon Seismic Safety Policy Advisory Commission
P	
PF	peaking factor
pH	hydrogen potential
PHD	peak hour demand
PGA	peak ground acceleration
PGD	permanent ground deformation
PGV	peak ground velocity
POD	point of diversion
PPC	Public Protection Classification
PRV	pressure reducing valve
PS	Pump Station
psi	pounds per square inch
PSU PRC	Portland State University Population Research Center

PVC	polyvinyl chloride
R	
RLIS	Regional Land Information System
RWPC	Regional Water Providers Consortium
RWTM	Raw Water Transmission Main
S	
SCADA	supervisory control and data acquisition
SDCs	system development charges
SRP	Seismic Resilience Plan
T	
TL	Transmission Line
TTHM	Total Trihalomethanes
TVID	Tualatin Valley Irrigation District
TVWD	Tualatin Valley Water District
U	
UGB	urban growth boundary
URA	Urban Reserve Area
USGS	United States Geological Survey
V	
VFDs	variable frequency drives
W	
WMCP	Water Management and Conservation Plan
WSMP	Water System Master Plan
WTP	water treatment plant

Executive Summary

Executive Summary

Introduction

The purpose of this Water System Master Plan (WSMP) is to perform an analysis of the City of Forest Grove's (City's) water system and:

- Document water system upgrades, changes, and growth since the 2010 *Water Master Plan*.
- Estimate future water requirements including potential water system expansion areas.
- Document the City's recent water system seismic resilience evaluation.
- Identify deficiencies and recommend water facility improvements that correct deficiencies and provide for growth.
- Provide a recommended, prioritized Capital Improvement Program (CIP) for the water system.
- Comply with water system master planning requirements for Public Water Systems established under Oregon Administrative Rules (OAR).

Water System Overview

Service Area

The City provides finished water to approximately 26,000 residents through approximately 6,800 residential, commercial, industrial, and municipal service connections. The current service area includes all areas within the existing city limits and historic customers located outside the Urban Growth Boundary (UGB) along Gales Creek, Stringtown Road, Oppenlander Lane, and Martin Road. The study area of this planning effort is the current UGB, including the David Hill and Purdin Road areas. See **Figure 1-1 in Section 1** for a map of the service area.

Supply

The City can source water from either City supply or Joint Water Commission (JWC) supply. Recently, approximately 40% of the City's annual supply has come from the JWC and 60% from the City. However, supply from either source is varied seasonally so that in the wet winter months, almost all supply is provided by the City and in the dry summer months, almost all supply is provided by the JWC.

The City owns and operates a water treatment plant (WTP) which treats water from the Clear Creek watershed and supplies finished water at the City's 5 MG Reservoir. The JWC treats Tualatin River raw water and supplies finished water to the City at the 10th Avenue Control Station. Supply from both the Clear Creek watershed and the Tualatin River is limited in the dry season due to in-stream flow requirements. The City WTP is typically reduced to a single older water right, while the JWC WTP can supplement in stream flows with water stored in local impoundments, Barney Reservoir and Hagg Lake (Scoggins Reservoir). Water is released from these impoundments into the Tualatin Reservoir and withdrawn at the JWC intake to be treated and supplied by the JWC to the City and other consumers. The City has one emergency intertie with the City of Cornelius and is preparing to construct an emergency connection to the JWC's 72-inch North Transmission Line at Heather Street. See **Figure 1-2 in Section 1** for a map of the supply system.

Distribution System

The City's existing distribution system is divided into four pressure zones, with two additional pressure zones proposed for future service. Pressure zones are usually defined by ground topography and designed to provide acceptable pressures to all customers in the zone. Zones are designated by hydraulic grade line (HGL) which are set by overflow elevations of water storage reservoirs or outlet settings of pressure reducing facilities serving the zone. An HGL approximately 100 feet above the elevation of a service connection results in a pressure of approximately 43 pounds per square inch (psi). Pressure zone boundaries are further refined by street layout and specific development projects.

Within each pressure zone, storage reservoirs provide gravity supply to looped distribution piping serving customers throughout the service area. The water system has 6.0 million gallons (MG) of available storage within the system and an addition 3.2 MG of available storage in the JWC Fern Hill Reservoirs, used for water system equalizing (fluctuations in demand throughout the day), fire suppression, and emergency conditions. See **Figure 1-3** and **Appendix A** for a system hydraulic schematic and detailed system map.

Water Demand

Water demand refers to all water required by the system including residential, commercial, industrial, and irrigation uses and unmetered use such as hydrant flushing, firefighting, or leakage. Demands are described using water metrics including average day demand (ADD) and maximum day demand (MDD).

Future expansion of the City's water service area will include development in the Purdin Road and David Hill Planning Areas within the UGB, and the David Hill Urban Reserve Area (DHURA), as well as infill development within the existing City limits. The forecasted future water demands are calculated based on the historical system demand and forecasted demands based on zoning of future development areas.

Population growth within the water service area was projected based on population forecasts from the Population Research Center (PRC, Portland State University, 2019) and estimates from prior City efforts for specific planning areas. Non-residential demand growth was based on the 2019 Economic Opportunity Analysis (Johnson Economics). Historical demand data was used to forecast water use per residential customer as well as water use for other customer categories including commercial, industrial, and irrigation accounts. MDD was projected based on the historic ratio of MDD to ADD, also called a peaking factor, by customer class. Both ADD and MDD were forecasted through 2071, shown for the planning years of 2026, 2031, 2041, and 2071 in Error! Reference source not found.. The forecasted time steps support identification of existing and future system deficiencies, prioritization of CIP projects to support development and growth, and sizing of future infrastructure to serve the long-term needs of the City.

Table ES-1-1 | Projected Water Demand

Year	ADD (mgd)	MDD (mgd)
2021	3.27	6.17
2026	3.52	6.64
2031	4.03	7.59
2041	4.68	8.80
2071	5.33	10.03

Analysis Criteria

Performance guidelines and system criteria are used with water demands presented in **Table ES-1-1** to assess the water distribution system's ability to provide adequate water service under existing conditions and to guide improvements needed to provide for future water needs. Criteria are established through a review of City design standards, state requirements, American Water Works Association (AWWA) acceptable practice guidelines, Ten States Standards, the Washington Water System Design Manual, and practices of other water providers in the region.

Water Supply

The City should plan for adequate peak season (summer) supply capacity to meet the future MDD projections in each of the following: raw water source, raw water transmission, treatment, and finished water transmission. During the off-peak season, the supply system must be capable of providing off-peak season demand.

Service Pressure

The acceptable service pressure range under ADD conditions is 40 to 100 psi. Per the *Oregon Plumbing Specialty Code*, maximum service pressures must not exceed 80 psi without individual PRVs to regulate pressure to less than 80 psi. During a fire flow event or emergency, the minimum service pressure is 20 psi, which meets requirements by Oregon Health Authority Drinking Water Services regulations.

Storage Capacity

Adequate storage capacity must be provided for each pressure zone. Recommended storage volume is the sum of three components.

- Operational Storage: the volume of water between operational setpoints of pumps and regularly used during daily operations, estimated as 25 percent of MDD
- Fire Storage: the volume of water needed in each zone to meet the largest required fire flow for the duration specified in the Oregon Fire Code
- Emergency Storage: the volume of water needed to supply customers in each zone in the event of an emergency that makes supply to the zone temporarily unavailable. Emergency storage was estimated as 1 x MDD.

Additionally, JWC supply contracts require partner agencies to provide three times the average take from the JWC in regional and partner-controlled storage.

Pump Stations

Pump stations should have adequate firm capacity to meet MDD in the pressure zones they serve. Firm capacity is defined as the station's pumping capacity with the largest pump out of service. In the case that a pump station serves a closed zone, or a zone with no storage or additional sources, the pumps station must provide peak hour demand plus fire flow.

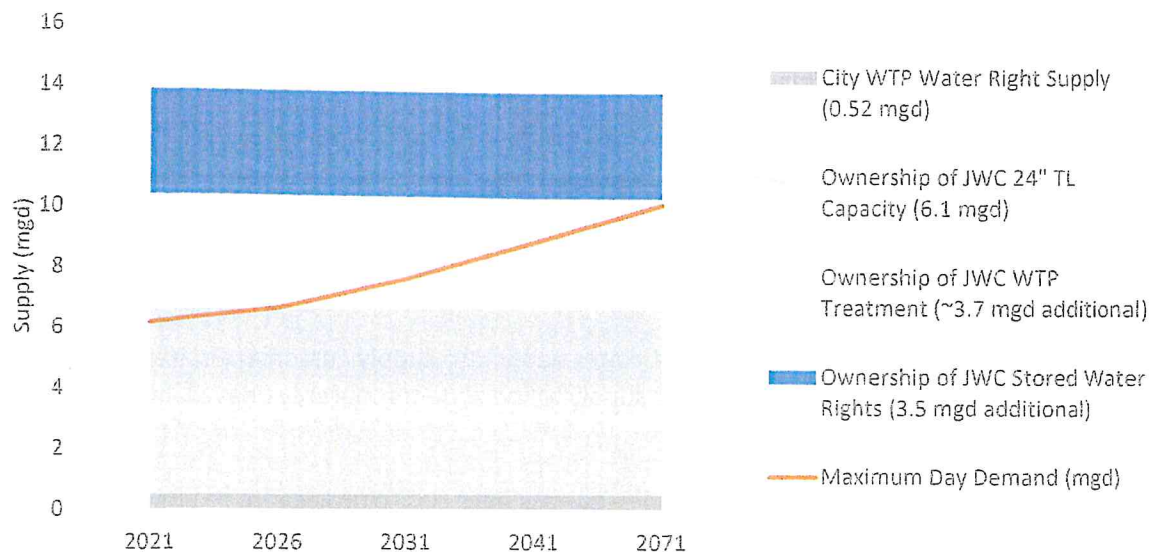
Fire Flow

The distribution system should be capable of supplying recommended fire flows while supplying MDD and maintaining minimum residual pressures of 20 psi everywhere in the system.

Water Supply Analysis

Historically, the City has had sufficient capacity in raw water supply, treatment capacity, and finished water transmission. As the City continues to grow, however, the City's water demands will start approaching the current supply system capacity. It is anticipated the dry season water demands will exceed the City's capacity ownership in the 24" JWC TL in just a few years. To address this shortfall, the City should consider leasing capacity from the City of Hillsboro in this line. A more permanent solution, including addressing seismic deficiencies in this line, should also be considered and is recommended in the SRP. **Figure ES-1-1** highlights the maximum day limitations in the supply system.

Figure ES-1-1 | Supply Limitations during Maximum Demand



Additional action may be required for raw water supply and treatment, depending on future climate conditions, City demand, and long-term supply contract obligations approaching the 50-year planning horizon. Exact limitations on each supply process will depend on how the City decides to address future water supply. Five supply scenarios are summarized at a high level in **Section 4**. To make an informed decision, the City must address a series of knowledge gaps such as documenting requirements for various facility replacements and improvements, understanding lease capabilities from neighboring providers, and estimating costs for each supply alternative and complete a detailed Water Supply Study.

Distribution System Analysis

A hydraulic network model was used to analyze the distribution system, which was evaluated based on the performance criteria described above and projected demands summarized in **Table ES-1-1**. Recommended CIP projects and pressure zone configuration or operational changes were developed based on the deficiencies identified through this analysis.

Fire Flow Analysis

Fire flow scenarios test the distribution system's ability to provide required fire flows at a given location while simultaneously supplying MDD and maintaining a minimum residual service pressure at all services.

Under existing piping conditions, the City has fire flow deficiencies particularly in the industrial area in the east. However, when the Heather Street Control Station is included for fire flow supply, and transmission is upsized between the City WTP, 10th Avenue Control Station, and the Heather

Street Control Station, most fire flow deficiencies are met. Additional limited distribution piping upsizing is included to address remaining deficiencies.

Transmission Limitations

Supply from the JWC through the 10th Avenue Control Station to the City's primary storage at the 5 MG Reservoir is limited by distribution piping. With existing infrastructure, over-pressurization of low elevation customers in the 368 Zone is a risk if the City wants to quickly fill the reservoir from the JWC. Additionally, supply from the new Heather Street connection to the JWC's North Transmission Line (NTL) is similarly limited by distribution piping. As system demands continue to grow, supply transmission through the system will be exacerbated. Therefore, the City should consider upsizing transmission from both the 10th Avenue Control Station and the Heather Street Control Station.

Additionally, transmission upsizing is also recommended from the Watercrest Pump Station to the David Hill Reservoir, assuming the resiliency improvements are made to the Watercrest Pump Station. This will improve supply to future upper zone customers.

Storage Capacity

System storage in all zones will be deficient within the next five years. The City should consider constructing two 5 MG reservoirs at the existing 5 MG Reservoir site and overflow elevation. A phased construction approach is recommended to maintain storage availability in the 368 Zone and match storage with demands as development occurs. Both reservoirs are recommended within the next 10 years, based on existing development assumptions, but site constructability may recommend an alternate phasing schedule.

A 0.5 MG 710 Reservoir is recommended once sufficient development occurs above the 540 Zone. Prior to construction, areas above existing service elevations can be served through future constant pressure pumping from the David Hill Reservoir.

Pump Stations

Pumping capacity is required for service to Zones above the 368 Zone. Pumping to the 540 Zone and David Hill Reservoir is evaluated based on the MDD of the combined upper elevation zones (435, 540, Gales Creek Service Area, and future 710 and 880). Pumping capacity to future closed zones (710 or 880) is evaluated based on the peak hour and fire flow requirement of each zone. Pumping to the 540 Zone must meet the needs of the 540, 435, future 710, and future 880 Zones.

The two existing 540 Pump Stations (David Hill and Watercrest) have sufficient capacity for future supply but need facility improvements to improve reliability and resiliency. Future 710 and 880 pump stations should be constructed as development necessitates. The 710 Pump Station will need to initially provide constant pressure until the 710 Reservoir is constructed. The 880 Pump Station is anticipated to only provide constant pressure.

Additional improvements should be considered for risk mitigation at all pump stations, including adding pump redundancy if it does not exist, regularly exercising pumps that are anticipated to be used as backup supply, and ensuring adequate power with automatic switching and seismic improvements are met.

Water Quality and Conservation

Water Quality Regulations

The City of Forest Grove, along with all public drinking water systems, must follow both state and federal regulations. At the federal level, the Environmental Protection Agency (EPA) establishes water quality standards, monitoring requirements, and enforcement procedures. At the state level, either the EPA or a state agency will implement the EPA rules. As a primacy state, Oregon administers most of the EPA's drinking water rules through the Oregon Health Authority (OHA) Drinking Water Services (DWS). The DWS rules for water quality standards and monitoring are adopted directly from the EPA. The DWS is required to adopt rules at least as stringent as federal rules. To date, the DWS has elected not to implement more stringent water quality or monitoring requirements.

At the Federal level, the Safe Drinking Water Act (SDWA) is the primary drinking water regulation. It was originally enacted in 1974 by Congress to ensure the quality of America's drinking water with a focus on water treatment. The act was reauthorized and updated in 1986 and 1996 to expand protections to source water and improve operator training, system improvement funding, and public education. The SDWA contains the following assignment and programs for the EPA and the states to administer including:

- State revolving loan fund for water system construction
- Public notification reports
- Source water assessment and protection
- Monitoring reductions based on source water protection
- Mandatory certification of operators

These assignments have been implemented by the EPA and/or individual states and are regularly updated. Under the authority of the SDWA, the EPA sets various rules and regulations to maintain safe drinking water.

The City currently meets all existing and proposed water quality regulations that govern the operation and performance of the water system.

Seismic Resilience Evaluation

The City conducted a separate Seismic Resilience Plan (SRP) with InfraTerra, completed in 2020. The SRP fulfills the seismic requirements for Water Master Plans in OAR 333-061-0060(5) (J) and

recommends mitigation measures that can be implemented over the next 50 years to improve seismic resilience of the water system. SRP recommendations are included in the CIP.

System Backbone

Consistent with the Oregon Resilience Plan (ORP) guidelines, the City identified critical facilities and customers like primary care centers that will need uninterrupted or quickly restored water service following the anticipated magnitude 9.0 Cascadia Subduction Zone (CSZ) earthquake. The approach included identification and hardening of key supply, transmission, and distribution facilities (backbone) so that water is available for critical needs such as fire suppression, health and emergency response, and drinking water at key distribution points immediately after the earthquake while damage to the rest of the water system is repaired. This “backbone” was then evaluated to assess risk and develop CIP projects. Figures included in **Appendix H, Water System Seismic Resilience Plan** by InfraTerra illustrate the backbone and seismic risks.

Seismic Hazards Assessment

Seismic hazards all have the potential to damage buried water mains and other water facilities. Within the Forest Grove water service area, these hazards were evaluated based on existing magnitude 9.0 CSZ earthquake hazard maps published for the Portland Metro region by the Oregon Department of Geology and Mineral Industries (DOGAMI). These maps were refined using geotechnical exploration data and subsurface boring logs from reservoirs, pump station sites, and various projects constructed near critical water facilities in the City’s water service area.

Summary of Recommendations

The seismic resilience recommendations are summarized below.

- Phase I Improvements were identified in the SRP and are intended to meet the ORP goal of 80-90 percent of the backbone operational within 24-hours of a seismic event. These projects are recommended to be completed within 0-5 years.
- Phase II improvements were identified in the SRP and are intended to meet the ORP goal of 80-90 percent of the entire system operational, except for goals related to the non-backbone water distribution system. To meet all the water system goals of the ORP, an additional 25.1 miles of existing ductile iron pipe would have to be replaced with seismically resistant pipe, which is likely cost prohibitive. The recommended phased approach will achieve many, but not all, of the ORP water system goals and when coupled with emergency operations planning, will significantly improve the City’s water system seismic resiliency. Projects are generally recommended to be completed within 11-20 years, except for improvements to the JWC Transmission Line which is recommended for 0-5 years and discussed in the supply section and a few long term projects to be completed in 20+ years.

- Additional recommended actions were identified in the SRP to mitigate seismic risk. See **Section 6.6.3** for additional description. These projects are generally either smaller projects or actions identified for the City to complete to aid in post disaster operations and planning. Projects are recommended to be completed within 0-5 years.

Recommended Capital Improvement Program (CIP)

A summary of all recommended improvement projects and estimated project costs is presented in **Table ES-1-2. Figure 7-1** included in **Section 7** illustrates these improvements. This CIP table provides for project sequencing by showing prioritized projects for the 5-year, 6 to 10-year, 11 to 20-year, and beyond 20-year timeframes defined as follows.

- 5-year timeframe - recommended completion through 2027
- 6 to 10-year timeframe - recommended completion between 2028 and 2032
- 11 to 20-year timeframe - recommended completion between 2033 and 2042
- 20+ year timeframe – recommended completion beyond 2042

Estimated project costs presented in the CIP are intended to provide guidance in system master planning and long-range project scheduling and implementation. Final project costs will vary depending on actual labor and material costs, market conditions for construction, regulatory factors, final project scope, project schedule, and other factors.

The City's proposed CIP includes significant investment, particularly in supply, storage, and seismic improvements. This new capacity will serve growth while also providing more resilient water facilities that benefit all customers. An evaluation of water rates and system development charges (SDCs) in support of the water system CIP will be completed as follow-on work to this WSMP.

Table ES-1-2 | CIP Cost Summary

Project Type	0-5 Years	6-10 Years	11-20 Years	20+ Years	20-Year Total
Supply	\$2,595,000	\$-	\$7,640,000	\$44,560,000	\$10,235,000
Storage Reservoirs	\$11,300,000	\$11,300,000	\$1,000,000	\$-	\$23,600,000
Pump Stations	\$2,100,000	\$-	\$850,000	\$-	\$2,950,000
Piping Improvements	\$7,840,000	\$5,040,000	\$8,210,000	\$-	\$21,090,000
Seismic Improvements	\$22,047,500	\$50,000	\$4,100,000	\$40,610,000	\$26,197,500
Planning	\$50,000	\$300,000	\$300,000	\$-	\$650,000
Total	\$45,932,500	\$16,690,000	\$22,100,000	\$85,170,000	\$84,722,500

Note:

1. 20 Year Total does not include projects after 20 years (approximately an additional \$85M).

Section 1

Section 1

Introduction and Existing Water System

1.1 Purpose

The purpose of this Water System Master Plan (WSMP) is to perform an analysis of the City of Forest Grove's (City's) water system and:

- Document water system upgrades, changes, and growth since the 2010 *Water Master Plan*
- Estimate future water requirements including potential water system expansion areas
- Document the City's recent water system seismic resilience evaluation
- Identify deficiencies and recommend water facility improvements that correct deficiencies and provide for growth
- Provide a recommended, prioritized Capital Improvement Program (CIP) for the water system
- Comply with water system master planning requirements for Public Water Systems established under Oregon Administrative Rules (OAR)

This report is divided into seven sections to address the goals described above. **Section 1**, **Section 2**, and **Section 3** summarize the existing system and water demands, estimate future water demands, and list the performance criteria used to analyze the system. **Section 4** and **Section 5** build off the prior sections to identify system deficiencies, vulnerabilities, and development improvements projects for the supply and distribution systems. **Section 6** summarized the Seismic Resilience Plan (SRP) developed by InfraTerra. **Section 7** compiles the proposed projects into a CIP prioritized in 5-year increments. The planning and analysis efforts presented in this WSMP are intended to provide the City with the information needed to inform long-term water supply and distribution infrastructure decisions.

This plan complies with water system master planning requirements established under Oregon Administrative Rules for Public Water Systems, Chapter 333, Division 61 (OAR 333-061-0060(5)).

1.2 Service Area

The City is located west of Portland, in rural Washington County adjacent to the City of Cornelius and provides finished water to approximately 26,000 residents through approximately 6,800 residential, commercial, industrial, and municipal service connections. In addition to residential development and a small downtown business district, the City's customers include Pacific University, technology industry manufacturers, and food processing companies. The current service area includes all areas within the existing city limits and historic customers located outside the Urban Growth Boundary (UGB) along Gales Creek, Stringtown Road, Oppenlander Lane, and Martin Road. The study area of this planning effort is the current UGB, including the David Hill and Purdin Road areas as described in the City's *2017 Westside Planning Program*. The City's service area is illustrated on **Figure 1-1**, located at the end of this section.

1.3 Supply

The City owns and operates a water treatment plant (WTP) which treats raw water from the Clear Creek watershed, a tributary of Gales Creek located northwest of the City. During seasonally high stream flows, the City has sufficient source water to meet existing demands. Additional supply is available from the Joint Water Commission (JWC) which treats Tualatin River raw water and supplies finished water to the City. The JWC is a water authority formed in 1976 through an intergovernmental agreement (IGA) between the Cities of Hillsboro and Forest Grove. Currently, the JWC also includes the City of Beaverton and the Tualatin Valley Water District (TVWD). Typically, the City draws from JWC supply from July through September. Supply from both the Clear Creek watershed and the Tualatin River is limited in the dry season due to in-stream flow requirements. During the dry season, the City must reduce raw water take from the watershed due to water right restrictions. The JWC, however, offsets lower in-stream flows with stored water released from local impoundments, Barney Reservoir and Hagg Lake (Scoggins Reservoir). The JWC then treats and supplies this finished water through its usual system. Key aspects of the supply system are illustrated in **Figure 1-2**, located at the end of this section.

1.3.1 Water Rights

The City holds live water rights on Roaring Creek, Clear Creek, and Gales Creek as well as the Tualatin River. The City's Tualatin River rights are used to supply raw water to the JWC WTP. The City also holds stored water rights in Barney Reservoir and Hagg Lake. Water rights are discussed in more detail in **Section 4**.

1.3.2 City Source Transmission

The City's raw water supply comes from five intake facilities within 4,225 City-owned acres of the Clear Creek watershed, a sub-watershed of the Gales Creek watershed. Intake facilities are located along Clear Creek, Deep Creek, Smith Creek, Thomas Creek, and Roaring Creek. The raw water is piped approximately 7.8 miles southeast to the WTP located on Watercrest Road, through 16-inch

concrete cylindrical pipe (CCP) alongside Gales Creek and Gales Creek Road. Watershed piping from the intake facilities to the 16-inch CCP Raw Water Transmission Main (RWTM) includes cast iron, cast iron tyton, and other pipe material. Typically, the RWTM flows by gravity with a maximum capacity of approximately 1,875 gallons per minute (gpm) (2.7 million gallons per day (mgd)). During high demand periods and when water is available in stream, the Raw Water Pump Station (PS), located along Gales Creek Road next to Forest Glen Park, can increase flows up to 2,600 gpm (3.7 mgd).

1.3.3 City WTP

The City's treatment plant is of conventional design with coagulation, flocculation, sedimentation, and rapid sand filtration. The plant has a maximum production capacity of approximately 3.7 mgd. According to City WTP staff, the minimum flow for efficient operation of feed pumps is approximately 475 gpm (0.68 mgd). The City adds alum as its primary coagulant and uses horizontal mounted, paddle wheel flocculators. Water is settled in a single sedimentation basin, then a low-head pump lifts the settled water to the gravity rapid sand filters. Prior to storage, two chlorine feed points can be operated either individually or simultaneously to meet disinfection requirements. Finished water is stored onsite at the 5.0 million gallon (MG) reservoir, which provides service pressure for the City's 368 Zone.

The WTP is primarily limited by the loading rate of its rapid sand filters, which operate at 5 gpm per square foot. WTP operation can also be affected by a storm that causes high turbidity in the Clear Creek watershed where the City's intakes are located. The WTP filters do not function efficiently with high volumes of suspended particles due to more frequent filter backwashing. This also results in higher volumes of waste solids that need to be removed from the site.

1.3.4 JWC Supply

The JWC supplies drinking water to communities in Washington County, including the Cities of Forest Grove, Hillsboro, Beaverton, TVWD, and other wholesale customers.

1.3.4.1 Source Intake and WTP

The JWC intake facility and treatment plant is located on the Upper Tualatin River off Fern Hill Road, in unincorporated Washington County and approximately 1.5 miles south of Forest Grove City limits. The plant is jointly owned by the JWC members but maintained and operated by the City of Hillsboro. The treatment plant is of conventional design with coagulation, flocculation, sedimentation, and rapid sand filtration processes. Treatment capacity is limited to 85 mgd, of which the City owns 10 mgd. A recent 10 mgd JWC WTP expansion was designed to meet current seismic standards, however Forest Grove did not participate in the expansion.

1.3.4.2 Finished Water Storage and Transmission

Finished water is pumped one-third of a mile east to the JWC's two 20 MG buried concrete reservoirs at Fern Hill (40 MG total storage capacity). Forest Grove is supplied by a 24-inch gravity JWC Transmission Line (TL) from either the Fern Hill reservoirs or directly from the JWC WTP. (This line is also sometimes referred to as the Forest Grove/Hillsboro Transmission Line.) This 24-inch CCP, approximately 8,200 linear feet (LF) as identified by geographic information system (GIS) data provided by the City of Hillsboro, is jointly owned by the Cities of Forest Grove and Hillsboro. JWC water enters the Forest Grove system at the 10th Avenue Control Station.

A 72-inch gravity transmission main from the Fern Hill reservoirs, the JWC North Transmission Line (NTL), runs through the east side of the City to supply JWC partners Hillsboro and TVWD. The City is not currently connected to the 72-inch JWC NTL.

1.3.4.3 10th Avenue Control Station

The 10th Avenue Control Station is Forest Grove's only connection to the City's JWC supply. At the station the JWC Fern Hill hydraulic grade line (HGL) is reduced to match the City's 368 Zone and flow into the Forest Grove system is metered for both the City's and JWC's use. The station can be operated on either pressure or flow control. Currently it is operated on pressure control following a 2020 replacement of the station's control valves. Water is also fluoridated at the control station.

As described previously, the City typically draws on JWC supply from July through September during low stream flows in the Clear Creek Watershed which supplies raw water to the City WTP. The City informs the JWC when they will begin withdrawing water at the 10th Avenue Control Station and notifies JWC operators of any significant expected changes in demand.

1.3.5 Emergency Interties

The City maintains a single 6-inch emergency intertie with the City of Cornelius, located on Heather Street at the city limits. This intertie has not been exercised in the past 10 years and capacity estimates for supply in either direction are unavailable. It is expected that supply will be limited and dependent on operating conditions of the two systems when an emergency occurs.

The City of Cornelius is planning a second intertie with the Forest Grove water system in N Adair Street, east of its intersection with Yew Street. According to Cornelius' *2017 Water Master Plan*, the project will connect an existing 12-inch line in N Adair Street in Cornelius to an existing 10-inch line in Adair Street in Forest Grove.

An existing blind flange along the JWC's 72-inch JWC NTL will serve as a future emergency intertie connection point at Mountain View Lane and Heather Street. In 2021 the City began designing the Heather Street Control Station, an emergency intertie with the 72-inch JWC NTL at this location.

1.4 Pressure Zones

The City's existing distribution system is divided into four service levels, or pressure zones. The pressure zones have previously been identified as the Lower, Intermediate, and Upper Pressure zones, and the Gales Creek Service Area (GCSA). Pressure zones are defined by ground topography based on the Forest Grove Vertical Datum and are designed to provide acceptable pressures to all customers in each zone. Zones are designated by HGLs which are set by overflow elevations of water storage facilities or by outlet settings of pressure reducing facilities serving the zone. Pressure zone boundaries are further refined by street layout and specific development projects. Because future growth is anticipated above the Upper Zone, the zones have been renamed according to their HGLs for the purposes of this report and future development: 368, 435, 540, and Gales Creek Service Area. The HGL varies considerably, from about 420 to 450 feet, among the six pressure reducing valves (PRVs) serving the Intermediate Zone. The approximate median of 435 feet lends the zone its new name.

Table 1-1 presents a summary of existing pressure zones. Pressure zones are illustrated on Plate 1 in **Appendix A** and the hydraulic schematic in **Figure 1-3** at the end of this section.

Table 1-1 | Pressure Zones

Zone	Previous Name of Zone ¹	HGL (ft)	Ground Elevations Served (ft)	No. Connections
368 ²	Lower	368	< 270	6,142
435 ³	Intermediate	381-446	270 – 330	188
540 ⁴	Upper	540	330 – 440	418
GCSA	Gales Creek	400	190 – 320	64

Notes:

1. The pressure zones were renamed according to their HGLs because future growth is anticipated in the David Hill UGB and David Hill Urban Reserve Area (DHURA) above the elevation currently served by the Upper Zone.
2. The Lower Pressure Zone was renamed as the 368 Zone, designated by the reservoir overflow elevation of 368 feet at the 5 MG Reservoir.
3. The Intermediate Pressure Zone was renamed as the 435 Zone, based on an average of the pressure settings of the six PRVs that serve the zone.
4. The Upper Pressure Zone was renamed as the 540 Zone, designated by the reservoir overflow elevation of 540 feet at the David Hill Reservoir.
5. Elevations are based on the Forest Grove Vertical Datum.

1.4.1 368 Pressure Zone

Most of the City is within the 368 Zone. The 368 Zone is supplied by the City's 5 MG Reservoir at the City WTP site and from the JWC at the 10th Avenue Control Station. The 5 MG Reservoir overflow elevation is 368.75, which sets the maximum HGL for the 368 Zone. There is one PRV station, the Forest Gale PRV, installed between the 435 and 368 Zones which only operates during fire flow conditions. The 368 Zone includes nearly all the City's industrial and commercial customers, along with Pacific University and most of the City's residential neighborhoods.

1.4.2 435 and 540 Pressure Zones

The existing 435 and 540 Zones primarily serve residential customers in the northwest reaches of the City. The 540 Zone is supplied by the David Hill Reservoir, which sets the zone's HGL at a maximum of 540 feet. The reservoir is filled through the distribution system by the David Hill and Watercrest Road Pump Stations. The 435 Zone is served by six PRVs supplying water from the 540 Zone's distribution system. These PRVs are summarized in **Table 1-2** and illustrated on Plate 1 in **Appendix A**.

1.4.3 Gales Creek Service Area

The GCSA serves customers northwest of the City, outside the UGB, along Gales Creek Road, Stringtown Road, and Oppenlander Lane. Until 1994, these customers were served directly off the 16-inch RWTM supplying the City's WTP. Water customers can no longer be served off the raw water line due to the surface water treatment regulations of OAR Chapter 333. Therefore, the GCSA has been disconnected from the raw water main. Currently, a distribution system of primarily 4 to 6-inch Class 160 polyvinyl chloride (PVC) pipes supplies customers from the 540 Pressure Zone through a PRV station located in a City utility access road near Gales Creek Road and NW Creekwood Place.

Portions of the GCSA distribution piping are unmapped and are believed to cross private property, including active farmland, without easements. The Service Area is operated at relatively high pressure, approximately 90 pounds per square inch (psi), to overcome head loss through the small diameter distribution mains and supply adequate service pressure to the last customers on the line who are also at the highest elevations. City distribution system operators perform a monthly water audit of the Service Area by comparing metered flows through the Gales Creek PRV station with GCSA customers' metered consumption. City staff have been able to identify some leaks and significantly reduce water loss; based on a water audit completed by City staff for this service area, water loss is currently estimated at approximately 21,500 gallons per day (645,600 gallons per month).

Table 1-2 | PRV Station Summary

Station Location	Higher Zone	Lower Zone	Pressure Setting (psi)	HGL (feet)
Forest Gale Drive & Gales Creek Road	435	368	63	380
3222 Valley Crest Way	540	435	52.5	446
Lavina & Forest Gale Drives	540	435	51	413
3214 Forest Gale Drive	540	435	49.5	419
3130 Forest Gale Drive	540	435	58	436
3145 Fleming Place	540	435	51	433
3151 Vista Drive	540	435	39	381
Gales Creek Road & NW Creekwood Place	540	GCSA	92.5	446

1.5 Storage Reservoirs

1.5.1 City Storage

The City owns two finished-water storage facilities with a combined storage capacity of 6.0 MG, the 5 MG Reservoir serving the 368 Zone and the David Hill Reservoir serving the 540 Zone.

1.5.1.1 WTP 5 MG Reservoir

The 5 MG Reservoir at the City's WTP is a buried 304-foot by 152-foot, rectangular hopper-bottom reinforced concrete structure built in 1948. The reservoir is divided into two equal tanks, allowing for continued operation during maintenance operations on half the reservoir. The 5 MG Reservoir typically operates at an HGL of 367 feet, 1.75 feet below the overflow. The reservoir features a 5-foot hopper bottom at its center. This reservoir sets the HGL for the 368 Zone.

1.5.1.2 David Hill Reservoir

Located on David Hill Road, just northwest of the city limits, the 1.0 MG David Hill Reservoir provides storage for the 540 and 435 Pressure Zones. The reservoir is a 96-foot by 76-foot partially buried reinforced concrete structure built in 1985. The reservoir sets the hydraulic grade for the 540 Zone and is typically operated at an HGL of 538 feet, two feet below the overflow.

1.5.2 JWC Storage

The JWC has a combined storage volume of 40 MG in two 20 MG reservoirs, known as the Fern Hill Reservoirs. Both reservoirs are located off Spring Hill Road, south of Forest Grove, just a third of a mile east of the JWC WTP. The first reservoir was built in 1978 and rehabilitated in 2006. The second reservoir was built in 2006.

The City owns 5.3 MG of the 40 MG storage volume; however, 40 percent of the combined storage is allocated to the JWC WTP for operation purposes (JWC Operations Manual, Section 6). The remaining 60 percent is distributed to JWC members by ownership. This leaves approximately 3.2 MG of Fern Hill storage available for City use. **Table 1-3** provides details of the four reservoirs serving the City.

Table 1-3 | Reservoir Summary

Name	Service Area	Capacity (MG)	Overflow Elevation (ft)	Operating Elevation (ft)	Floor Elevation (ft)	Year built	Tank Type
JWC Fern Hill 1 & 2	368 Zone	40 MG Total/ 3.2 MG Available ¹	520	515	492	1982/ 2006	Partially-buried prestressed concrete
WTP (5 MG)	368 Zone	5.0	368.75	367	348	1948	Buried reinforced concrete
David Hill	540 and 435 Zones	1.0	540	538	520	1985	Partially-buried reinforced concrete

Note:

1. 40 percent of total JWC storage (40 MG) dedicated to JWC WTP operations. Remaining 24 MG divided by ownership results in 3.2 MG storage available for City use.

1.6 Pump Stations

The City's water system includes a raw water booster pump station used to increase transmission capacity from the Clear Creek watershed intakes to the City's WTP and two finished water distribution system pump stations used to boost finished water from the 368 Zone to the 540 Zone. Pump stations are summarized in **Table 1-4**.

1.6.1 Raw Water Pumping

The Raw Water Pump Station is located along Gales Creek Road. Under normal conditions, the raw water system operates under gravity, which is limited to approximately 2.7 MGD. During high demand periods, the Raw Water Pump Station increases flows up to 3.7 MGD. This station, constructed in 1979, consists of a single, split-case pump housed in an underground vault. The pump is exercised yearly.

1.6.2 Distribution System Pumping

The City's two finished water distribution pump stations lift finished water from the 368 Pressure Zone to the 540 Zone through 10 and 12-inch ductile iron piping.

1.6.2.1 David Hill Pump Station

Built in 1985, the David Hill Pump Station is located on David Hill Road, about one-quarter mile west of Thatcher Road. A brick pump station building houses two identical 25 horsepower (hp), 400 gpm vertical turbine pumps. The pumps run lead-lag based on the level of the David Hill

Reservoir. The pumps are exercised monthly during the low demand winter season and are otherwise only needed during peak demand.

1.6.2.2 Watercrest Pump Station

The Watercrest Pump Station consists of one 280 gpm end-suction centrifugal pump, with a provision for a second pump, housed in a partially buried concrete structure. It is located on Watercrest Road, adjacent to the WTP. As of 2006, the Watercrest Pump Station is used as the primary pump station feeding the David Hill Reservoir and 540 Pressure Zone. The pump was upgraded as part of WTP modifications and the David Hill Pump Station is now used as the back-up.

Table 1-4 | Pump Station Summary

Pump Station	From Zone	To Zone	No. of Pumps	Station Capacity (gpm)	Firm Capacity (gpm)	Pump Type
Raw Water PS	Intakes	368	1	2,600	0	Split-case
David Hill PS (Finished Water)	368	540	2	800	400	Vertical turbine
Watercrest Road PS (finished Water)	368	540	1	280	0	End-suction centrifugal

Note:

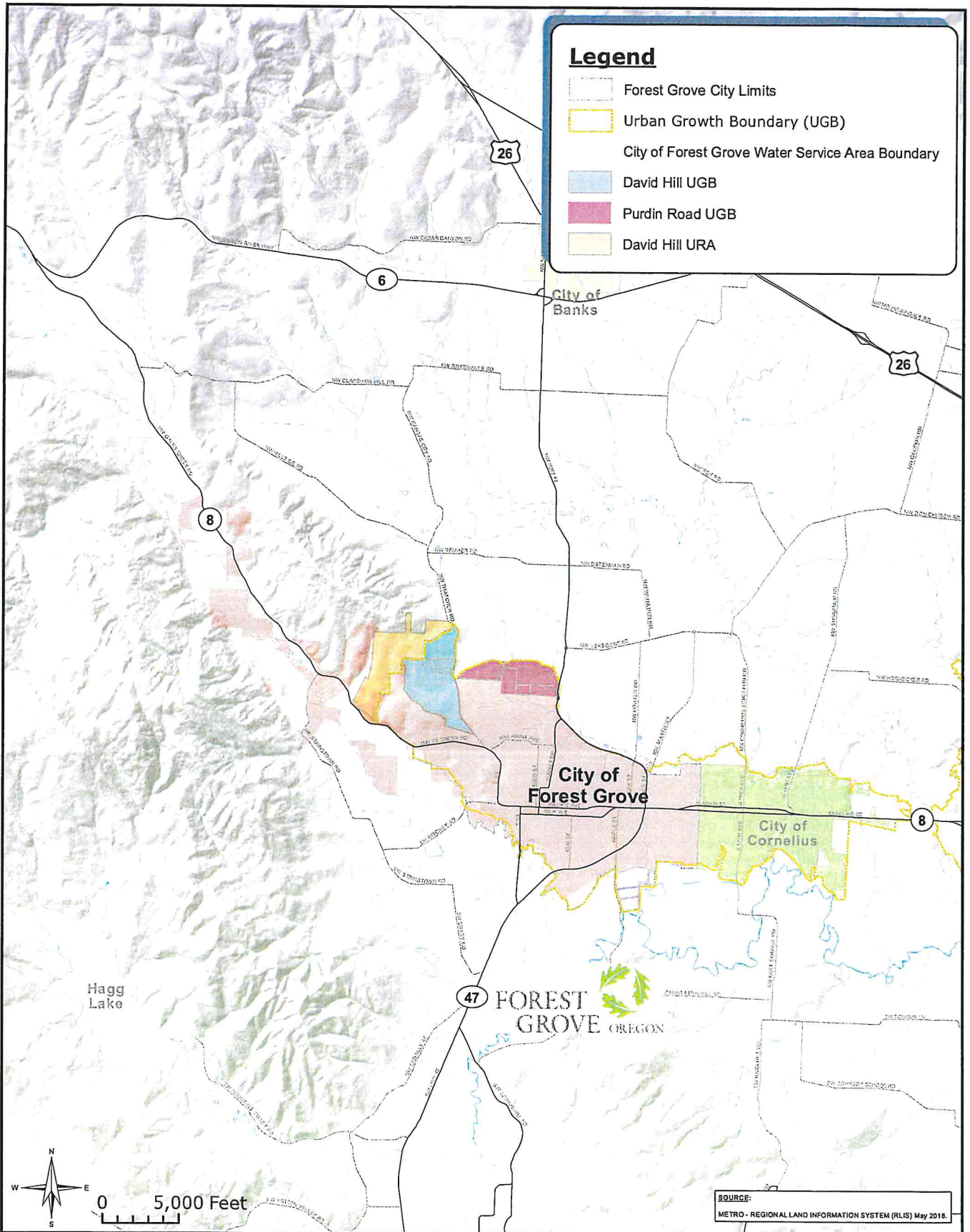
1. Firm capacity is the station capacity with the largest pump out of service. Firm capacity of the Raw Water PS and the Watercrest PS is 0 gpm as there is only one pump at each facility.

1.7 Distribution System

The City's distribution system contains approximately 91 miles of distribution main piping, most of which is 8-inch diameter, ductile iron pipe. Pipes are composed of various materials, including cast iron, ductile iron, asbestos cement (AC), and PVC, in sizes up to 24 inches in diameter. Cast iron mains were constructed mostly in the 1950s and 1960s while most newer distribution piping is ductile iron. A total of 692 fire hydrants are located throughout the system. Table 1-5 presents an inventory of piping by diameter and material.

Table 1-5 | Length (miles) of Transmission and Distribution Piping by Diameter and Material

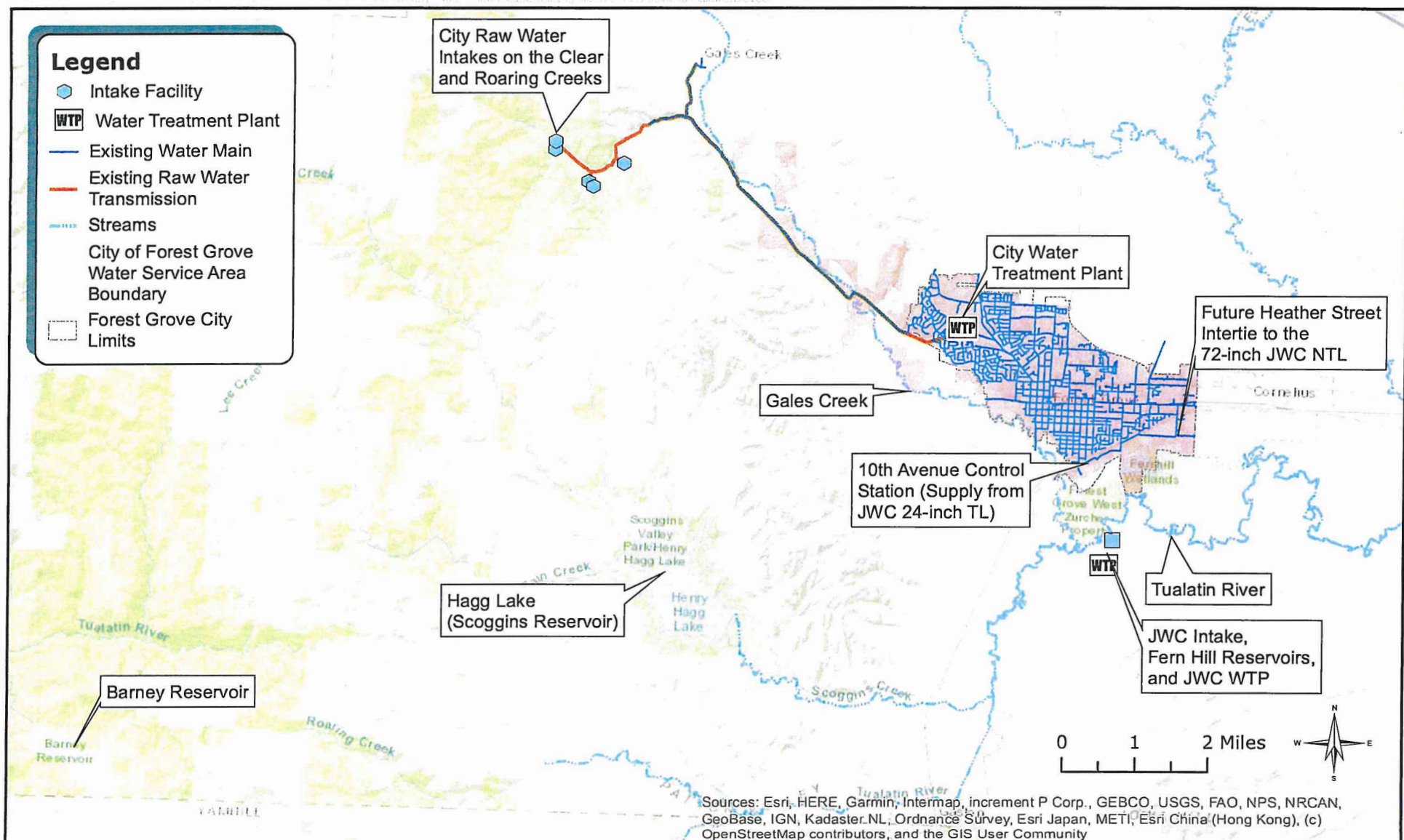
Diameter (inch)	Ductile Iron	Cast Iron	Other	Total (miles)
≤ 4	0.88	1.13	9.66	11.68
6	11.01	15.75	1.46	28.22
8	25.19	9.52	0.26	34.96
10	4.90	3.58	0.13	8.60
12	4.02	1.66	-	5.68
16	0.08	0.38	0.01	0.47
20	-	1.28	-	1.28
24	0.56	-	-	0.56
Total (miles)	46.64	33.30	11.52	91.45

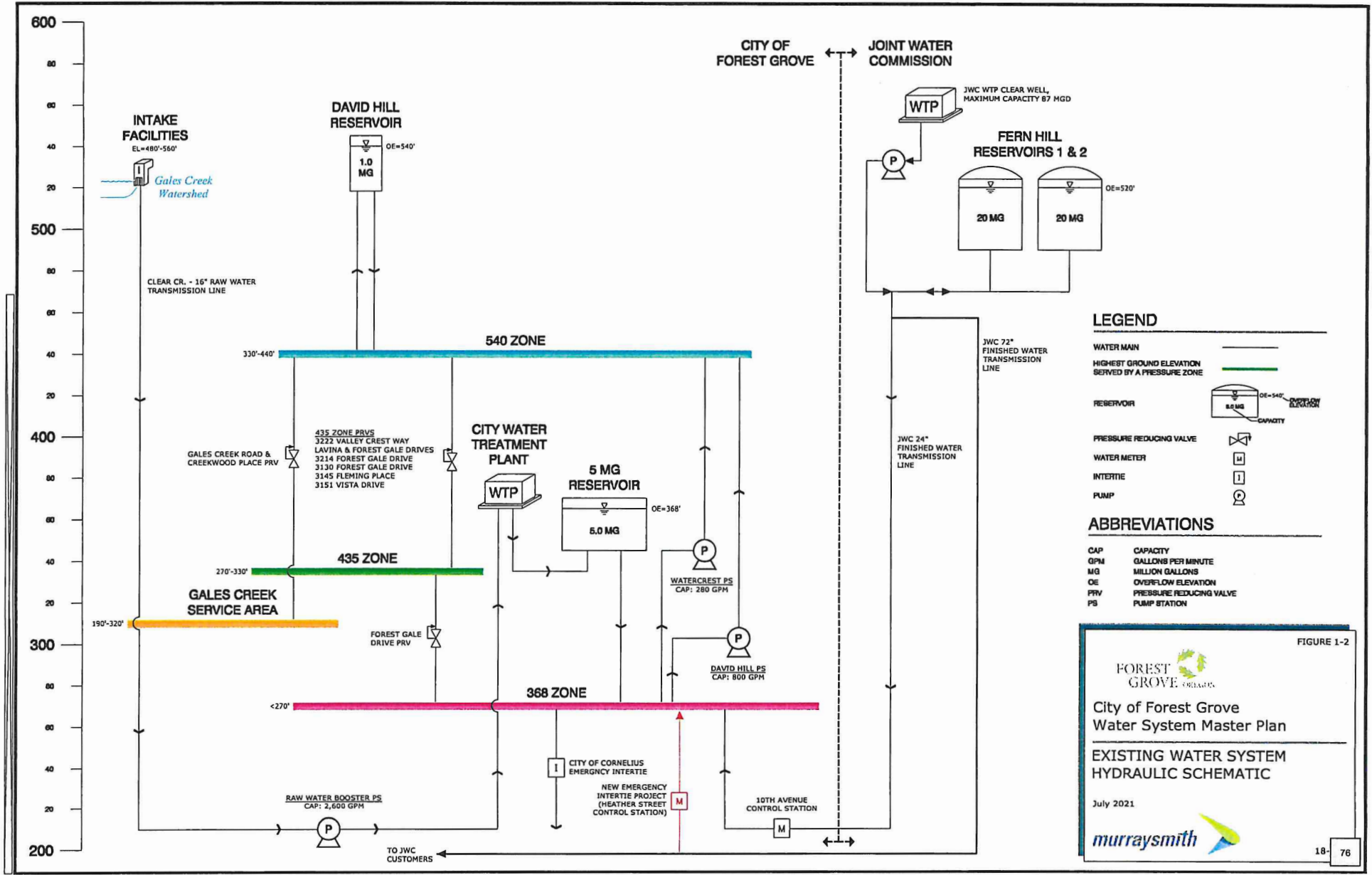


City of Forest Grove Water System Master Plan

Figure 1-1 Water Service Area Map







Section 2

Section 2

Water Requirements

This section presents existing and projected future water demands for the City's water service area. Water demand forecasts presented in this section are used with performance criteria presented in **Section 3** to evaluate the existing water system's capacity to serve current customers and future growth. Demand forecasts are developed from historical water consumption and production records, regional planning data, current land use designations, and previous City water planning efforts.

2.1 Water Service Area

2.1.1 Existing Service Area

As illustrated in **Figure 1-1**, the City's existing water service area encompasses all areas within the existing city limits and customers located outside the UGB along Gales Creek Road, Stringtown Road, and Oppenlander Lane (referred to as the GCSA), and along Martin Road.

2.1.2 Future Service Area

The future service area and the study area for this WSMP includes all areas within the city limits, the GCSA, and the UGB, including the David Hill and Purdin Road areas as described in the City's *2017 Westside Planning Program*. The GCSA and services along Martin Road are assumed to remain constant without adding new customers.

The David Hill Area has been included in the City's UGB since the 1980s. The Purdin Road Area was added to the UGB in 2014. The majority of these two areas is anticipated to be developed within 20 years.

Water demand projections presented in this section also include consideration of the existing David Hill Urban Reserve Area (DHURA) within a 50-year planning horizon. It is assumed future development in the DHURA would begin sometime after 2041.

2.2 Planning Period

The planning period for this WSMP is 20 years, through the year 2041, consistent with OAR requirements for WSMPs (OAR 333-061). Water demand projections presented in this section also include a 50-year projected water demand for long-range water supply planning.

2.3 Water Demand Description

Water demand refers to all finished water required by the system including residential, commercial, industrial, and institutional uses. Water demands are described using three water use metrics: average daily demand (ADD), max day demand (MDD), and peak hour demand (PHD). Each of these metrics is stated in gallons per unit time such as mgd and in gallons per capita per day (gpcd). Peaking factors are used to convert between ADD, MDD, and PHD.

- ADD is the total annual water volume used system-wide divided by 365 days per year.
- MDD is the largest 24-hour water volume for a given year. In western Oregon, MDD typically occurs each year between July 1st and September 30th.
- PHD is estimated as the largest hour of demand on the peak water use day.

2.3.1 Water Production vs. Consumption

Water demand can be calculated using either water consumption or water production data. Water consumption data is taken from the City's customer billing records and includes all revenue metered uses. This data can be analyzed by geographical location and customer type which is useful for quantifying typical water use for different land uses. However, consumption data does not capture any water loss or unmetered uses and is only recorded in monthly totals making it less useful in determining system-wide peak demands.

Water production is measured as the water supplied to the distribution system. The City's total daily water production is the sum of the recorded finished water flow measured at the City's WTP and at the 10th Avenue Control Station (JWC Supply). Total water production is used for analyzing seasonal water demand trends, supply, and storage capacity. Water production includes billed consumption (customer billing records), unmetered uses such as hydrant flushing, and water loss through minor leaks and unregulated use.

The difference between water production and consumption including unmetered uses is known as water loss and is typically presented in a percent. Oregon rules set a maximum water loss allowance for systems such as Forest Grove of 10%. Systems that do not meet this maximum are required to implement programs to reduce water loss.

2.4 Historical Water Demand

System-wide historical water demand is presented in **Table 2-1**. Typically, 5 years of historical data would be used to evaluate system demands. However, due to lack of valid metering, only the prior 3 years were used. This is discussed more in **Section 2.4.1**. It is also worth noting that the Covid-19 pandemic affected 2020 data. However, with only one year of data, it is unclear exactly to what extent water use patterns changed. Even with these unique circumstances, the City's water use

has remained constant over the past three years and so 2018-2020 data was assumed sufficient to develop a baseline for this plan.

Water consumption is calculated from the City's monthly billing data. Unmetered water use was provided by the City and includes permitted hydrant use, flushing, and backwash at the City's WTP. Water production is calculated daily as finished water supplied from the City's WTP plus the water supplied from the JWC through the 10th Avenue Control Station.

The City's average water loss for 2018-2020 was 14%. The City currently has a water loss reduction framework in place as recommended and discussed in the JWC Water Management and Conservation Plan (WMCP, 2021). The reduction program includes annual water audits, replacement of master meters, a regular meter testing and maintenance program, a water rate structure to encourage conservation, a public education program, potential expansion of the home energy audit program to include water use, and the continuation of a rebate program for high efficiency machines. Benchmarks at 2 and 5 years are also in place to ensure reduction of water loss to 10% or less. Future demands are estimated based on consumption factors, then scaled up to include water loss and unmetered water use. In 2021, water loss is estimated as 14% and unmetered use at 2% of the total demands, while in future years, water loss is estimated as 10% water loss and unmetered use at 2% of the total demands.

Table 2-1 | Historical Water Demand

Year	Production Total (MG) ¹	Consumption Total (MG)	Unmetered Water Use (MG) ²	Water Loss (MG)	Water Loss (%)
2018	1181	990	20	172	15%
2019	1141	978	21	142	12%
2020	1153	957	19	177	15%
Average	1158	975	20	164	14%

Note:

1. Production data calculated as the sum of Forest Grove WTP production and JWC supply through 10th Ave. As discussed in Section 2.4.1, the 10th Ave meter reads low, therefore corrections were used to develop JWC supply assumptions.
2. Unmetered water use includes permitted hydrant use, flushing, and backwash volumes as calculated by the City. This accounts for approximately 2% of the total production.

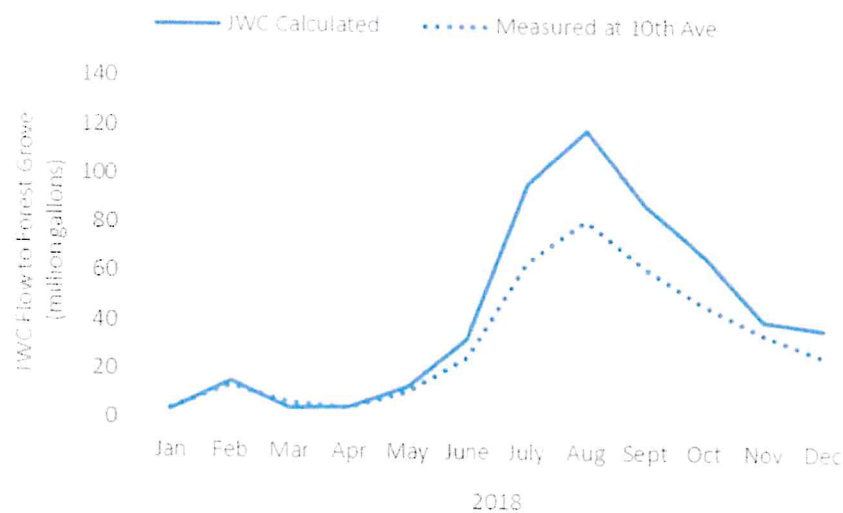
2.4.1 JWC Meter Corrections

In spring 2019, the City discovered that the 10th Avenue Control Station flow meter had not been accurately measuring flows into the distribution system from the JWC. Installation of a JWC flow meter in late 2017 that measures finished water in the 24-inch JWC TL allowed comparison of JWC flow to Forest Grove with metered flow at the 10th Avenue Control Station. Findings of the JWC's metered flow analysis are documented in the May 6, 2019 memo "Uncounted flows along 24-inch JWC TL between JWC Plant and delivery points at the City of Hillsboro Dilley and Forest Grove pressure reducing valve (PRV) facilities" (included as **Appendix B**).

The metered flow differences are generally at flow rates greater than approximately 500 gpm (approximately 22 million gallons/month assuming average flow) and are thus more pronounced

during the peak summer season as shown in **Figure 2-1**. These 10th Avenue Control Station meter inaccuracies impact both historical average and MDD metrics. It is unknown how long the 10th Avenue meter may have been registering inaccurate flow readings because JWC's 24-inch flow meter data is only available starting in fall 2017. For the purposes of this WSMP, demand metrics that reference JWC supply use the corrected flows developed using a combination of the 10th Ave meter for flows less than 500 gpm, the difference between the JWC 24" meter and the Hillsboro Dilley meter when available, and an escalated 10th Ave meter when no better information is available.

Figure 2-1 | 2018 Monthly JWC Metered Flow Differences



Note: November and December 2018 Hillsboro Dilley meter flows were not available due to meter updating. JWC calculated flows for these months are estimated based on 2017 Dilley meter data scaled based on the ratio of 2017 to 2018 peak flows.

2.4.2 Historical Demand and Peaking Factors

Average day and maximum day demand (ADD and MDD) are calculated based on production data. A system wide peaking factor to convert from ADD to MDD is calculated, however more specific peaking factors based on customer classification are used for demand projections in this analysis. Data was not available to calculate a PHD:MDD peaking factor. Based on recent experience with other regional water providers, a peak hour factor of 2 is assumed for future demand projections. An MDD to maximum month peaking factor was also calculated from production data. This conversion factor is 1.19 and is used for calculating MDD from consumption based data, where only monthly demands are available.

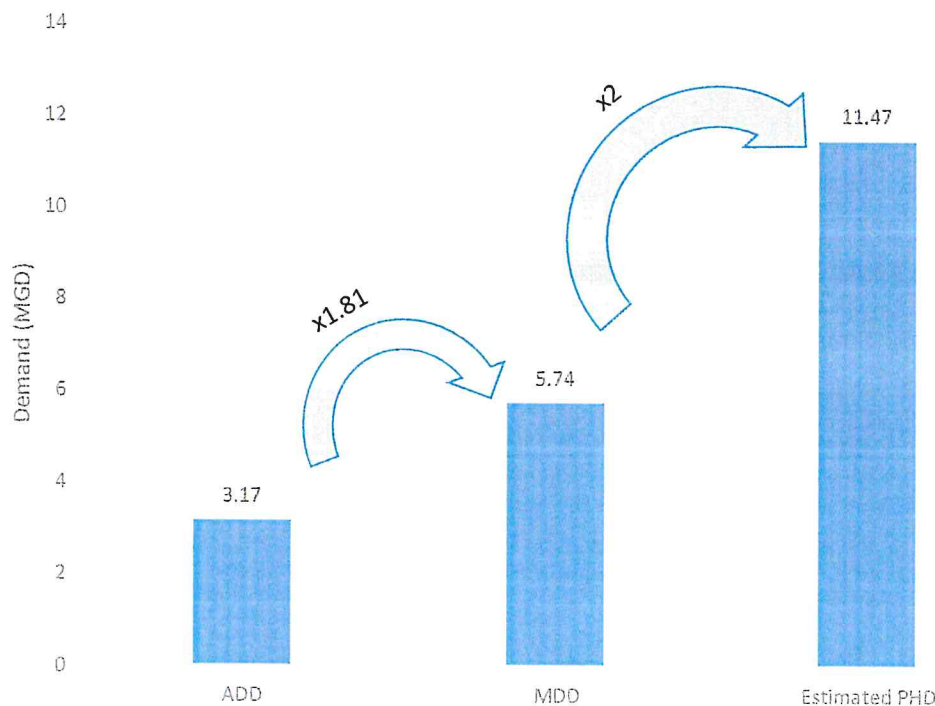
Table 2-2 | Historical ADD, MDD, and PHD

Year	ADD, based on Production (MGD)	MDD, based on Production (MGD)	Estimated PHD (MGD)	MDD:ADD Peaking Factor
2018	3.24	5.83	11.66	1.80
2019	3.13	5.62	11.23	1.80
2020	3.15	5.76	11.53	1.83
Average	3.17	5.74	11.47	1.81

Note:

1. A peaking factor of 2 was assumed for PHD:MDD conversion. No hourly data was available to calculate this from City data and so a factor typical of similar systems was used.

Figure 2-2 | Average Production (2018-2020)



2.4.3 Water Demand by Pressure Zone

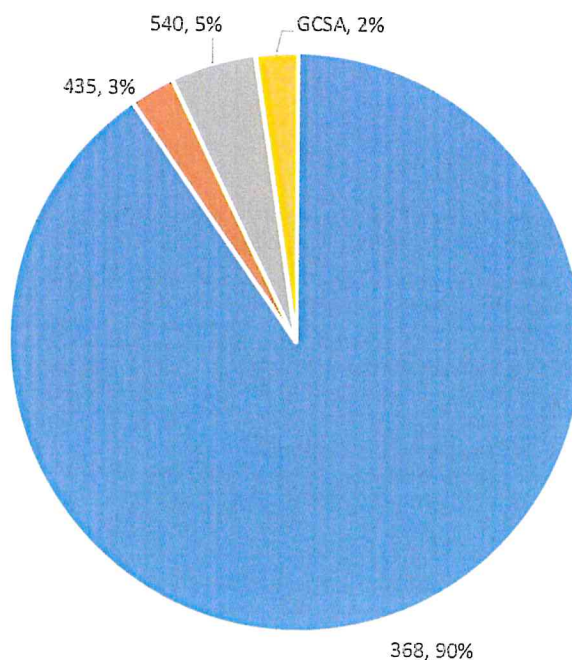
Water billing records provided by the City were used to document current average daily water consumption by pressure zone, customer type, and to correlate non-residential water demand to land use for future demand projections.

Table 2-3 and Figure 2-3 present ADD by zone, based on the geolocated billing records. Almost all the water use in the system occurs in the main, 368 Zone.

Table 2-3 | Historical ADD by Pressure Zone, Average 2018-2020

Zone	ADD (MGD)	Water Use %
368	2.40	90%
435	0.07	3%
540	0.13	5%
GCSA	0.06	2%
TOTAL	2.66	

Figure 2-3 | Historical ADD by Pressure Zone, Average 2018-2020



2.4.4 Water Demand by Customer Type

Current water use is dominated by residential customers, although the City also supplies significant commercial and industrial demand. When geolocating demands, some billing classifications didn't match the corresponding land use classification from taxlot data. In these cases, land use was assumed based on billing data classification.

The upper pressure zones have different use characteristics than the 368 Zone. Almost all customers in the 435 and 540 Zones are residential, however all multifamily customers are in the 368 Zone. Additionally, all industrial customers and most commercial customers are in the 368 Zone. The industrial demand is almost all from a few customers in the food processing and technology manufacturing industries.

Peaking factors were developed for each customer type. As irrigation is a major contributor in most peaking factors, parks and residential customers have much higher peaking factors than industrial customers who typically have a much more consistent water use.

The percentage of average daily water consumption for each customer type is presented in **Table 2-4** and **Figure 2-4**, along with peaking factors in **Figure 2-5**, to be used in future demands.

Table 2-4 | Water Consumption by Customer Type, Average 2018-2020

Customer Type	ADD (MGD)	Water Use %	MDD PF
Residential	1.26	47%	2.0
Multifamily	0.40	15%	1.5
Commercial	0.39	15%	1.8
School	0.15	6%	2.8
Industrial	0.34	13%	1.6
City	0.13	5%	2.4

Note:

1. MDD Peaking factors developed by scaling consumption data maximum month demand by 1.19 to estimate MDD. This maximum month demand peaking factor was developed from production data.

Figure 2-4 | Water Consumption by Customer Type, Average 2018-2020

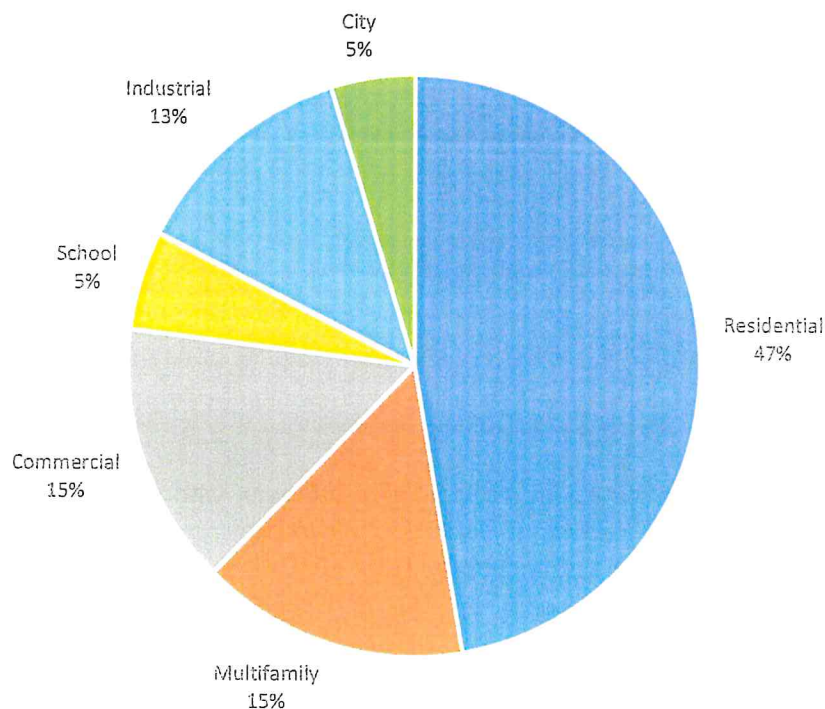
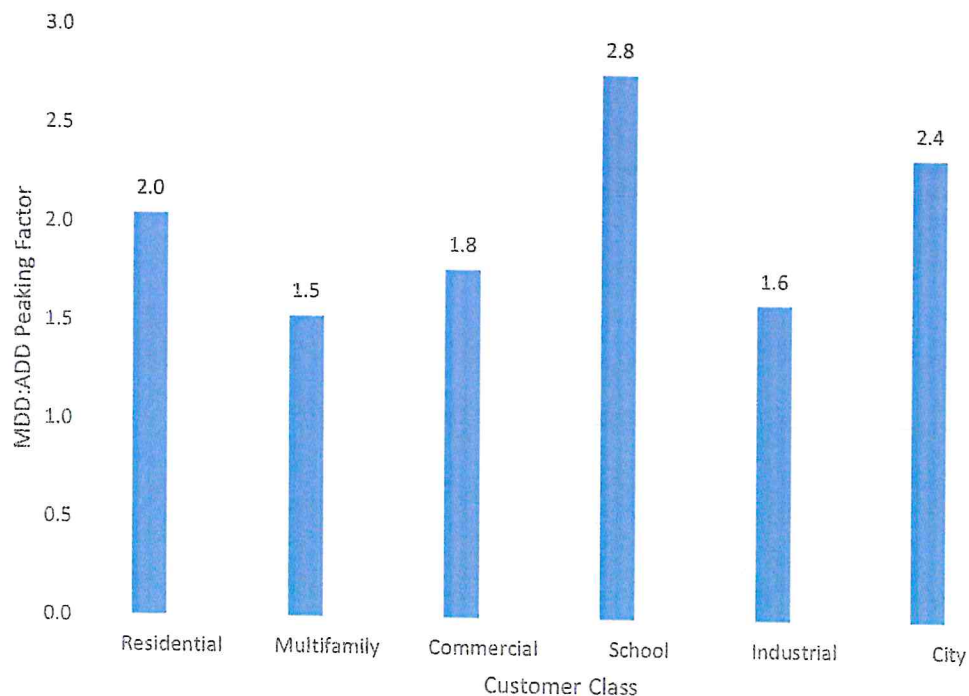


Figure 2-5 | MDD:ADD Peaking Factors by Customer Type, Average 2018-2020



Note:

1. MDD Peaking factors developed by scaling consumption data maximum month demand by 1.19 to estimate MDD. This maximum month demand peaking factor was developed from production data.

2.4.4.1 Average Residential per Capita Water Demand

Per capita ADD for residential customers is estimated based on historical residential water consumption for all customers in the City's water service area, including the GCSA, and population within the city limits as summarized in **Table 2-5** and **Figure 2-6**. Historical population and demands from the 2010 WSMP are also included for comparison. A residential ADD per capita of 70 gpcd was assumed for future residential demand projections. This is slightly higher than the recent historical average but given the limited data set and variation in historical demand, a conservative estimate is appropriate.

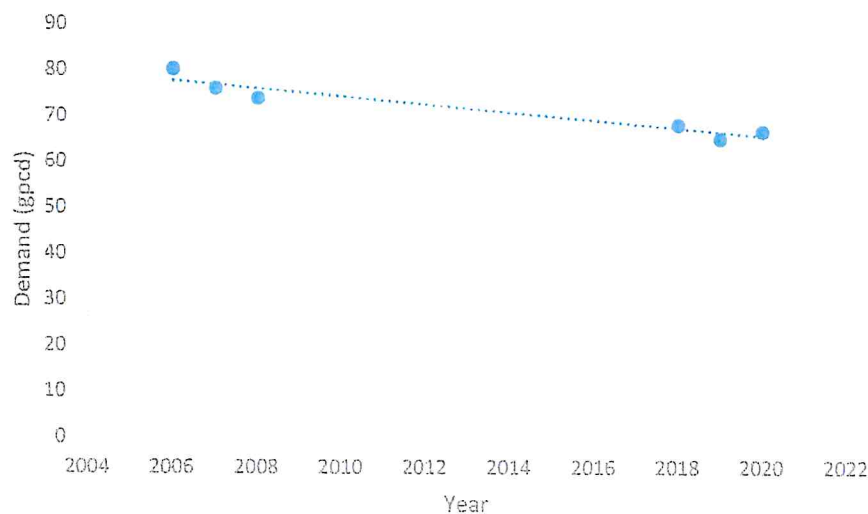
Table 2-5 | Historical Residential Demand per Capita

Year	Population	Residential + MF Demand (MGD)	Demand/Capita (gpcd)
2006, 2010 WSMP Estimate	20,380	1.64	80
2007, 2010 WSMP Estimate	20,775	1.58	76
2008, 2010 WSMP Estimate	21,465	1.58	74
2018	24,125 ¹	1.65 ²	68
2019	25,180 ¹	1.64 ²	65
2020	25,435 ¹	1.70 ²	67
For future projections:			70

Note:

1. City population for 2018-2020 is from the Portland State University Population Research Center (PSU PRC) population reports.
2. Residential + multifamily demand for 2018-2020 is summarized from consumption data.

Figure 2-6 | Historical Residential Demand per Capita



2.4.4.2 Average Non-Residential Water Demand per Acre

While residential water demand generally correlates well with population growth, non-residential water demands may be independent of population, particularly if system growth is not consistent across all customer classifications. To forecast future non-residential demands, an ADD per acre is estimated for different land uses based on billing records as presented in **Table 2-6**.

Five land use types were identified for future development: Fire Station, Elementary School, Park, Industrial, and Mixed Use/Commercial. ADD per acre was developed for each of these land uses based on existing examples. Elementary schools are considered with their adjacent parks to include irrigation demands for fields, even though taxlots may be split between park and school. Park demands are based on local parks not adjacent to schools. Future Mixed Use/Commercial development is assumed to be more like the existing downtown core than large box stores.

Therefore, a two-block estimate near Pacific Ave and Main Street was used as to develop demand per acre. Peaking factors from customer class developed in **Section 2.4.4** were used to calculate MDD.

Table 2-6 | Non-residential ADD per Acre

Development Type	Classification	Description of Data Source	ADD/Acre
Fire station	City	Fire Station at 1919 Ash St	730
Elementary School	School	Tom McCall, Harvey Clarke, and Joseph Gale Elementary Schools and adjacent parks	730
Park	City	Bard, Talisman, Hazel Sills, Knox Ridge parks ¹ .	1,380
Industrial	Industrial	All existing industrial demands and their corresponding taxlots.	2,550
Mixed Use/Commercial	Commercial	Sample of downtown core (approx. 2 blocks near Pacific Ave and Main Street)	1,710

Note:

1. Forest Glen and Rogers parks were not considered in this estimate because demands were not consistent with total demands and irrigation peaking seen at the other parks.
2. Industrial demand per acre in this plan is significantly higher than the industrial demand per acre calculated in the 2010 plan because this estimate uses all industrial demands, rather than a subset. As the future industrial users are unknown, a more conservative approach based on total existing industrial demands was selected.

2.4.4.3 Top Non-Residential Water Users

The following customers are the largest water users in the system, in 2020, from billing records.

Table 2-7 | Top Water Users in 2020 from Billing Records

Customer Name	Site Address	Customer Class	2020 Annual Consumption (gal)
Viasystems Technologies Corp.	1521 POPLAR ST	IND	34,360,000
Lieb Foods LLC	2550 23RD AVE	IND	25,606,000
Clean Water Services	1345 FERN HILL RD	COM	19,871,400
Rose Grove Mobile Home Park LTD	3839 PACIFIC AVE	MF	17,423,100
Westak of Oregon	3941 24TH AVE	IND	16,125,700
MGC Pure Chemicals America Inc.	701 ELM ST	IND	13,245,400
Homestead Community Inc.	1201 MOUNTAIN VIEW LN WTR	MF	12,857,000
W. Pendarvis Global Land	4115 24TH AVE (NEW BLDG)	COM	11,923,200
Forest Place Apartments LLC	3802 PACIFIC AVE3706-3834	MF	9,536,800
City of Forest Grove WTP	WTP 501 WATERCREST RD	CTY	8,394,000

2.5 Future Water Demand Forecast

Future water demand is estimated as the combination of projected residential/multifamily and non-residential demand. Residential/multifamily demand is based on population growth and

average per capita water demand. Non-residential demand is forecast based on available developable land by land use and average demand per acre.

Growth within the David Hill and Purdin Road UGB areas is based on proposed zoning and future dwelling units from the *2017 Westside Planning Program* and average persons per dwelling from the United States Census Bureau. Timing of the growth shown in this plan deviates from the 2017 report as growth has been slower in the area than previously anticipated. It is now projected that both UGB areas will be built-out within the 20-year planning window. Lower elevation development and critical infrastructure (fire station, school) were assumed to develop first.

Non-residential development and redevelopment within the existing system is based on the Employment Opportunities Analysis (EOA) developed by Johnson Economics in 2019. This report identifies taxlots available for development or redevelopment and provides 5- and 20-year City needs for industrial and mixed-use/commercial acreage.

Future water demands are forecast at 5, 10, 20, and 50 years. The UGB is anticipated to be built out within 20 years. The 50-year water demand projection assumes growth in the existing DHURA, gradual population growth which reflects potential densification and redevelopment within the existing service area after 2041, and development of the remaining non-residential land identified in the EOA.

2.5.1 Residential Densification, Housing Choices - HB 2001

In 2019, the Oregon legislature passed House Bill (HB) 2001. HB 2001 is landmark legislation that preempts local zoning regulations by doing away with the exclusively single unit residential zoning within the Portland regional urban growth boundary and within cities with a population of at least 25,000 persons elsewhere in the state. For these cities, HB 2001 requires that local zoning allow duplexes on any lot that allows a single unit dwelling as well as triplexes, quadplexes, townhouses and cottage clusters in areas zoned for single unit housing. Development Code amendments needed to comply with HB 2001 will be adopted by June 2022.

While it's clear that HB 2001 allows for higher density development within areas zoned for single unit homes, it is uncertain what impact the legislation might have on demand for public services. HB 2001 provides some guidance to cities for the purposes of utility planning. For infill areas, HB 2001 allows for a housing capacity increase of one percent over current estimates. In newly developing urban growth areas, HB 2001 allows for a housing capacity increase of three percent. Until the impacts of HB 2001 are better understood, it is assumed that the legislation will have marginal impacts on anticipated development levels, thus the potential increase in population resulting from HB 2001 was not included in the population projections in **Section 2.5.2**.

2.5.2 Projected Residential and Multifamily Water Demand

Future residential and multifamily water demand within the existing water service area, David Hill UGB area, Purdin Road UGB area, and DHURA is estimated based on population forecasts developed for the City's water service area by the Portland State University Population Research

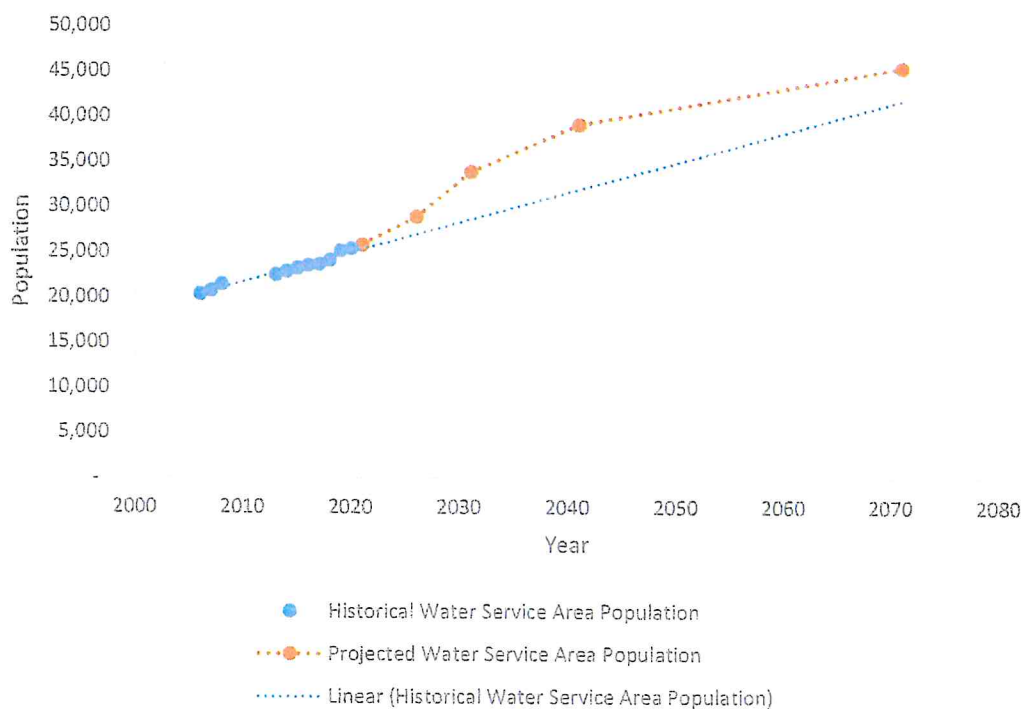
Center (PSU PRC). The PSU PRC provides annual population estimates for all Oregon cities. The population forecast for the City's water service area was part of a special 2019 study commissioned by the Portland metro area Regional Water Providers Consortium (RWPC) of which the City is a member. The population estimates from the RWPC study show an average annual growth rate (AAGR) between 1.0 and 2.0 percent through 2050. This AAGR reflects growth within the existing water service area and some growth in the UGB. Adjustments were made to this population projection based on more refined planning information specific to the GCSA and UGB development areas. This is discussed in **Section 2.5.2.1**.

Population growth beyond 2041 is estimated at approximately 0.5 percent annually to reflect potential densification and redevelopment within the existing service area and development of the DHURA. Historical and projected population growth is summarized in **Table 2-8** and **Figure 2-7**.

Table 2-8 | Historical and Future Population Growth

Year	Water Service Area Population	Data Source	Average Annual Growth Rate
2006	20,380	2010 WSMP	1.9%
2007	20,775	2010 WSMP	3.3%
2008	21,465	2010 WSMP	1.0%
2013	22,518	2018 PRC Report	1.6%
2014	22,873	2018 PRC Report	1.6%
2015	23,253	2018 PRC Report	1.3%
2016	23,559	2018 PRC Report	0.5%
2017	23,672	2018 PRC Report	1.9%
2018	24,125	2018 PRC Report	4.3%
2019	25,180	2019 PRC Report	1.0%
2020	25,435	2020 PRC Report	1.7%
2021	25,877	2021 Projections	2.3%
2026	28,988	2021 Projections	3.2%
2031	33,948	2021 Projections	1.4%
2041	39,192	2021 Projections	0.5%
2071	45,517	2021 Projections	

Figure 2-7 | Historical Population Growth



Notes:

1. Blue dashed line represents average historical growth rate projection at 1.81% AAGR.
2. Orange dashed line and dots represent projected population based on 2017 Westside Planning Program, 2019 RWPC estimates, DHURA development estimates, and densification past 20 years.
3. Assumed growth rate for 2041-2071 is 0.5%.

2.5.2.1 2019 RWPC Population Estimate Adjustment

The 2019 RWPC population estimates were adjusted based on more refined development planning estimates. The following changes were made to the RWPC estimates:

- **Subtract RWPC 2019 projected growth in the GCSA:** The GCSA is not anticipated to supply any additional water customers in the future. Thus, the additional population associated with GCSA growth has been subtracted from the RWPC 2019 forecast population.
- **Subtract partial projected growth in the David Hill and Purdin Road UGB and replace with refined projections:** RWPC 2019 population estimates include portions of the David Hill and Purdin Road UGB areas. The basis for UGB growth projections in the City's 2017 *Westside Planning Program* includes more detailed analysis of likely future land use including non-residential uses. Thus, the *Westside Planning Program* growth estimates are assumed to provide a more refined picture of likely future water demand for this area.

2.5.2.2 David Hill and Purdin Road UGB Areas – Residential and Multifamily

Consistent with the 2017 *Westside Planning Program*, residential zoning, available land, and projected population for the David Hill and Purdin Road UGB areas is summarized in **Table 2-9** and allocated by year in **Table 2-10**. Units were calculated based on density assumed in the report, and population was calculated based on the 2040 estimate of 2.59 people per household, provided in the 2019 RWPC growth assumptions.

The Purdin Road UGB area was assumed 50% developed in 5 years and 100% developed in 10 years. All development in this area is located within the 368 Pressure Zone. The David Hill UGB area was assumed 50% developed in 10 years and 100% developed in 20 years. Development was allocated to the 368, 435, 540, and 710 pressure zones based on percentage of the total area within each zone by elevation. 710 development was assumed to begin after lower elevation development.

Table 2-9 | David Hill and Purdin Road UGB Population by Zoning

Zoning	Net Units per Acre	Net Area (acres)	Estimated Total Units	Estimated Population (units x 2.59)
Suburban Residential	1	28.5	24	62
Single Family - Low Density (R-10)	4.35	113.3	432	1,119
Single Family - Standard Density (R-7)	6.22	126.1	749	1,940
Single Family - Medium Density (R-5)	8.71	57.3	498	1,290
Residential Multifamily Low (RML)	12	8.7	103	267
Mixed-Use	Varies	22.6	144	373
David Hill & Purdin Rd Residential Units & Population			1,950	5,051

Note:

1. Additional reduction in acreage due to steep slopes not shown.

Table 2-10 | David Hill and Purdin Road UGB Projected Population

Year	Purdin Rd UGB			David Hill UGB		
	% Developed	Units	Population	% Developed	Units	Population
5	50%	587	1,521	0%	0	0
10	100%	1,174	3,041	50%	388	1,005
20	100%	1,174	3,041	100%	776	2,010
50	100%	1,174	3,041	100%	776	2,010

2.5.2.3 David Hill Urban Reserve Area

The DHURA includes higher-elevation land to the northwest of the existing UGB between Gales Creek and Thatcher Roads. Although development is not anticipated in the DHURA until after the 20-year planning horizon of this WSMP, potential growth in the area is relevant to long-term supply and storage planning. Metro policy requires adopting a concept plan for the urban reserve

area before the area is brought into the UGB; this has yet to be completed for the DHURA. A significant portion of the DHURA has ground elevations higher than the maximum service elevations for the existing water distribution system. Thus, any development in this area would require planning for new pumping and/or storage facilities to supply adequate service pressure. The DHURA concept plan will help refine any projections or facilities planned for this area.

It is assumed that future development in the DHURA would be residential with limited mixed-use neighborhood commercial. Based on the weighted average of residential (R-7 and R-10) and neighborhood mixed-use (NMU) zoning in the David Hill UGB area, future units within the DHURA are estimated at 5 net units per acre. Future developable area in the DHURA is estimated as the total area minus a 25 percent allowance for future right-of-way, approximately 183 acres. Estimated future units, approximately 915, are multiplied by 2.54 persons per unit (2019 RWPC 2050 estimate) to estimate DHURA build-out population. Growth projections would have been based off 2071 persons per unit estimates if available. However, the RWPC estimates only project to year 2050.

2.5.2.4 System Wide Residential and Multifamily Demand Growth

Summarized projected population, residential ADD, and residential MDD are listed in **Table 2-11** and illustrated in **Figure 2-8**.

33% of the population in the 368 Zone is assumed to be multifamily. This number is derived from single family unit counts, people/unit estimates, and subtraction was used to develop a weighted peaking factor for this zone of 1.88. This peaking factor was maintained throughout the projections for the 368 Zone. The upper zones were assumed to be essentially all single family and so the SFR peaking factor of 2.0 was used for those zones.

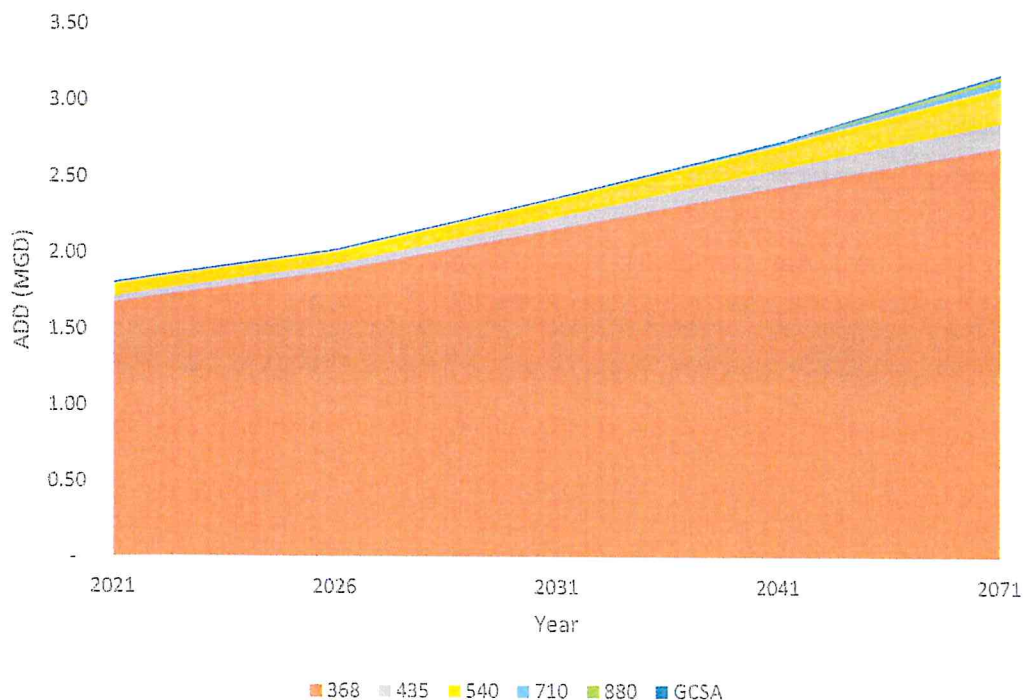
Table 2-11 | Residential and Multifamily - Projected Population and Water Demand by Zone

Population							
Year	Total	368	435	540	710	880	GCSA
2021	25,877	23,954	530	1,218	-	-	175
2026	28,988	26,958	563	1,293	-	-	175
2031	33,948	30,961	1,079	1,733	-	-	175
2041	39,192	34,954	1,633	2,258	173	-	175
2071	45,517	38,685	2,215	3,402	724	316	175
ADD (MGD)							
Year	Total	368	435	540	710	880	GCSA
2021	1.81	1.68	0.04	0.09	-	-	0.01
2026	2.03	1.89	0.04	0.09	-	-	0.01
2031	2.38	2.17	0.08	0.12	-	-	0.01
2041	2.74	2.45	0.11	0.16	0.01	-	0.01
2071	3.19	2.71	0.16	0.24	0.05	0.02	0.01
MDD (MGD)							
Year	Total	368	435	540	710	880	GCSA
2021	3.42	3.15	0.08	0.17	-	-	0.03
2026	3.83	3.54	0.08	0.19	-	-	0.03
2031	4.49	4.07	0.15	0.25	-	-	0.03
2041	5.20	4.59	0.23	0.32	0.02	-	0.03
2071	6.06	5.08	0.32	0.49	0.10	0.05	0.03

Note:

1. Projected water demands in this table do not include water loss or unmetered water use.
2. 368 Zone MDD:ADD peaking factor based on estimate of population living in multifamily or single family residential housing.

Figure 2-8 | Residential and Multifamily Demand Projection by Zone, ADD



2.5.3 Projected Non-residential Water Demand

Non-residential future demand is estimated based on historical non-residential demand and demand characteristics, projected land needs developed in the Economic Opportunity Analysis (EOA, Johnson Economics, 2019), and revised available land from the 2018 Buildable Lands Inventory (BLI) and projected land use from the 2017 Westside Planning Program.

2.5.3.1 David Hill and Purdin Road UGB Areas – Non-Residential

Consistent with the *2017 Westside Planning Program*, developable mixed use and public zoned land in the David Hill and Purdin Road UGB areas is summarized in **Table 2-12**. Per-acre ADD is based on historical data of similar development types as discussed in **Table 2-6**, MDD peaking factors are based on demand classification as discussed in **Table 2-4**. All non-residential development in the David Hill and Purdin Road UGB areas is anticipated to be in the 368 Zone. It was also assumed that Mixed-Use/Commercial demand is in addition to any residential demand developed for the same acres, as the existing mixed-use classification is generally based on commercial supply only.

Table 2-12 | Projected Non-Residential UGB Water Demand

UGB Area	Development Type	Net Acres	Classification	Timing	ADD (mgd)
Purdin Road	Park	6	City	5	0.008
	School	10	School	5	0.007
	Fire Station	2.4	City	5	0.002
David Hill	Mixed Use/Commercial	19.7	Commercial	10	0.034
	Mixed Use/Commercial	2.9	Commercial	10	0.005

Note:

1. The Mixed Use/Commercial development for both Purdin Road and David Hill is shown in this table and in Table 2-15. It is only counted once in the demand summary.

2.5.3.2 Industrial and Mixed-Use/Commercial Land Needs

The EOA developed a land use supply and demand forecast for Industrial and Mixed-Use/Commercial development. Supply was determined by refining the 2018 BLI and includes vacant and redevelopable land. Demand was determined through an employment need assessment. Any supply within the David Hill and Purdin Road UGB areas was replaced with the 2017 Westside Planning Program estimates, as it is a better estimate of available land in these areas.

While the EOA reports a total excess in 20-years, there is a significant mismatch of land use need (mostly mixed-use/commercial) and land use availability (mostly industrial). Therefore, it was assumed that land use would be redesignated in the future. All lands identified in the EOA are located within the 368 Zone.

The EOA developed projections for 5 and 20 years. 10-year demands were linearly interpolated from the 5 and 20-year demands. By 50 years, it was assumed that all land identified in the EOA and refined with the Westside Planning Program was developed, at the same split between Industrial and Mixed-Use/Commercial as 20-year development. Table 2-13 includes supply acreage, need acreage, and resultant demand forecast for Industrial and Mixed-Use/Commercial areas in the EOA.

Table 2-13 | EOA Demand Forecast

		Industrial	Mixed-Use/ Commercial	Total
Supply (acres)	EOA	237.1	55	292.1
	Adjusted	237.1	54.5 ¹	291.6 ¹
Need (acres)	5	11.1	37	48.1
	10	23.4	81.2 ²	104.6
	20	47.9	169.6 ²	217.5
	50	64.2	227.3 ²	291.6
	5	0.03	0.06	
ADD (MGD)	10	0.06	0.14	
	20	0.12	0.29	
	50	0.16	0.39	

Note:

1. 23.2 acres of commercial development located in the UGB identified by EOA replaced with 22.6 acres of commercial identified in 2017 Westside Planning, resulting in a total reduction of 0.5 acres of supply.
2. 22.6 acres of commercial located in UGB.

2.5.3.3 System Wide Non-Residential Demand Growth

Non-residential demands are not anticipated to change in the upper zones and are listed in **Table 2-14**. Growth in the 368 Zone is calculated from existing demands with growth calculated in the prior two sections. Projected Non-Residential ADD and MDD are listed in **Table 2-15** and illustrated in **Figure 2-9**.

Table 2-14 | Existing Non-Residential Demands by Pressure Zone, ADD

Zone	Commercial	Industrial	City	School	Total
368	0.38	0.34	0.07	0.15	0.94
435			0.02		0.02
540	0.001				0.001
GCSA	0.004		0.04	0.001	0.05
Total	0.39	0.34	0.13	0.15	1.00

Note:

1. Water demands in this table do not include water loss or unmetered water use.
2. Water demands from average 2018-2020 metered consumption.

Table 2-15 | Non-Residential Demand Projection, 368 Zone

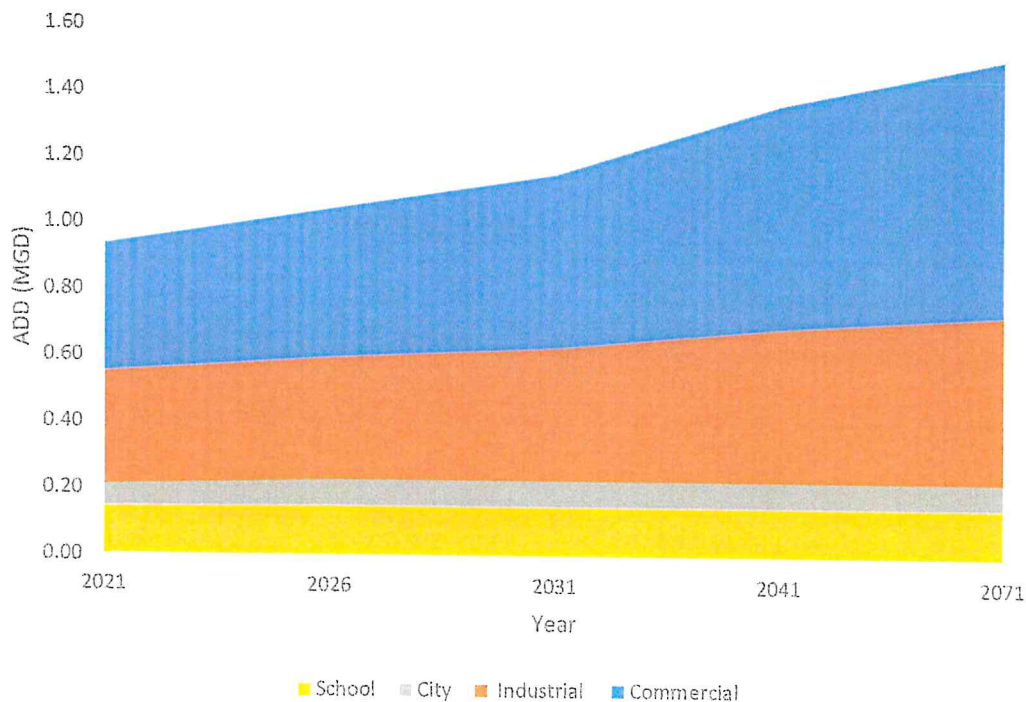
368 Zone ADD					
Year	Commercial	Industrial	City	School	TOTAL
2021	0.38	0.34	0.07	0.15	0.94
2026	0.45	0.37	0.08	0.15	1.05
2031	0.52	0.4	0.08	0.15	1.15
2041	0.68	0.46	0.08	0.15	1.37
2071	0.77	0.5	0.08	0.15	1.51

368 Zone MDD					
Year	Commercial	Industrial	City	School	TOTAL
2021	0.68	0.55	0.15	0.41	1.79
2026	0.8	0.59	0.18	0.43	1.99
2031	0.93	0.64	0.18	0.43	2.18
2041	1.2	0.75	0.18	0.43	2.55
2071	1.38	0.81	0.18	0.43	2.79

Note:

1. Projected water demands in this table do not include water loss or unmetered water use.

Figure 2-9 | Non-Residential Demand Projection by Class, 368 Zone



2.6 Projected Water Demand Summary

Future system demands are the sum of residential and non-residential projections, scaled to include both unmetered water use and water loss. In the Forest Grove system, unmetered water use is calculated at approximately 2%. Existing water loss is assumed at 14% with a reduction to 10% within 5 years, and then maintained at 10% through buildout. ADD and MDD are summed from existing demands and projections discussed in the prior sections, PHD is calculated using an estimated peaking factor of 2.0. **Table 2-16** and **Figure 2-10** present system wide ADD, MDD, and PHD for the 50-year projection period.

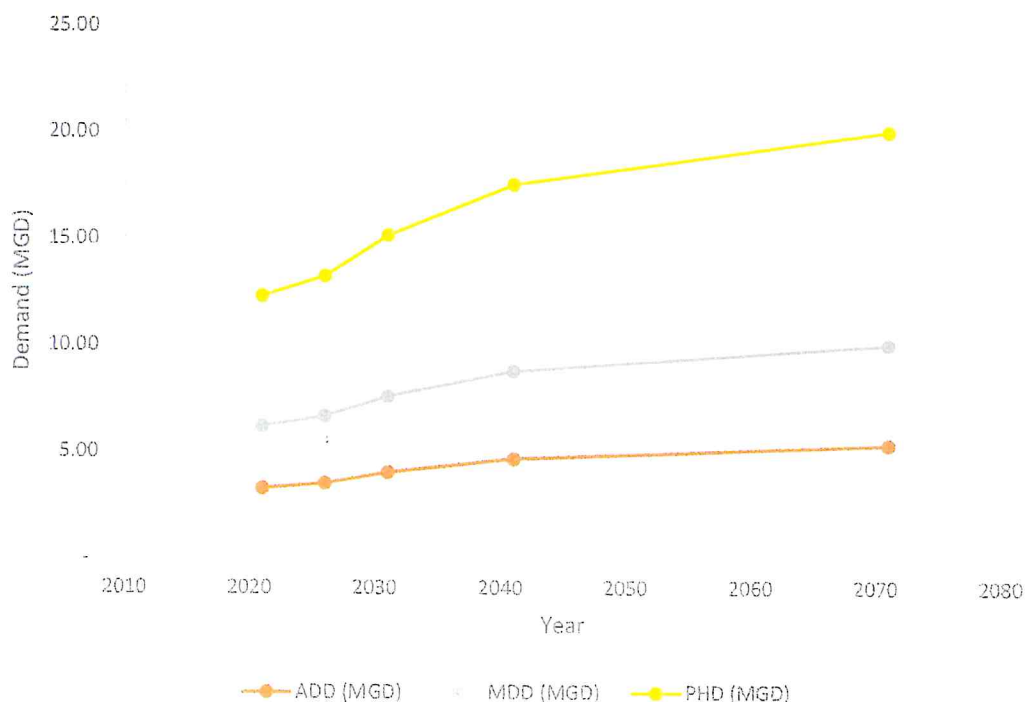
Table 2-16 | Projected Water Demand Summary

Year	Forecast Population	Assumed Water Loss (%)	ADD (mgd)	MDD (mgd)	PHD (mgd)
2021	25,877	14%	3.27	6.17	12.34
2026	28,988	10%	3.52	6.64	13.29
2031	33,948	10%	4.03	7.59	15.19
2041	39,192	10%	4.68	8.80	17.59
2071	45,517	10%	5.33	10.03	20.07

Note:

1. Assumed water loss and additional 2% unmetered use are included in the ADD, MDD, and PHD shown in this table.

Figure 2-10 | Projected Water Demand Summary



2.6.1 Water Demand by Pressure Zone

Water demand by pressure zone is used with performance criteria presented in **Section 3** to analyze the capacity of water facilities supplying each zone. Almost all non-residential and high-density developable land within the City's UGB is in the 368 Zone. The 435, 540, and future zones are primarily residential. It is assumed that the GCSA demand will remain constant over the planning period with no new customers added. Water demands by pressure zone are summarized in **Table 2-17** and **Figure 2-11**.

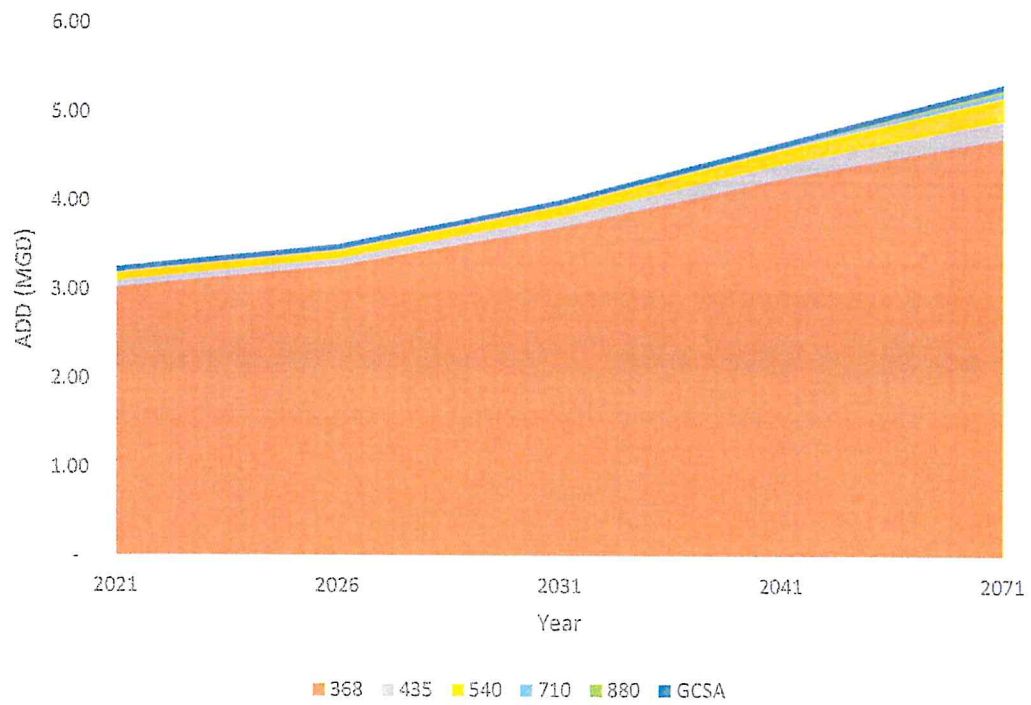
Table 2-17 | Water Demand by Pressure Zone

ADD (MGD)							
Year	TOTAL	368	435	540	710	880	GCSA
2021	3.27	3.03	0.07	0.10	-	-	0.07
2026	3.52	3.28	0.07	0.10	-	-	0.07
2031	4.03	3.72	0.11	0.14	-	-	0.07
2041	4.68	4.27	0.15	0.18	0.01	-	0.07
2071	5.33	4.72	0.20	0.27	0.06	0.02	0.07
MDD (MGD)							
Year	TOTAL	368	435	540	710	880	GCSA
2021	6.17	5.73	0.12	0.21	-	-	0.11
2026	6.64	6.20	0.12	0.21	-	-	0.11
2031	7.59	7.00	0.21	0.28	-	-	0.11
2041	8.80	8.00	0.30	0.37	0.03	-	0.11
2071	10.03	8.82	0.39	0.55	0.12	0.05	0.11

Note:

1. Demands include water loss (14% in 2021, 10% in remaining years) and 2% of additional water use for unmetered use.

Figure 2-11 | ADD by Pressure Zone



Section 3

Section 3

Planning and Analysis Criteria

3.1 Introduction

This section documents the performance criteria used for analyses of the City's water supply and distribution system. Criteria are established for evaluating water supply, distribution system piping, service pressures, and storage and pumping facilities. Recommended water needs for emergency fire suppression are also presented. These criteria are used in conjunction with the water demand forecasts developed in **Section 2** to complete the analyses of the City's water supply presented in **Section 4** and the distribution system in **Section 5** of this WSMP.

3.2 Performance Criteria

The water distribution system should be capable of operating within certain performance limits under varying customer demand and operational conditions. The recommendations of this plan result from evaluations based on the performance criteria listed in this section and summarized in **Table 3-3**. The performance guidelines have been developed through review of State requirements, American Water Works Association (AWWA) acceptable practice guidelines, *Ten States Standards*, the Washington State *Water System Design Manual*, and practices of other water providers in the region.

3.3 Water Supply Capacity

As described in **Section 1**, the City receives most of its non-peak season, October to June, supply from the Clear Creek Watershed through the City's WTP. During the peak summer season, July through September, the City receives almost all supply from the JWC WTP and JWC Fernhill Reservoirs through the 10th Avenue Control Station.

The City's WTP draws water from five intake facilities located within the Clear Creek Watershed which is delivered through an approximately 7.8-mile RWTM. The JWC draws its water from the Tualatin River until summertime low stream flows in the Tualatin River require sourcing raw water from Barney Reservoir and Hagg Lake. Raw water is treated at the JWC WTP and pumped to transmission mains and the adjacent finished water storage tanks, the Fernhill Reservoirs. Finished JWC water is transmitted to the City through approximately 1.6 miles of 24-inch JWC TL to the 10th Avenue Control Station.

The City's overall supply capacity is impacted by each of these components: water source, raw water transmission, treatment, and finished water transmission. Current supply vulnerabilities are discussed in more detail in **Section 4** including seasonal water rights limitations in the City's

watershed and finished-water transmission limitations with the City's JWC supply. The City should plan for adequate peak season (summer) supply capacity to meet the future MDD projections in each of the following: raw water source, raw water transmission, treatment, and finished water transmission.

3.4 Service Pressures and Distribution Piping

Water distribution systems are separated by ground elevation into pressure zones to provide service pressures within an acceptable range to all customers. Typically, water from a reservoir will serve customers by gravity within a specified range of ground elevations to maintain minimum and maximum water pressures at each individual service connection. When it is not feasible or practical to have a separate reservoir for each pressure zone, pump stations or PRVs are used to serve customers in different pressure zones from a single reservoir.

Most City water customers are served by the 368 Pressure Zone, which is supplied by the City's 5 MG Reservoir. The David Hill and Watercrest Pump Stations supply the David Hill Reservoir, which feeds the 540 Pressure Zone and, through a PRV, the GCSA. The 435 Pressure Zone is served by six PRVs providing water from the 540 Pressure Zone. **Figure 1-3** illustrates the existing system.

3.4.1 Normal Service Pressure

Consistent with the criteria used in the City's 2010 Water Master Plan, the acceptable service pressure range under ADD and normal operating conditions is 40 to 100 psi. Whenever feasible, it is desirable to achieve the lower limit at the highest fixture within a structure. Where mainline pressures exceed 80 psi, services must be equipped with individual PRVs to maintain their static pressures at no more than 80 psi in compliance with the Oregon Plumbing Specialty Code (OPSC 608.2).

The distribution system should be capable of supplying the PHD while maintaining service pressures of not less than 75 percent of normal system pressures, and not less than 30 psi.

3.4.2 Service Pressure in an Emergency

During a fire flow event or emergency, the minimum service pressure is 20 psi, as required by Oregon Health Authority (OHA) Drinking Water Services (DWS) and OAR 333-061-0025(7). The system should be capable of providing fire flow capacity while simultaneously delivering MDD and maintaining 20 psi throughout the distribution system. The system should meet this criterion with operational storage in the City's reservoirs depleted.

Table 3-1 | Recommended Service Pressure Criteria

Service Pressure Criterion	Pressure (psi)
Normal range, during ADD	40-100
Maximum, without PRV	80
Minimum, during emergency or fire flow	20
Minimum, during PHD	75% of normal, not less than 30 psi

3.4.3 Distribution Main Criteria

Typically, new water distribution mains should be at least 8 inches in diameter and looped to supply minimum fire flows. However, 8-inch mains may cause water quality concerns in areas with small demands. A minimum 6-inch diameter main may be acceptable as long as pressures and velocities in the pipe remain within acceptable levels. Four-inch diameter mains may be acceptable on runs less than 300 feet if no fire hydrant connection is required and future extension of the main is not anticipated. Potential water quality issues will be considered on a case-by-case basis when sizing pipes for proposed water main improvements identified during distribution system analysis.

3.5 Storage Capacity

Water storage facilities are typically provided for three purposes: operational storage, fire storage, and emergency storage. A brief discussion of each storage element is provided below. Recommended storage volume is the sum of these three components. Adequate storage capacity must be provided for each pressure zone. In some cases, storage volume can be partially or fully provided by a reservoir in a separate zone. This usually occurs for zones that do not have reservoirs and are instead supplied either by PRV or constant pressure pump station, or for zones with smaller gravity storage and if pumping is sufficiently redundant and expected to be available in an emergency.

Operational storage remains consistent with criteria established in the City's 1989, 2000, and 2010 Water Master Plans. Fire storage was updated to reflect updated Oregon Fire Code (OFC) requirements and current requirements provided by the Fire Marshall. Emergency storage capacity was increased from the 75 percent of MDD documented in prior WSMPs to 100 percent of MDD. This expanded emergency storage recommendation is due to the City's multiple supply sources and potential vulnerabilities of each as discussed in more detailed in **Section 3.5.3**.

3.5.1 Operational Storage

Operational storage volume is intended to address daily reservoir cycling and water system demands in excess of delivery capacity from the supply source to system reservoirs under PHD conditions. For the purpose of calculating operational storage, the 368 Zone is assumed to be supplied from both the 5 MG Reservoir at the City's WTP and the JWC supply from the 10th Avenue Control Station under peak demand conditions. The 540 Zone, 435 Zone, and GCSA are supplied

by the David Hill Reservoir. Operational storage is calculated as 25 percent of MDD for each pressure zone, which is a standard value typical of similar water systems.

3.5.2 Fire Storage

Fire storage should be provided to meet the single most severe fire flow demand within each zone. The fire storage volume is determined by multiplying the recommended fire flow rate by the expected duration of that flow consistent with the OFC and the Insurance Services Office (ISO) Supply Gradings for Public Protection classification. Specific fire flow and duration recommendations are discussed later in this section.

3.5.3 Emergency Storage

Emergency storage is provided to supply water from storage during emergencies such as pipeline failures, equipment failures, power outages or natural disasters. The amount of emergency storage provided can be highly variable depending upon an assessment of risk and the desired degree of system reliability. The City has elected to follow the guidelines in the 2020 *Washington Water System Design Manual* (Washington Guidelines) for determining the emergency storage volume of the water system. The Washington Guidelines recommend emergency storage equal to one day of MDD, which is an increase from the 2010 WSMP emergency storage criteria of 75 percent of MDD. The City has made this decision based on the following reasons:

- *The City is heavily reliant on the JWC in the summer and additional emergency storage will provide a buffer for a JWC outage.* If the JWC supply, including treatment, storage, and transmission, is not available to the City during the high demand season, then the City emergency storage is limited to in system storage and approximately 0.52 mgd from the City's WTP. However, the City WTP supply at this rate is approximately less than 5% of the projected 2041 total MDD and thus provides limited benefit. Increasing the emergency storage volume requirements reduces the immediate impact of a JWC outage.
- *The existing JWC and City systems are vulnerable to seismic events; additional emergency storage will be constructed current seismic standards and more likely to be available after a seismic event.* As discussed later in **Section 6**, the 2020 Water System Seismic Resiliency Plan (SRP, InfraTerra, 2020, **Appendix H**) states that there is a 16 to 22 percent probability of an earthquake with magnitude 8.5 or greater along the Cascadia Subduction Zone (CSZ) in the next 50 years (Goldfinger et al., 2016). Such an earthquake will likely pose a significant risk to the JWC and Forest Grove Water systems, including:
 - JWC evaluations have identified significant seismic deficiencies at the existing JWC WTP, excluding the recent expansion. The CSZ may result in the loss of JWC's ability to produce finished water.
 - The existing 24" and 72" JWC Transmission Lines are subject to damage from the CSZE that may result in breaks or leaks that will have to be repaired before they are able to

convey finished water from the JWC Fern Hill Reservoirs and/or the JWC WTP to the City.

- The City's existing raw water transmission line is subject to breaks and leaks caused by CSZ event along a majority of its alignment that would result in the loss of raw water supply to the City's WTP.
- The City's existing distribution system is also subject to damage from the CSZ that would have to be repaired before water could be conveyed through the system from the reservoirs
- This WSMP and the SRP have identified capital improvement projects to address seismic resiliency improvements to the City's water system, while the JWC is currently developing their Water System Master Plan, which will also include seismic resiliency improvements to the JWC system. The seismic resiliency improvements that will likely be required for both systems will be expensive and may take a long time complete due to the high cost.

One MDD of emergency storage is a somewhat conservative approach which will be reviewed as part of future reservoir preliminary design phases. During the preliminary design phase, some of the factors that may be reviewed include:

- Comparison of this WSMP projected growth to the future water demand
- Whether large industrial or commercial users locate to the City, thus adjusting system needs
- Impact on water quality
- Impact on future rates
- Risk assessment
- Completed and planned seismic resiliency improvement projects

3.5.4 JWC Contractual Storage Requirements Comparison

The JWC supply contracts require partner agencies to provide three times the average take from the JWC in regional and partner-controlled storage. This storage volume refers to total storage (including emergency, fire, and operational) in all zones.

The existing regional and City-controlled storage will be compared against this benchmark and the emergency storage criteria to determine the range of emergency storage deficiencies. Emergency storage criteria considerations are:

- Emergency Storage – 1.0 x MDD in City and regional storage

- JWC Contract guidelines – 3.0 x average take from the JWC in City and regional storage

3.6 Pump Station Capacity

Pumping capacity requirements vary depending on how much storage is available, the number of pumping facilities serving a pressure zone, and the zone's maximum fire flow requirement. Pumping recommendations are based on firm capacity which is defined as a pump station's capacity with the largest pump out of service.

3.6.1 Pump Station Supplying Pressure Zone with Gravity Storage

For pump stations supplying pressure zones with gravity storage available, the station must have adequate firm capacity to supply MDD for the zone.

3.6.2 Pump Station Supplying Constant Pressure to Zone

Although it is desirable to serve water system customers by gravity from storage, constructing and maintaining a reservoir for a small group of customers may be prohibitively expensive and lead to water quality issues associated with slow reservoir turnover during low demand times. Constant pressure pump stations supply a pressure zone without the benefit of storage and are commonly used to serve customers at the highest elevations in a water service area where only an elevated reservoir would be capable of providing the necessary hydraulic head to achieve adequate service pressures by gravity. Pump stations supplying constant pressure service should have firm pumping capacity to meet PHD while simultaneously supplying the largest fire flow demand in the zone.

Constant pressure pump stations are only recommended for areas with low water demand and limited potential for future looping with adjacent pressure zones.

3.6.3 Standby Power

Standby power facilities are needed for constant pressure stations and for pump stations serving pressure zones with inadequate emergency storage capacity. Standby power is typically provided in the form of an on-site backup generator sized to operate the pump station at firm capacity with automatic transfer switches and on-site fuel storage.

3.7 Fire Flow Recommendations

While the water distribution system provides water for domestic uses, it is also expected to provide water for fire suppression. The amount of water required for fire suppression purposes is associated with the building size and type or land use of a specific location within the distribution system. Fire flow requirements are typically much greater in magnitude than the MDD in any local area. Adequate hydraulic capacity must be provided for these potentially large fire flow demands. Recommended fire flow requirements by land use type are based on the 2019 OFC and the ISO Supply Gradings for Public Protection Classification (PPC).

The ISO PPC ratings are used to inform property insurance rates throughout the United States. Public water system performance accounts for approximately 30 percent of a City's PPC rating. Overall, City ratings are not impacted by individual properties with fire flow demands over 3,500 gpm.

Additionally, the 2019 OFC (B106) limits required fire flow to a maximum of 3,000 gpm for buildings in protected areas with adequate and reliable water systems, such as the City's system. Therefore, the maximum fire flow considered within the Forest Grove Service Area is 3,000 gpm.

In 2016, the City completed an *Industrial Zone Development Analysis (HDR)*. This analysis included a review of the City's fire flow criteria by land use type. Recommended fire flows from the 2016 study are used for this WSMP analysis. Fire flow requirements by land use type are summarized in **Table 3-2**.

3.7.1 Low Density - Single-Family and Duplex Residential

The OFC guidelines specify a minimum fire flow of 1,000 gpm for single-family and two-family dwellings with square footage less than 3,600 square feet. For residential structures larger than 3,600 square feet, the minimum fire flow requirement is 1,750 gpm.

For the purposes of this WSMP, distribution piping fire flow capacity will be tested in the water system hydraulic model with a minimum requirement of 1,750 gpm to accommodate the range of potential future residential development in the City. Where deficiencies are identified in the existing system based on this 1,750 gpm requirement, existing development will be evaluated to determine if a 1,000 gpm fire flow requirement is appropriate for the local area.

3.7.2 Medium Density Residential

Based on the OFC requirements, a required fire flow of 2,000 gpm is recommended for medium density residential properties consistent with the City's *2016 Industrial Zone Hydraulic Analysis (HDR)*.

3.7.3 High Density Residential, Commercial, Industrial, and Institutional

A 3,000 gpm fire flow is recommended for high density residential, commercial, and industrial development consistent with OFC maximum fire flow guidelines. This maximum fire flow requirement is also appropriate for institutional facilities, although 2,500 gpm fire flow may be allowed for some public facilities.

Recommended fire flow requirements by land use type are summarized in **Table 3-2** and are consistent with the *2016 Industrial Zone Hydraulic Analysis (HDR)*.

Table 3-2 | Recommended Fire Flow Summary

Land Use Designation	Recommended Available Fire Flow (gpm)	Fire Flow Duration (hours)
Residential		
Low density	1,750	2
Medium density	2,000	2
High density	3,000	3
Commercial		
Town Center District	3,000	3
Commercial auto	3,000	4
Commercial heavy	3,000	4
Commercial neighborhood	3,000	3
Industrial		
Light industrial	3,000	3
General industrial	3,000	4
Institutional		
Public	2,500	2
Semi-public	3,000	4

Table 3-3 | Performance Criteria Summary

Water System Component	Evaluation Criterion	Value	Design Standard/Guideline
Water Supply	Peak Season (Summer) Capacity	MDD ² from reliable sources	Washington Water System Design Manual
	Normal Range, during ADD ¹	40-100 psi	City of Forest Grove 2010 Water Master Plan
Service Pressure	Maximum, without PRV	80 psi	Oregon Plumbing Specialty Code 608.2
	Minimum, during emergency or fire flow	20 psi	OAR 333-061
	Minimum, during PHD ²	75% of normal, not less than 30 psi	Murraysmith recommended
	Velocity during PHD ³ or fire flow	Not to exceed 10 fps	AWWA M32
Distribution Mains	Minimum Pipe Diameter	8-inch recommended for fire flow, 6-inch may be acceptable for short loops, 4-inch may be acceptable for mains less than 300 feet with no fire hydrants	Murraysmith recommended
	Operational Storage	25% of MDD ²	2010 Water Master Plan
Storage	Fire Storage	Zone Dependent	2019 Oregon Fire Code B106
	Emergency Storage	Criteria 1 - 2xMDD (City + Regional Storage) Criteria 2 - 3x average JWC take (City + Regional)	2020 Washington Water System Design Manual, JWC contract storage guidelines
	Supplying Storage - Required Capacity	MDD ² at firm capacity	Washington Water System Design Manual
Pump Stations	Supplying Constant Pressure to Zone ⁴ - Required Capacity	PHD ³ + Fire Flow	Washington Water System Design Manual
	Backup Power - Supplying Storage	Manual transfer switch and connection for portable generator	Murraysmith recommended
	Backup Power - Critical Facilities and Sole Supply to Zone	Automatic transfer switch and on-site generator and fuel storage	Murraysmith recommended
	Required Fire Flow and Duration	Low Density - Single Family and Duplex Residential <= 3,600 sq ft 1,000 gpm for 1 hour	2019 Oregon Fire Code Appendix B, Insurance Services Office (ISO) Supply Gradings for Public Protection

Water System Component	Evaluation Criterion	Value	Design Standard/Guideline
	Single Family and Duplex Residential >3,600 sq ft	1,750 gpm for 2 hours	Classification (PPC), 2016 Forest Grove Industrial Zone Development Analysis
	Medium Density Residential	2,000 gpm for 2 hours	
	Public	2,500 gpm for 2 hours	
	High Density Residential, Commercial, Industrial, Semi-Public Institutional	3,000 gpm for 3 or 4 hours	
	368 Zone	3,000 gpm for 4 hours	
	435, 540, 710, 880	2,000 gpm for 2 hours	

Note:

1. ADD: Average daily demand, defined as the average volume of water delivered to the system or service area during a 24-hour period = total annual demand/365 days per year.
2. MDD: Maximum day demand, defined as the maximum volume of water delivered to the system or service area during any single day.
3. PHD: Peak hour demand, defined as the maximum volume of water delivered to the system or service area during any single hour of the maximum demand day.
4. There are no existing zones in the Forest Grove distribution system served solely from a constant pressure pump station. Potential future development of the Purdin Road Planning Area and the northernmost David Hill Planning Area which is too high in elevation to be served by gravity from the existing David Hill Reservoir may require constant pressure pumping.

Section 4

Section 4

Water Supply Analysis

4.1 Existing Supply

The City's finished water supply is provided from two sources: the City's WTP with raw water supply from the Clear Creek watershed and the JWC regional WTP with raw water supply from the Tualatin and Trask River systems. The JWC is jointly owned by the cities of Hillsboro, Beaverton, and Forest Grove, and the TVWD. Both WTPs rely on water rights that are regulated off in the summer due to low in stream flows. The City's WTP can only operate if there is water available in the stream while the JWC can release water from stored impoundments, Barney Reservoir and Hagg Lake (Scoggins Reservoir), when in stream flows are too low. Therefore, the City currently relies on the City WTP primarily in the winter and the JWC WTP primarily in the summer.

4.1.1 Forest Grove WTP Supply

The City's existing WTP uses conventional filtration to treat raw water from the Clear Creek watershed, a tributary of Gales Creek located northwest of the City. The raw water is conveyed from intakes in the Clear Creek watershed approximately 7.8 miles southeast to the Forest Grove WTP through a 16-inch diameter CCP transmission main (the RWTM). See Plate 1 in **Appendix A** for system map. Typically, the RWTM flows by gravity to the WTP to supply up to 2.7 mgd if flows are available in the creek. The Raw Water PS can increase flows up to 3.7 mgd. Finished water is stored on the WTP site in the City's 5.0 MG Reservoir, which acts as the WTP clearwell and provides service pressure for the City's 368 Pressure Zone.

4.1.2 Joint Water Commission Supply

The JWC treats raw water from the Tualatin River. Supply from the Tualatin River is limited in the dry summer season due to low in-stream flow. During the summer, the JWC raw water supply is released from local impoundments, Barney Reservoir and Hagg Lake (Scoggins Reservoir), and withdrawn by the JWC from the Tualatin River for treatment at the JWC WTP. Finished water is supplied to the City directly from the JWC WTP or from the two JWC 20 MG Fern Hill Reservoirs through approximately 8,200 linear feet of 24-inch diameter JWC TL, which is jointly owned by the cities of Forest Grove and Hillsboro. Finished JWC water enters the City's system at the 10th Avenue Control Station (see Plate 1 in **Appendix A**). The City owns 10 mgd of the total 85 mgd treatment capacity of the JWC WTP.

4.1.3 Emergency Supply Interties

The City maintains a single 6-inch emergency intertie with the City of Cornelius distribution system, located on Heather Street at the city limits (see Plate 1 in **Appendix A**). This intertie has not been exercised in the past 10 years and capacity estimates are not available for supply in either direction. It is expected that supply will be limited and dependent on operating conditions of the two systems when an emergency occurs. Cornelius purchases their non-emergency water supply from the City of Hillsboro through three connections to the 72-inch diameter JWC NTL which is owned by the City of Hillsboro, the City of Beaverton, and TVWD.

The City of Cornelius is planning a second emergency intertie with the City's water system in N Adair Street, east of its intersection with Yew Street. According to Cornelius's *2017 Water Master Plan*, the project will connect an existing 12-inch line in N Adair Street in Cornelius to an existing 10-inch line in Adair Street in Forest Grove.

The City is currently designing and has in place an emergency intertie IGA connection directly to the 72-inch JWC NTL at an existing blind flange near Mountain View Lane and Heather Street near the Forest Grove-Cornelius city boundary. Although the City is a partner agency in the JWC, the City does not own capacity in the 72-inch JWC NTL. As an emergency intertie, the proposed Heather Street Intertie is limited to short term emergency use and to supplement fire supply. Non-emergency supply capacity in the 72-inch JWC NTL may become available for lease from Hillsboro to supply the City's system although the timing of this is unclear. More discussion on the proposed Heather Street Intertie and supply transmission within the City water system is included in **Section 4.4** and **Section 5**.

4.1.3.1 Evaluation of Groundwater Source for Emergency Use

As part of this master planning effort, GSI Water Solutions, Inc (GSI) evaluated existing groundwater wells within 2 miles of the City as a potential emergency water supply, primarily in the event of a Cascadia Subduction Zone Earthquake (CSZE). The full report of this analysis is included as **Appendix C**. The evaluation followed Environmental Protection Agency (EPA) and Federal Emergency Management Agency (FEMA) emergency water capacity recommendations of 1 gallon per person per day. To meet this estimated emergency demand, the City would need to develop 2 to 4 wells at 10 to 30 gpm production rates within the next 10 years. This well development would be in addition to continued City investment in seismic improvements throughout the system to meet long-term Oregon Resilience Plan (ORP) recovery goals.

Two wells, WASH 10597 and WASH 60859, were identified for further study based on the quality of well data, location relative to geohazards, and proximity to Catastrophe Reception Centers and backbone infrastructure. The existing production rates of the two wells are 320 gpm and 72 gpm, respectively. Further recommendations for the identified wells include:

- Add auxiliary power supply
- Add disinfection equipment
- Evaluate seismic resilience

- Develop agreements with well owners addressing site visits, contamination studies, and water rights

At this time, the City has elected to pursue the development of emergency water supplies as a separate project, therefore the use of emergency groundwater supplies will not be addressed further in this report. A future emergency water supply project should include evaluating sources of emergency water supply such as new wells, packaged water treatment plants, and more detailed review of existing groundwater wells.

4.2 Water Rights

The City has water rights on Clear Creek, Roaring Creek, Gales Creek, and the Tualatin River. **Table 4-1** details the City's live water rights.

Table 4-1 | Live Water Rights

Source	Priority Date	Certificate	Type	Authorized Rate	
				cubic feet per second (cfs)	mgd
Clear Creek	3/29/1917	2194	Municipal	0.80	0.52
Clear Creek	4/16/1935	13471	Municipal	1.00	0.65
Clear Creek	7/27/1939	13797	Municipal	1.00	0.65
Gales Creek	2/14/1947	T-11677	Municipal	4.46	2.88
Roaring Creek	4/28/1976	92949	Municipal	2.43 ¹	1.57 ¹
Clear Creek	4/28/1976	92949	Municipal	2.83 ¹	1.83 ¹
Tualatin River	4/28/1976	85916	Municipal	33.0	21.3

Note:

1. Combined authorized rate of both rights under certificate 92949 not to exceed 4.46 cfs (2.88 mgd).

In the winter, in-stream flows are sufficient to allow the City to use their full water rights. In the summer, however, available raw water in the Clear and Roaring Creeks is typically reduced to a minimum of the City's 1917 water right, or 0.52 mgd. Remaining finished water supply to the City distribution system comes from the JWC.

Although the City holds a water right on Gales Creek, there is currently no intake. The City transferred this Gales Creek right (formerly certificate 85513) to a new point of diversion (POD) in 2013 which was approved by the State under transfer application T-11677. The new POD is at the JWC Springhill Pump Station intake facility. At this time, the water can be taken at the new POD between October 1 and May 31, but not between June 1 and September 30 because the City has not installed a suitable stream-flow gaging station at the original POD per the Final Order. In addition, during the period of June 1 to September 30, there must be sufficient water in Gales Creek at the original POD for water to be withdrawn at the new POD. Full beneficial use of the water at the new POD shall be made on or before October 1, 2035.

The JWC's Tualatin River raw water intake is also limited due to in-stream demands during this dry summer season. Typically, from mid to late May through October, it is assumed that JWC is regulated off the Tualatin River due to its junior water right. Therefore, during this period all raw water supply to the JWC WTP is provided by the two local impoundments which are Hagg Lake (Scoggins Reservoir) and Barney Reservoir. In 2018 and 2019 the raw water supply from the two local storage impoundments continued into November and December respectively.

4.2.1 Stored Water Rights

The City holds water rights to stored water in the two JWC raw water supply impoundments, Barney Reservoir and Hagg Lake (Scoggins Reservoir). Hagg Lake is located approximately five miles southwest of the City and has a water elevation of 306 feet at maximum storage capacity. At a surface elevation of more than 1,600 feet, Barney Reservoir is situated about 15 miles southwest of the City. **Table 4-2** summarizes the City's stored water rights. During the summer months, once Washington County's Watermaster has ordered users to stop using Tualatin River flow as a raw water supply source, the JWC begins releasing raw water from the two local impoundments.

The City has a "buy-back" option for stored water in the Barney Reservoir that is currently owned by TVWD (see **Table 4-2**). To initiate the buy-back option, the City must provide written notice of their intent to buy-back the stored water right in Barney Reservoir from TVWD. The transfer of the stored water rights in Barney Reservoir from TVWD to the City may take up to four years from when the City submits the written notice. The Barney buy back option has no expiration date for the City to initiate the buy-back option or the cost to purchase the stored water rights in Barney Reservoir. The text of the Buy-Back Option is included in **Appendix D**.

Table 4-2 | Forest Grove Stored Water Rights – Source Water to JWC WTP

Reservoir	Stored Water Rights		Potential Maximum Release Season Average Daily Supply of Total Storage (MGD)
	acre-ft (AF)	MG	
Barney Reservoir	500	163	0.9
Barney Reservoir Buy-Back Option	800	260	1.4
Hagg Lake	4,500	1,465	7.7
Total (Without buy-back)	5,000	1,628	8.6
Total (Including buy-back)	5,800	1,888	9.9

Note:

1. Release season average daily supply of total storage assumes a release season of 190 days (see Section 4.3.1.2) and an initial total stored water volume equal to the full water right. This number has not been reduced by loss/reduction factors (see Section 4.3.1.2).

4.2.1.1 Historical Stored Water Release Rates

Typically, water is released from JWC impoundments at lower rates in the early summer and fall, with the highest release rates in August. **Table 4-3** presents release rates for the City from the 2018 and 2019 seasons and the combined release factors. Currently, the Barney Reservoir is used

later in the season at much less than the full available water right as shown in **Table 4-2**. Therefore, a combined release factor will be used to predict total availability. The combined release factors are calculated by dividing the average monthly release rate by the overall average release rate for the actual release period for each year. The combined release factor will be used in the water supply analysis to predict future raw water availability.

Table 4-3 | Historical Release Rates

Month	Hagg Lake (Scoggins Reservoir) 2018/19 Avg Release Rate (mgd)	Barney Reservoir 2018/19 Avg Release Rate (mgd)	Average Combined Release Rate (mgd)	2018/19 Combined Release Factor ¹	2010 WMP Release Factor ²
May	0.49	0	0.49	0.2	0.4
June	1.65	0	1.65	0.8	0.8
July	2.66	0	2.66	1.3	1.2
August	2.99	0	2.99	1.5	1.5
September	1.83	0.08	1.91	1.0	1.4
October	1.36	0.06	1.42	0.7	0.7
Post-October	1.39	0.04	1.44	0.7	0
Release Season Average	1.96	0.03	1.99	-	-

Note:

1. Combined Release Factors are calculated by dividing a given months average release rate by the overall average release rate for the season. Release season for this calculation is from the start of release through the last day of release, rather than the release days within the regulation period.
2. Not used in this analysis – shown for reference.

4.3 Water Supply Analysis

A water supply system must have adequate source water, treatment, and transmission to serve customers and accommodate projected future growth. Any one of these components may be a limiting factor in the water supply system's capacity. The following analysis shows raw water source capacity for the City's water rights and finished water supply capacity in the City and JWC WTPs and transmission facilities.

Source Water - The City likely has adequate water rights and existing nominal raw water supply capacity to meet projected MDD through the 50-year planning horizon. Hydrologic changes, such as drought, are likely to continue to impact stream flows in the Tualatin Basin which will mean a longer release season for stored raw water with the JWC and potentially shorter operating season for the City's WTP if available flow from the Clear Creek watershed declines earlier in the year.

Treatment – The City has sufficient treatment in the City's WTP and the JWC WTP to meet future demands through the 50-year planning horizon. Available flow from the Clear Creek watershed is the limiting factor for finished water supply from the City's WTP which is at its lowest annual capacity during the highest annual system demand. This capacity challenge along with aging infrastructure at the WTP is a key consideration for long-term investment in this facility. It is

recommended that the City develop a facility plan for the WTP which includes evaluations of facility condition and operation.

Transmission and Storage – The City currently has sufficient transmission to meet MDD but will likely need expanded capacity from the JWC within 5 years. The City relies on JWC finished water supply to meet peak summer demands. This finished water supply is currently vulnerable due to the single 24-inch diameter JWC TL connecting the City system to the JWC.

The existing 5 MG Reservoir acts as the clearwell for the City's WTP, provides terminal storage for the JWC finished water supply, and pressurizes the 368 Zone when JWC supply is reduced. This critical facility should be replaced with a seismically resilient structure with adequate capacity and redundancy to meet future storage requirements. Storage limitations are discussed further in **Section 5.3**.

4.3.1 Raw Water Capacity Analysis

4.3.1.1 Forest Grove WTP – Clear Creek

Source water from the Clear Creek intakes is limited during the dry summer season when in-stream flows are low and the City may be “regulated off” the creeks by the Watermaster. In the City's *2010 Water Master Plan* seasonal limitations in raw water flow were estimated as 1.5 mgd. More recently, seasonal limitations have been closer to 0.55 mgd (2013-2018 historical average low monthly supply rate). As discussed in **Section 4.2**, it is expected that the City will typically retain Clear Creek supply in the summer through its 1917 water right (2194) at a rate of 0.52 mgd. The City should plan for a reduced source water availability of 0.52 mgd.

4.3.1.2 JWC Supply – Stored Water Rights and Available Water

The City relies on the JWC supply system to meet peak summer demands. As a junior water right, the City's 1976 Tualatin River water right that helps supply the JWC WTP is assumed to be regulated off during this period. Instead, the JWC releases raw water from Hagg Lake (Scoggins Reservoir) and Barney Reservoir storage impoundments. The released raw water from the storage impoundments then flows to the Tualatin River where it is withdrawn by the JWC for treatment at the JWC WTP.

Impoundment release data from 2018 and 2019 show a possible trend towards longer storage release seasons ending later in the fall. Based on 2018 and 2019 data, the release season is assumed to be 190 days when evaluating future raw water availability.

In 2019, the raw water available in both reservoirs at the beginning of the release season was approximately 85 percent of the City's stored water rights. However, between 2015 and 2019, the City has used on average less than 30 percent of its water rights capacity in Hagg Lake (Scoggins Reservoir) and less than 10 percent of water right capacity in Barney Reservoir. While the 2019 initial stored volume of 85 percent of the City's stored water right capacity still exceeds the current

summer demand, the City may need to plan for reduced initial capacity from the JWC storage impoundments in the future.

Water released from Barney and Hagg Lake (Scoggins Reservoir) travels down the Tualatin River before it reaches the JWC WTP intake. Some of the released flow is lost or reduced before reaching treatment and a smaller percentage is lost through treatment and transmission. Loss/reduction factors described in the City's *2010 Water Master Plan* are applied here to estimate the supply benefit gained from stored raw water rights. Loss/reduction factors are also applied to the Barney Reservoir buy-back option storage.

- Barney Reservoir – 24 percent reduction of total storage volume
 - Two percent dead pool – water level too low to be accessed
 - 15 percent fish flow
 - Two percent blow-by
 - Five percent transmission & treatment loss
- Hagg Lake (Scoggins Reservoir) – 7 percent reduction of total storage volume
 - Two percent blow-by
 - Five percent transmission & treatment loss

4.3.1.3 Drought Considerations

Quantifying future drought potential is challenging and research is continually evolving. Granular climate model data was not available for this Plan. A 20 percent reduction in available raw water was chosen as a drought planning assumption based on City staff analysis of historical fill data for Hagg Lake (Scoggins Reservoir) between 1976 and 2020 and Barney Reservoir between 1999 and 2020.

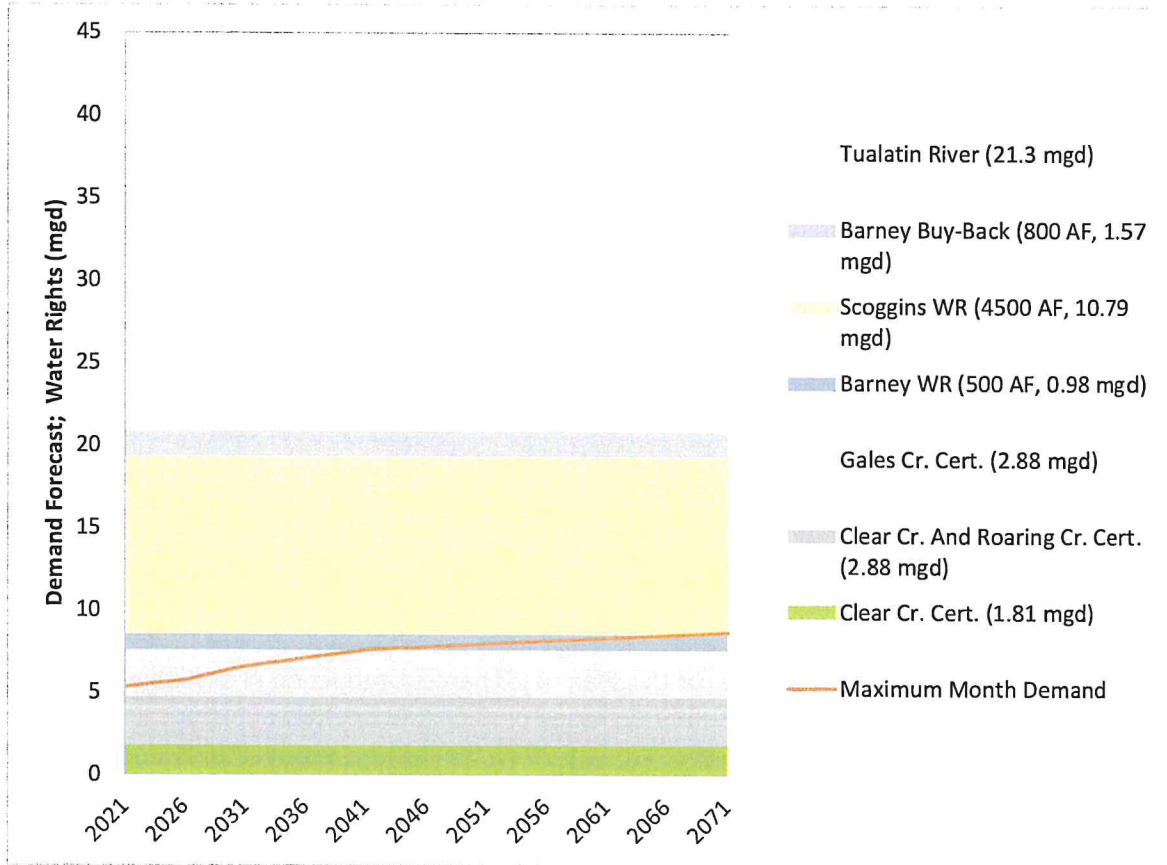
Both Barney and Hagg Lake (Scoggins Reservoir) have filled to over 85 percent by May 1 every year of data except 2001. In 2001, an extreme drought reduced fill at the beginning of the summer to approximately 50 percent. This 50 percent fill is four to five standard deviations away from the mean fill and thus represents an extreme condition beyond what is anticipated for future non-curtailed supply planning needs based on available information at the time of this Plan. It is recommended that the City consider potential drought conditions when evaluating long-term supply strategy scenarios summarized at the end of this section.

4.3.1.4 Raw Water Capacity Findings

The City has adequate water rights to supply anticipated growth through 2071, even when seasonal limitations are considered, including a blanket 20% drought reduction (**Figure 4-1** and **Figure 4-2**). When looking at month by month supply, the City is most vulnerable during early and late summer, especially under drought conditions (**Figure 4-3** and **Figure 4-4**). However, barring an extreme drought or other extenuating circumstances, the City has sufficient raw water rights.

The Water Supply Study, recommended in **Section 4.4.4**, should consider raw water supply vulnerabilities due to seasonal limitations and drought. Additional finished water treatment and transmission limitations are discussed in **Section 4.3.2.1**.

Figure 4-1 | Full Water Rights, Assuming No Seasonal Limitations

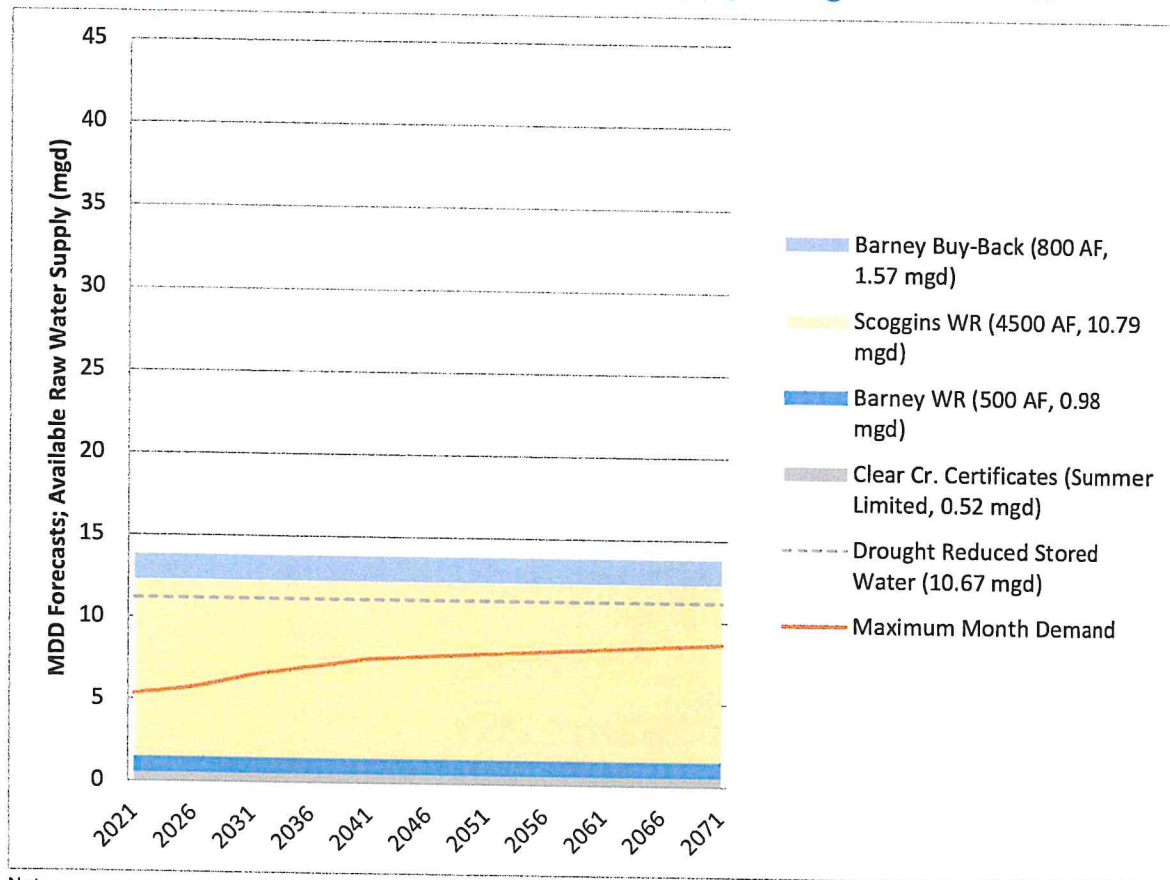


Note:

1. Stored water rights (Barney Buy-Back, Hagg Lake, and Barney Reservoir) have been converted from total stored volume to release rate assuming the full stored right, a 190 day release period, 1.5 maximum month release peaking factor, and loss/reduction factors listed in Section 4.3.1.2.

Figure 4-1 – If all water rights were accessible and available during the maximum demand month (typically August or July), the City would have over four times the necessary combined water rights from both in-stream and storage impoundment sources, treated by either the City or the JWC, to supply system demands beyond 2071. However, all water rights are not currently available when demands are greatest.

Figure 4-2 | Estimated Available Raw Water Supply during Peak Demands

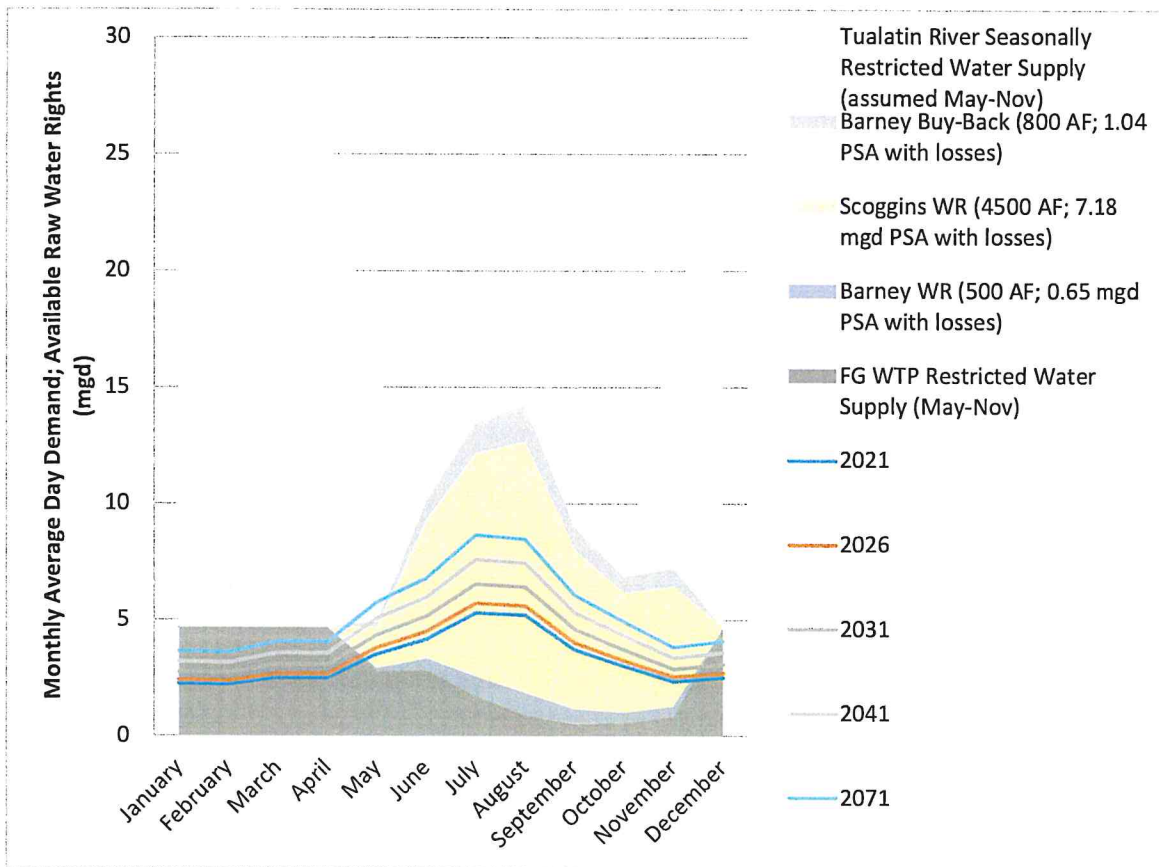


Note:

1. Only water rights that are not regulated off in the summer are shown (assumed 1917 Clear Creek Right and impoundment storage rights).
2. Available raw water from the Clear Creek Certificates is limited to WR 2194 at 0.52 mgd.
3. Impoundment release flow rates are calculated assuming the full stored right, a 190 day release period, 1.5 maximum month release peaking factor, and loss/reduction factors listed in Section 4.3.1.2
4. The drought reduced stored water volume shown (dashed line) is assumed to be 80 percent of the City's initial stored volume in both Hagg Lake and Barney Reservoirs. Clear Creek maintained at 0.52 mgd.

Figure 4-2 - Raw water supply is limited during peak summer season demands to only the 1917 Clear Creek water right supplied by the City, and stored impoundment rights supplied by the JWC. Assuming no drought restrictions, it is anticipated that the City has sufficient existing rights to meet summer season demands through 2071. If a 20 percent drought reduction is included to the stored water rights, the City still maintains sufficient raw water supply.

Figure 4-3 | Estimated Raw Water Availability, Regular Seasonal Limitations

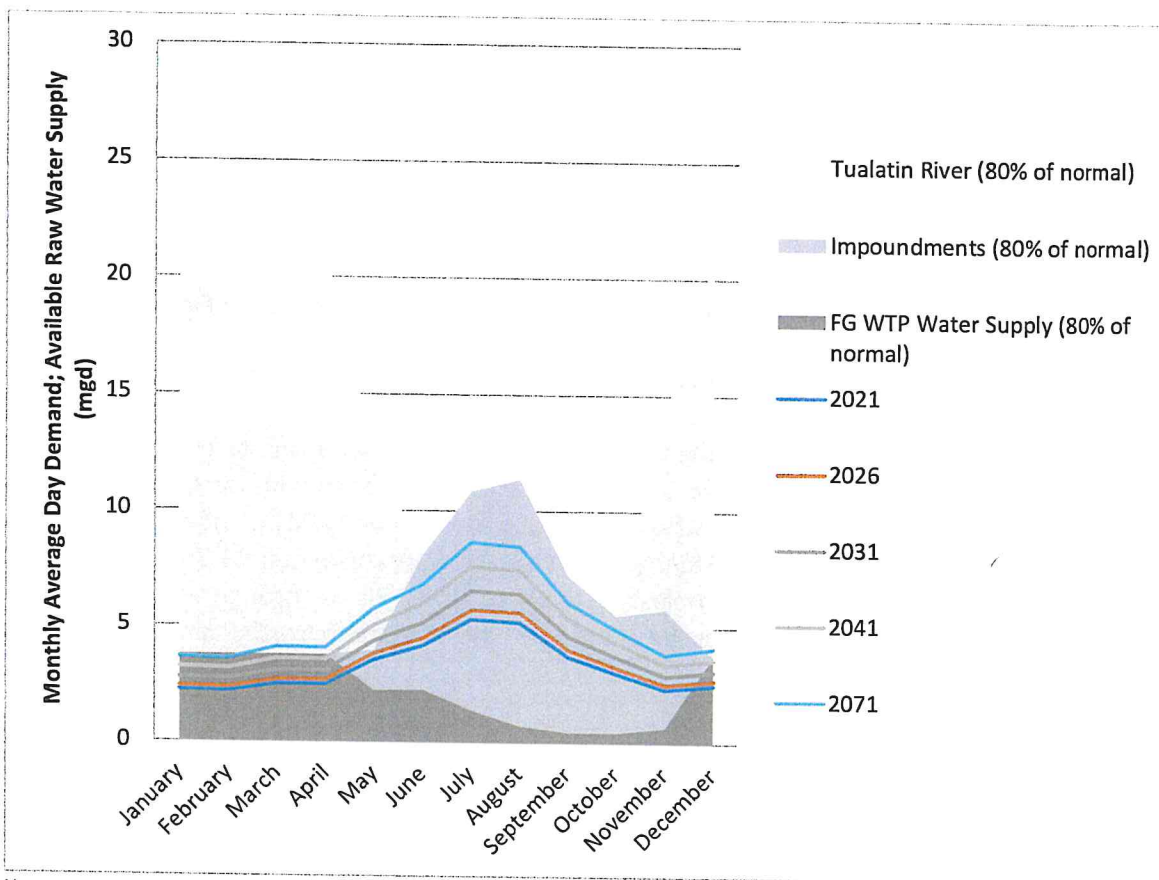


Note:

1. Raw water impoundment stored water rights (Barney, Hagg Lake) assume the full stored right, a 190 day release period, historical monthly peaking factors (Table 4-3), and loss/reduction factors listed in Section 4.3.1.2.
2. Raw water supply to the City WTP is represented by 2019 average flows for May through November.

Figure 4-3—Historically, water right availability has been limited in the summer. If the City has full access to these assumed rights, adequate supply is available through 2071. The Tualatin River Right is assumed regulated off for May-November. The City’s Clear Creek Rights are shown at historical takes for May – November, and the full treatment capacity of the WTP for the rest of the year. The impoundment storage shown is assumed 100 percent of the stored capacity, released from May-November (190 days), with loss/reduction factors and historical peaking factors applied.

Figure 4-4 | Estimated Raw Water Availability, Seasonal and 20% Drought Limitations



Note:

1. Although drought may not impact raw water supplies in non-summer months, drought was assumed throughout the year for a conservative estimate.
2. Under drought conditions, all raw water supplies are assumed to be reduced by 20 percent.
3. Drought impoundments include all potential water rights from Barney Reservoir and Hagg Lake, including the buy-back option capacity in Barney Reservoir. Supply assumes 80 percent total stored water capacity, a 190 day release period, historical monthly peaking factors (Table 4-3), and loss/reduction factors listed in Section 4.3.1.2

Figure 4-4 – Even under a 20 percent drought condition, the City maintains sufficient raw water rights throughout the year. See **Section 4.3.1.3** for additional discussion on drought limitations.

4.3.2 Hydraulic and Finished Water Capacity Analysis

4.3.2.1 WTP Supply Limitations

The City supply system and the JWC supply system are both limited by raw water availability, treatment capacity, and transmission capacity.

The City WTP supply is currently limited by:

- Raw water supply in the summer, as low as 0.52 mgd (Clear Creek Certificate 2194)
- Raw Water Transmission and treatment, maximum 3.7 mgd

The City's JWC supply is limited by:

- **Currently**—transmission capacity through the 24-inch JWC TL, approximately 6.1 mgd
- **Within 20 years**
 - Raw water availability in the summer under drought conditions, see **Figure 4-4**

4.3.2.2 North Plains Wholesale Demand

The JWC provides wholesale water to the City of North Plains through a long-term supply contract which includes supply capacity increases over time to account for growth in North Plains. The City is obligated to supply a portion of this wholesale need proportional to City owned capacity in the JWC WTP which is 10 mgd of the total 85 mgd WTP capacity, approximately 11.76 percent. **Table 4-4** presents the JWC's contractual wholesale supply to North Plains through 2035 and Forest Grove's portion of this. For this analysis, future supply beyond 2035 to North Plains was assumed to be constant at 0.29 mgd.

By 2035, Forest Grove will have 9.71 mgd available of the original 10 mgd capacity. North Plains is supplied off the 72-inch JWC NTL, not the 24-inch JWC TL, and so the full 6.1 mgd capacity of the 24-inch JWC TL is available to the City.

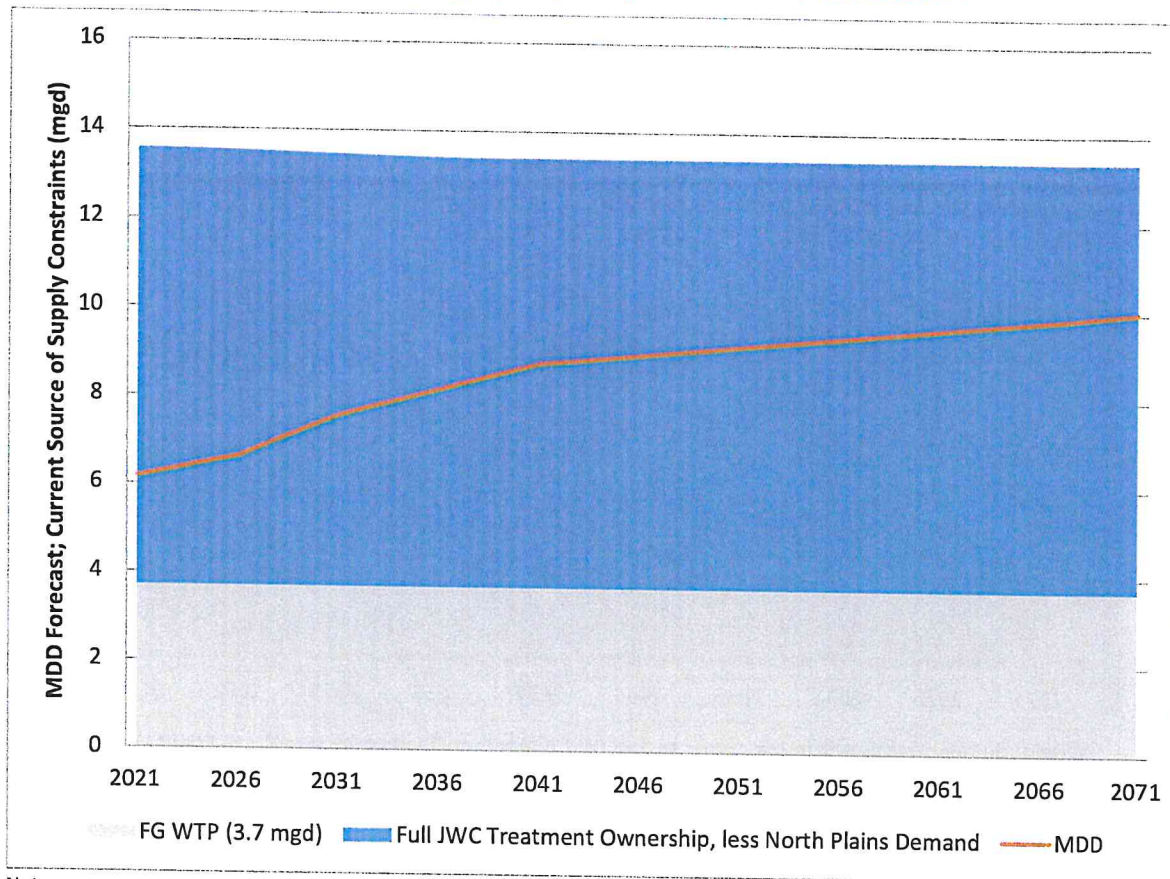
Table 4-4 | North Plains Wholesale Supply – Contracted Capacity

Year	JWC supply to North Plains (mgd)	Forest Grove portion (mgd)
2020	1.2	0.14
2025	1.5	0.18
2030	2.0	0.24
2035	2.5	0.29

4.3.2.3 Finished Water Capacity Findings

The City does not have sufficient available summer raw water rights or transmission capacity to utilize the full treatment capacity of either the City of JWC WTPs (**Figure 4-5** and **Figure 4-6**). City supply is most limited by the lack of water right availability other than the 1917 water right and JWC supply is most limited by the 24-inch JWC TL capacity. The most immediate finished water capacity need is additional transmission capacity in the 24-inch JWC TL within the next five years to serve MDD. This recommendation is addressed in the CIP section.

Figure 4-5 | Finished Water Supply Capacity: Treatment Limitations



Note:

1. JWC Supply Less North Plains calculation linearly interpolated between years listed in Table 4-4.

Figure 4-5 – Assuming the City has access to the full treatment capacity/ownership at the JWC and City WTPs, no additional treatment capacity is required through 50 years.

Figure 4-6 | Finished Water Supply Capacity: Treatment, Transmission, and Raw Water Supply Limitations

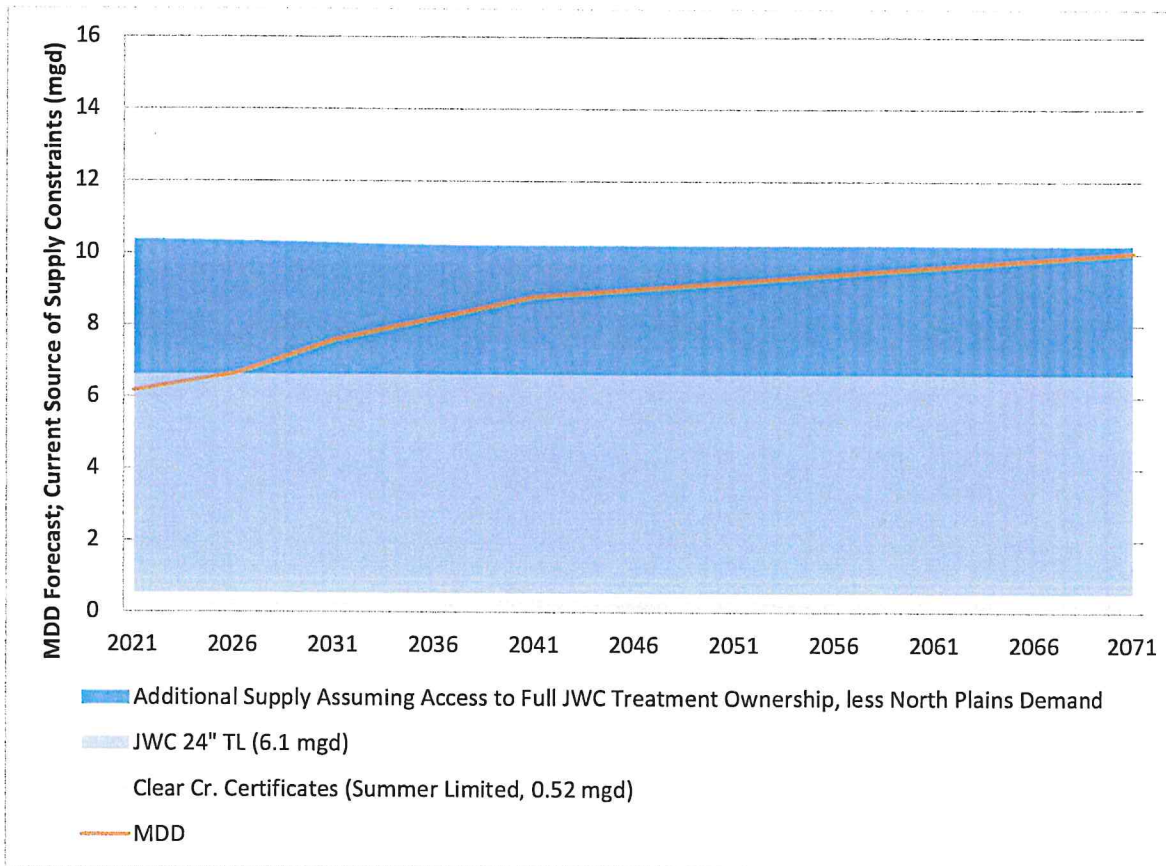


Figure 4-6 – The City does not have sufficient available summer rights or transmission capacity to utilize the full treatment capacity of either the City WTP or the JWC WTP. City supply is limited to the 1917 water right, and JWC supply is most limited by the 24-inch JWC TL capacity. With current agreements, the City will need additional capacity within the next five years to meet MDD. If the full JWC treatment right could be accessed, the City would have sufficient capacity through 50 years, assuming no additional North Plains supply.

4.4 Supply Strategy

The most pressing supply need for the City is increased transmission from the JWC to the 10th Ave Control Station. The City should evaluate transmission options in conjunction with seismic resilience evaluations as recommended by the SRP and continued coordination with the City of Hillsboro.

While there is not a near term need to develop additional source of supply, the City should begin planning to complete a separate Water Supply Study to address supply deficiencies. An initial review based on City public works and engineering staff observations of the City's existing

infrastructure was documented and is included in **Appendix E**. The following sections document several alternatives, but significant key information is missing to make an informed decision. The next steps documented in **Section 4.4.4** should be completed to address the knowledge gaps and select an alternative to meet supply.

4.4.1 Supply Scenarios

Five supply scenarios were explored to accommodate existing and projected future City water demands. Supply scenarios considered are briefly described in the following list and summarized in **Table 4-5**. Supply scenarios are illustrated in **Figure 4-7** through **Figure 4-11** at the end of this section. Plate 1 in **Appendix A** is available for reference of the existing system.

1. Base Scenario - Maintain existing supply system and construct emergency Heather Street Intertie on 72-inch JWC NTL
2. Decommission existing City WTP, replace and expand 5 MG Reservoir, improve existing JWC connection, construct emergency Heather Street Intertie, and add a second POD for the Clear Creek watershed water rights at the JWC Springhill Pump Station intake facility
3. Decommission existing City WTP, replace 5 MG Reservoir, add a second point of diversion for the Clear Creek watershed water rights at the JWC Springhill Pump Station intake facility, and construct Heather Street Intertie for both normal and emergency supply, construct new storage tank and booster pump near Heather St Intertie
4. Maintain existing City WTP, replace and expand 5 MG Reservoir, improve existing JWC connection, and construct emergency Heather Street Intertie
5. Maintain existing City WTP, replace and expand 5 MG Reservoir, improve existing JWC connection, construct emergency Heather Street Intertie, construct connection from Tualatin Valley Irrigation District (TVID) supply line to City WTP to increase raw water supply

Table 4-5 | Supply Scenarios

Facilities	Scenarios				
	1	2	3	4	5
Rehab City WTP and Raw Water Supply	X			X	X
Decommission City WTP and Raw Water Supply		X	X		
Continue JWC participation and investment	X	X	X	X	X
Improve Existing 24-inch JWC TL to 10th Ave		X		X	X
Improvements to 10th Ave Control Facility	X	X	X	X	X
Construct Heather St Emergency Intertie	X	X	X	X	X
Construct Heather St Supply Intertie			X		
Replace 5 MG Reservoir with Like Reservoir	X		X		
Replace and expand 5 MG Reservoir onsite		X		X	X
New Reservoir and Pump Station at Heather St Intertie			X		
Connect to TVID					X

4.4.2 Facility Investments

The following sections discuss the implications for selecting each of the supply facility options listed in **Table 4-5**. Some data such as required infrastructure improvements and cost, seismic resilience, or capacity available for lease requires further study or coordination with other water utilities which is beyond the scope of this Plan. It is recommended the City acquire this additional information to make a fully informed decision on long-term supply strategy. This additional required information is summarized by supply scenario in **Section 4.4.3**.

Unless noted otherwise, seismic improvements listed in the following sections are summarized from the City's *Seismic Resiliency Plan (SRP)* prepared by InfraTerra, Inc. As of the writing of this master plan, the SRP is in draft final format and will be finalized with the completion of the master plan. The bulk of the work for the SRP was completed in September 2020. The SRP did not address improvements required at JWC facilities. Additional structural or geotechnical investigations may be required for specific JWC or City facilities. **Section 6** of this master plan presents a full summary of the SRP findings.

4.4.2.1 Rehab City WTP and Raw Water Supply

The City's WTP and raw water supply is aging, with some facility components over 100 years old, and could likely benefit from rehabilitation, replacement, and facility improvement. Maintaining these facilities would allow the City to retain local control over some supply and provide source redundancy to the City's connection to the 24-inch JWC TL. However, the City's WTP is only a three-season finished water supply due to raw water supply limits during the summer. Currently, summer finished water supply is reduced to approximately 0.52 mgd.

Per the SRP, the City's WTP meets the SRP's Immediate Occupancy performance criteria and is expected to survive the CSZE. The SRP also states that some structural and non-structural damage

is possible at the WTP, but it is unlikely that such damage will result in significant disruption of plant operation. Per the SRP, the RWTM is vulnerable to significant damage from a CSZE due to areas of liquefiable soil and a potentially vulnerable creek crossing at the Stringtown Road Bridge. The SRP recommends replacing the RWTM with earthquake resistant pipe and/or doing additional geotechnical analysis to narrow the areas where seismic geohazards indicate more seismically resilient pipe is needed. The SRP indicates the City's 5 MG Reservoir, which serves as the chlorine contact basin for the WTP, is vulnerable to structural damage in a CSZE which could result in the loss of some or all the stored water. It was also noted that the slope below the 5 MG Reservoir may deform, leading to damage to the 20-inch diameter distribution main which provides finished water to the 368 pressure zone as well as finished water supply to the David Hill and Watercrest pump stations.

A comprehensive facility plan for the City WTP is recommended to assess operational limitations and address age and condition issues identified by City staff, including:

- **WTP Transfer pumps**— City staff observed the transfer pumps, which pump water from the sedimentation basin up to the WTP filters, seem to have shortened motor lives and require repairs more frequently than expected. The pumps are not covered or in a building and operational issues may be due to exposure to the elements.
- **WTP Sedimentation basin** - constructed in 1912, the sedimentation basin is the oldest facility on the WTP site. This reinforced concrete structure has exceeded its expected useful life.
- **WTP Dewatering and solids handling** - the existing dewatering process requires the addition of perlite which increases cost. The dewatering equipment is currently housed inside the WTP shop making the space unusable for other City operations and maintenance needs. The location of the dewatering equipment in the shop may also indicate a lack of appropriate storage on the WTP site.
- **Raw Water Pumps** - The raw water booster pump station, located in an underground vault adjacent to Gales Creek Road, was connected to the raw water transmission main in 1979 and is used to increase flows to the WTP from the gravity RWTM flow of 2.7 mgd to 3.7 mgd to accommodate higher system demands. The remaining lifespan for this facility is unknown.
- **16-inch Raw Water Transmission Main to City WTP** - Clear Creek watershed source water is conveyed to the WTP via a 7.8 mile 16-inch CCP RWTM. The RWTM serves as the sole pipeline for raw water supply to the City's WTP. City staff have observed cracking in the exterior mortar coating. Water industry research indicates that cracks in the coating is the most common cause CCP failure. A portion of the RWTM was also constructed in a known landslide area between the Clear Creek crossing and Soda Springs Road. The SRP recommends that over half the RWTM be replaced due to seismic risk and additional geotechnical work be done to maintain the pipeline (see **Section 6** for additional SRP discussion). Due to the location of the RWTM and the current condition, it is considered

vulnerable to damage from a potential landslide or CSZE. Loss of the RWTM will result in the loss of raw water supply to the WTP.

4.4.2.2 Decommission City WTP

City staff have identified operational challenges and facility condition issues due to age and construction at the existing WTP and RWTM. The WTP has inadequate capacity to independently meet the forecasted ADD within 10 years. Seasonal limitations on the Clear Creek watershed source also mean the City's WTP finished water supply is at its lowest annual capacity during the highest annual system demand. The City WTP currently meets less than one tenth of MDD during in-stream raw water supply restrictions.

Decommissioning the WTP would reduce the capital expenditures necessary to improve operational performance and to mitigate seismic vulnerability which might be required to prevent a loss of the finished water supply from the WTP. However, decommissioning the City WTP would make the JWC the City's only finished water supply and increase dependence on the capacity-limited 24-inch JWC TL.

4.4.2.3 Continue JWC Participation and Investment

Under all scenarios, the City should continue to participate and invest in the JWC supply infrastructure. The City is reliant on the JWC Fern Hill Reservoirs for both system storage and significant supply, particularly in the summer months. According to the *2018 JWC WTP Facility Plan*, the existing JWC WTP is not anticipated to withstand a CSZE. Investment in retrofitting or replacing existing JWC WTP facilities is anticipated with the timing of improvements to be determined by the JWC partners.

4.4.2.4 Improve Existing JWC Transmission to 10th Avenue Control Station

Currently, the City receives JWC finished water supply through a single 24-inch JWC TL jointly owned with the City of Hillsboro. As stated in the *2010 Water Master Plan*, The City's 50 percent share of capacity in this transmission line is limited to 6.1 mgd, rather than the 10 mgd City treatment ownership in the JWC WTP. This 6.1 mgd is not sufficient to meet projected future summer demand and the JWC is the City's primary finished water supply during summer months. Several alternatives were discussed to increase finished water supply from the JWC to the 10th Avenue Control Station:

- ***Replace and upsize transmission main*** - The existing 24-inch JWC TL could be replaced with a larger pipe. Per the SRP, the existing transmission main is vulnerable to damage in a CSZE. A replacement main would be built for seismic resilience as well as increased capacity. This would likely mean the existing transmission main would be out of service during construction and the City would need to rely on the City WTP which does not have adequate capacity to meet summer demands. This alternative would be costly and Hillsboro may not want to invest in additional capacity they do not need, leaving a larger share of the pipe replacement cost to the City.

- ***Parallel transmission main*** - A parallel, seismically resilient transmission main could be built to increase capacity. This would allow for the existing 24-inch JWC TL to remain in service during construction and would also address seismic resilience.
- ***Lease capacity from Hillsboro*** - The City of Hillsboro uses their share of the existing 24-inch JWC TL to serve a small number of customers in the Cherry Grove area. Hillsboro may have capacity available in the 24-inch JWC TL which they would be willing to lease to the City. Depending on Hillsboro's future finished water supply needs, leasing capacity may not be a long-term solution for the City. Although this alternative is the lowest cost it does not address seismic vulnerability of the existing 24-inch JWC TL.

If the JWC becomes the sole finished water supply for the City, there is no existing redundant JWC pipeline that connects to the City water system, or an alternate source of finished water should the 24-inch JWC TL fail or be taken out of service. The *2010 Water Master Plan* identifies a parallel transmission line as a recommended system improvement which would enable the City to receive the full JWC capacity under normal operating conditions. This project is included in the CIP, separate from the Water Supply Study. Completion of this project may adjust impacts and costs of other facility improvements discussed in this section.

4.4.2.5 Improve 10th Avenue Control Facility

The 10th Avenue Control Station houses the control valves from the 24-inch JWC TL to City distribution mains. An 18-inch Cla-Val pressure and flow control valve was replaced with parallel 8 and 16-inch Singer pressure and flow control valves in 2020. These control valves are currently operated as PRVs.

Per the SRP, the soil around the 10th Avenue Control Station is susceptible to liquefaction and pipe failure is possible where the pipes pass through the floor and walls of the station with rigid connections. In addition, the SRP recommends a detailed structural evaluation to determine if the Control Station building meets Immediate Occupancy performance criteria and what improvements may be required.

4.4.2.6 Construct Heather Street Intertie – Emergency

Hillsboro, TVWD, and Beaverton jointly own and operate the 72-inch JWC NTL that extends along the eastern city limits and currently provides JWC partners Hillsboro and TVWD with finished water. An existing 16-inch tee and blind flange located near the intersection of Mountain View Lane and Heather Street could serve as a future City connection point to the 72-inch JWC NTL and provide emergency redundancy with the existing 24-inch JWC TL connection to the 10th Avenue Control Station, should the 10th Avenue Control Station or the 24-inch JWC TL fail. The City is currently designing an emergency intertie connection, the Heather Street Intertie, to the 72-inch JWC NTL at this location.

As an emergency connection, this intertie is only anticipated to operate under extreme conditions such as a fire flow event. While emergency finished water supply is available, the potential for

long-term leasing of finished water supply capacity in the 72-inch JWC NTL from JWC is still unknown.

Distribution system improvements will be needed to provide higher flows from the proposed intertie without over-pressurizing customers near the intertie. Recommended improvements depend on the ultimate design flows selected by the City but upsizing to 20-inch diameter transmission is proposed. Distribution limitations and improvement options are discussed in more detail in **Section 5**.

4.4.2.7 Construct Heather Street Intertie – Supply

As discussed in the prior emergency Heather Street Intertie section, an emergency only connection is currently being designed for finished water supply from the 72-inch JWC NTL. This connection could be expanded to a regular finished water supply intertie, much like the 10th Avenue Control Station. This would provide redundancy to 10th Avenue and the 24-inch JWC TL. It would not provide a fully redundant finished water supply like the City's WTP because both the 72-inch JWC NTL and the 24-inch JWC TL receive water from the JWC WTP and Fern Hill Reservoirs.

The City does not currently own capacity in the 72-inch JWC NTL and would be required to lease or purchase available capacity to use the intertie as a regular finished water supply. Hillsboro and TVWD are currently partnering in the development of a second regional source, the Willamette Water Supply Program. With this new supply available in 2026 leasing capacity may become available in the 72-inch JWC NTL at least for the near-term future until Hillsboro and TVWD system demands increase to the point where both Willamette and 72-inch JWC NTL full capacities are needed.

Distribution system improvements will be needed to provide higher flows from the proposed intertie without over-pressurizing customers near the intertie. Recommended improvements depend on the ultimate design flows selected by the City but upsizing to 20-inch diameter transmission is proposed. Distribution limitations and improvement options are discussed in more detail in **Section 5**.

4.4.2.8 Replace 5 MG Reservoir

The 5 MG Reservoir was constructed in 1948 and is a buried reinforced concrete structure divided in to two 2.5 MG cells for operational flexibility. Per the SRP, the 5 MG Reservoir is vulnerable to structural damage in a CSZE and the fill slopes below the tank are susceptible to deformation under high ground water conditions.

The reservoir is a critical facility for the City water system, supplying service pressure to the 368 Zone which serves most City customers and providing suction supply to the Watercrest and David Hill Pump Stations which fill the David Hill Reservoir. City staff have observed voids in the sidewalls and floor of the existing 5 MG reservoir from the original construction where wooden concrete forms have deteriorated. As these forms continue to degrade, the voids may be an on-going source of minor leaks in the reservoir. A more substantial leak was identified by City staff in 2018

northwest of the discharge sump, in the floor of the reservoir on the north side. The concrete was patched to seal the leak.

Replacing the 5 MG Reservoir with a seismically resilient similar volume tank would address condition and seismic issues with the existing tank. Additionally, replacing only the existing volume would allow for a smaller footprint, which may be amenable to the site slope. However, this would mean additional storage required to address future storage deficiencies in the 368 Zone would need to be placed elsewhere.

4.4.2.9 Replace and Expand 5 MG Reservoir Onsite

As discussed in the prior section, the 5 MG Reservoir is a critical facility and needs to be replaced due to age, condition, seismic vulnerability, and projected capacity issues. As presented in **Section 5** the existing 5 MG Reservoir has inadequate capacity to meet finished water storage. One option for reservoir replacement is to expand the 5 MG Reservoir at the existing site. A preliminary tank siting by City staff indicates that two cylindrical 5 MG prestressed concrete tanks may fit on the existing site. The existing 5 MG Reservoir would have to be demolished and replaced in phases, one cell at a time, to use the existing site, to allow the City WTP to continue receiving adequate chlorine contact time, and to provide 368 Zone system pressure during construction.

4.4.2.10 New Reservoir and Pump Station at Heather Intertie

To complement a new finished water supply intertie with the 72-inch JWC NTL and to offset 368 Zone storage deficiencies (see **Section 5**), the City could construct a ground-level storage reservoir and booster pump station near the Heather Street Intertie. The storage reservoir and pump station capacity would mitigate future 368 Zone storage deficiencies in lieu of expanding the 5 MG Reservoir. Locating this ground-level reservoir and pump station near the 72-inch JWC NTL intertie would also help to mitigate industrial fire flow deficiencies in the distribution system near the intertie. The ground-level reservoir would not be able to supply customers by gravity and the pump station would be vulnerable to power outages or require back-up power.

4.4.2.11 Connect to TVID

The TVID receives raw water from the Tualatin River and storage impoundments through the JWC's Springhill Pump Station, a 33-inch diameter raw water transmission main which travels through the City. The City has proposed leasing capacity in the TVID raw water transmission line to access the City's in-stream and stored water rights in the Tualatin River system. This proposed raw water supply essentially transfers the raw water supply that would have been treated at the JWC WTP to the City's WTP and at the same time does not increase the total raw water supply available to the City. Instead, it would allow expanded operation of the City's WTP which would increase the City's overall treatment capacity in the summer when in-stream flows in Clear and Roaring Creeks are low, without needing to expand the City's treatment ownership in the JWC WTP. The capacity available for lease in the TVID transmission main is unknown and total supply benefit would continue to be limited by the City WTP capacity of 3.7 mgd.

To transmit water from TVID’s transmission main near NW Thatcher Road and NW David Hill Road to the City’s WTP, the City would need to construct and maintain a minimum of 3,000 feet of new, seismically resilient transmission main.

This alternative currently has several uncertainties including:

- unknown capacity available for lease in the TVID transmission main, particularly during summer months when irrigation use is highest
- unknown seismic resilience and required maintenance of the TVID transmission main
- potential issues with water rights

4.4.3 Scenario Benefits, Challenges, and Information Gaps

While many of the facilities described in the preceding section are shared between multiple supply scenarios, each scenario presents a unique set of benefits and challenges. Additionally, the City does not currently have access to some information such as expected performance during a seismic event or cost of improvements which will impact scenario selection. **Table 4-6** summarizes the benefits, anticipated challenges, and additional information required to make an informed decision for each of the five supply scenarios.

4.4.4 City Next Steps

The City should complete a Water Supply Study to make an informed decision on the best long-term supply strategy and fill the remaining information gaps. The following actions are recommended as part of the Water Supply Study.

- Document and estimate costs for City WTP age and condition replacements.
- Document and estimate costs for City WTP and RWTM seismic improvements.
- Document and estimate costs for JWC seismic improvements for the JWC WTP, Fern Hill Reservoirs, and 24-inch JWC TL.
- Continue discussions on lease capabilities in the 72-inch JWC NTL and the 24-inch JWC TL with the City of Hillsboro.
- Discuss lease capabilities in the TVID transmission main with TVID.
- Investigate water rights requirements for TVID transmission.
- Perform a formal cost-benefit analysis of the supply scenarios.

- Investigate options to expand long-term raw water supply including groundwater, reducing raw water supply need through leasing finished water capacity from JWC partners, and participating in JWC planning and conservation efforts.

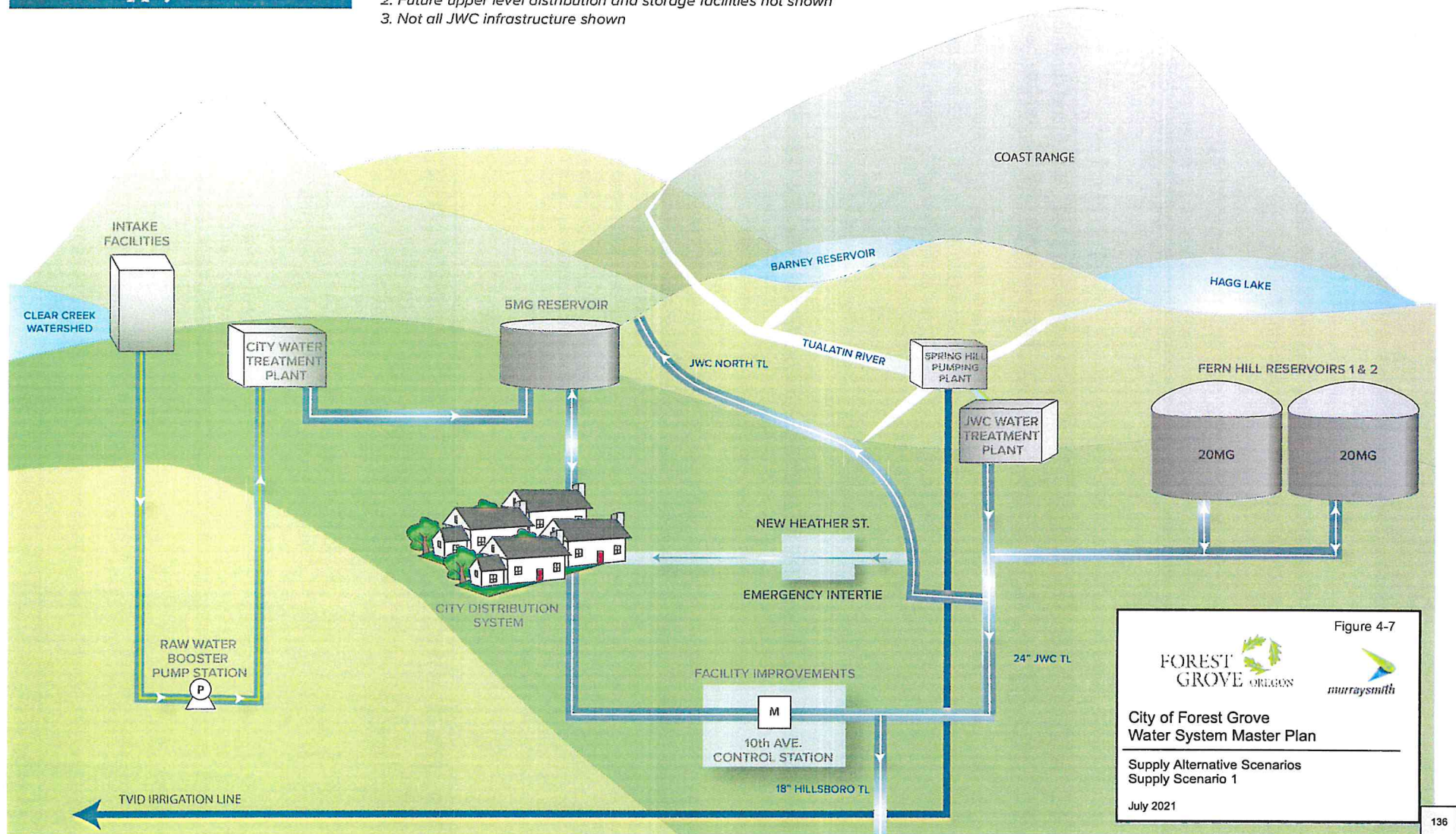
Table 4-6 | Scenario Benefits, Challenges, and Information Gaps

Scenario	Benefits	Challenges	Information Gaps
1 – Base Maintain Existing	▪ Known O&M ▪ Local supply control	▪ Does not address finished water storage deficit ▪ RWTM and 5 MG Reservoir seismically vulnerable	▪ City WTP required seismic improvements, age, and condition replacements
2 – JWC only Expand 5MG storage	▪ Consolidate future investment ▪ Simplify system ▪ Address storage deficit	▪ Reliant on a single source (JWC) ▪ Transmission through City distribution creates overpressure	▪ Lease capabilities in 72-inch JWC NTL & from the City of Hillsboro in the 24-inch JWC TL
3 – JWC only New Ground Reservoir	▪ Consolidate future investment ▪ Simplify system ▪ Storage adjacent to JWC supply point	▪ Pumped service to 368 Zone - o energy cost - o mechanical vulnerability - o maintenance cost	▪ Siting and cost of reservoir and pump station ▪ Lease capabilities in 72-inch JWC NTL
4 – City WTP & JWC Expand storage	▪ Maintain 2 supply sources ▪ Local supply control ▪ Address storage deficit	▪ RWTM and 5 MG Reservoir seismically vulnerable ▪ Significant investment in seismic retrofitting and condition upgrades for both City WTP and JWC supplies	▪ Lease capabilities in 72-inch JWC NTL & from the City of Hillsboro in the 24-inch JWC TL ▪ City WTP seismic improvements, age, and condition replacements
5 – TVID Raw Water Supply to City WTP & JWC Expand storage	▪ Maintain 2 supply sources ▪ Local supply control ▪ Address storage deficit ▪ Continue to use Clear Creek watershed rights	▪ Significant investment in seismic retrofitting and condition upgrades for both City WTP and JWC supplies ▪ Investment in TVID transmission, including seismic evaluation and retrofitting	▪ Lease capabilities in TVID transmission ▪ City WTP seismic improvements, age, and condition replacements ▪ Water right requirements

Supply Scenario 1

Notes

1. City distribution system includes the David Hill Reservoir, the Watercrest & David Hill Pump Stations, PRV's, and distribution piping.
2. Future upper level distribution and storage facilities not shown
3. Not all JWC infrastructure shown



Supply Scenario 2

Notes

1. City distribution system includes the David Hill Reservoir, the Watercrest & David Hill Pump Stations, PRV's, and distribution piping.
2. Future upper level distribution and storage facilities not shown
3. Not all JWC infrastructure shown

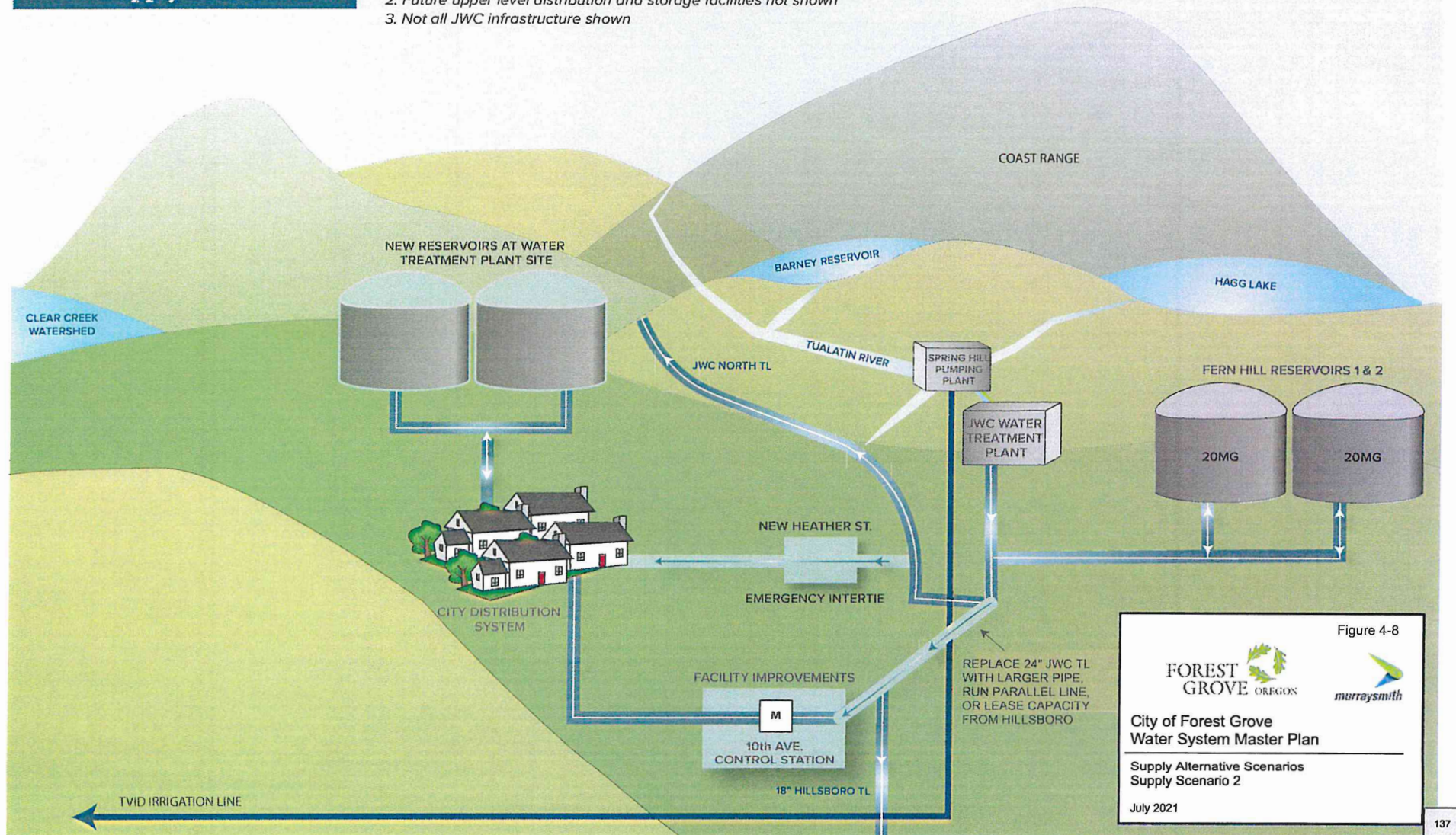


Figure 4-8



City of Forest Grove
Water System Master Plan

Supply Alternative Scenarios
Supply Scenario 2

July 2021

Supply Scenario 3

Notes

1. City distribution system includes the David Hill Reservoir, the Watercrest & David Hill Pump Stations, PRV's, and distribution piping.
2. Future upper level distribution and storage facilities not shown
3. Not all JWC infrastructure shown

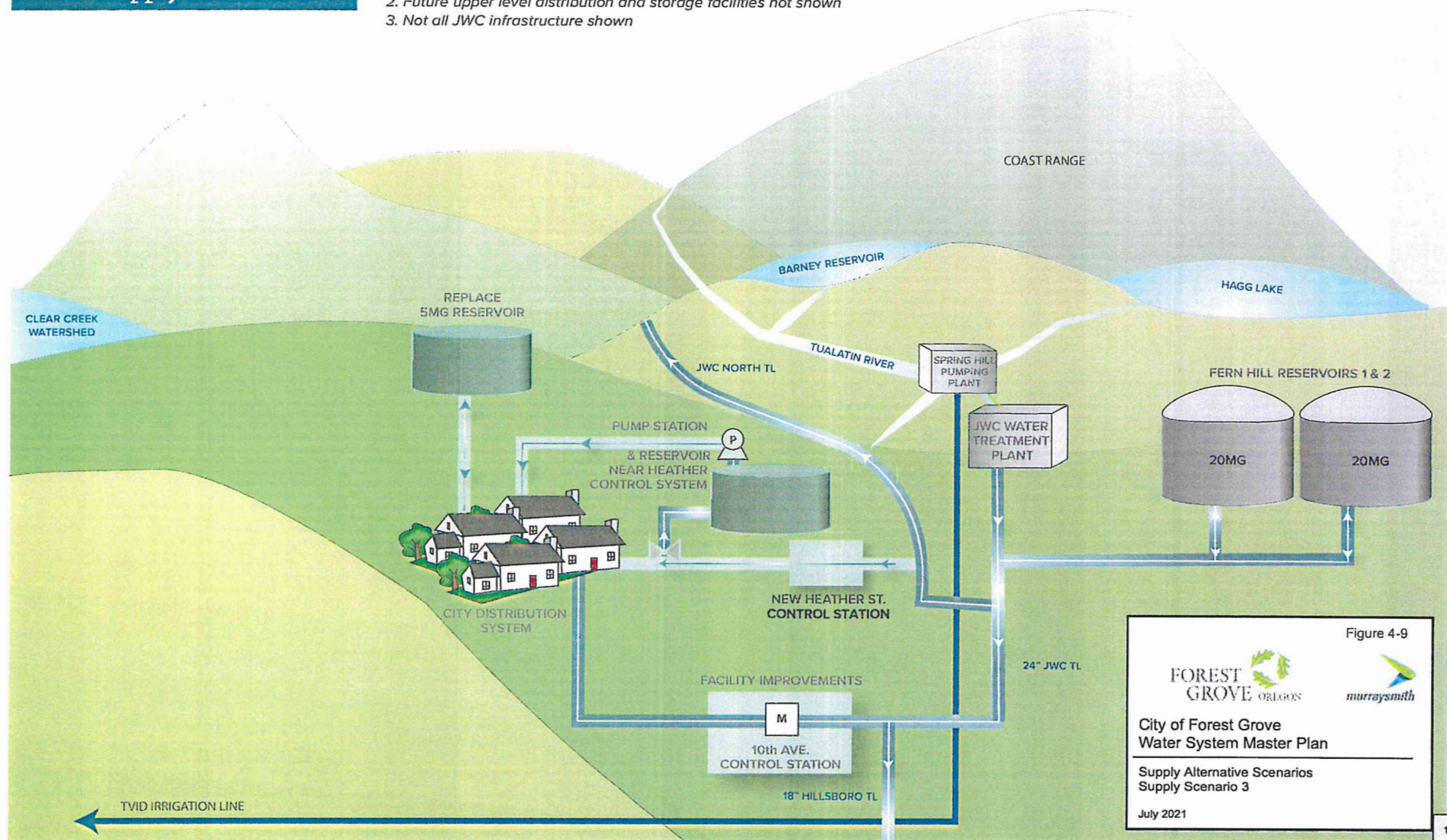


Figure 4-9



City of Forest Grove
Water System Master Plan

Supply Alternative Scenarios
Supply Scenario 3

July 2021

Supply Scenario 4

Notes

1. City distribution system includes the David Hill Reservoir, the Watercrest & David Hill Pump Stations, PRV's, and distribution piping.
2. Future upper level distribution and storage facilities not shown
3. Not all JWC infrastructure shown

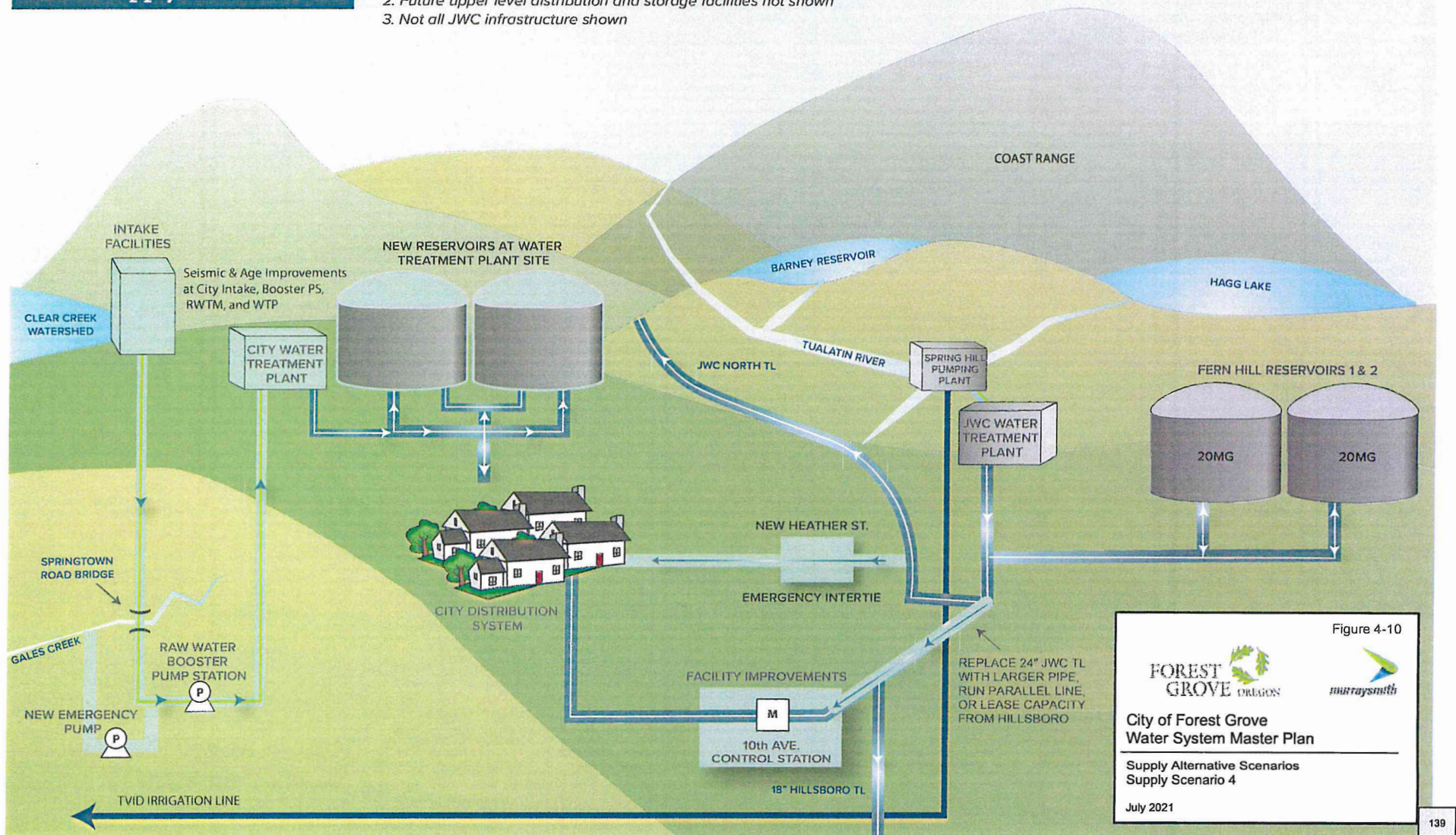


Figure 4-10



City of Forest Grove Water System Master Plan

Supply Alternative Scenarios
Supply Scenario 4

July 2021

Supply Scenario 5

Notes

1. City distribution system includes the David Hill Reservoir, the Watercrest & David Hill Pump Stations, PRV's, and distribution piping.
2. Future upper level distribution and storage facilities not shown
3. Not all JWC infrastructure shown

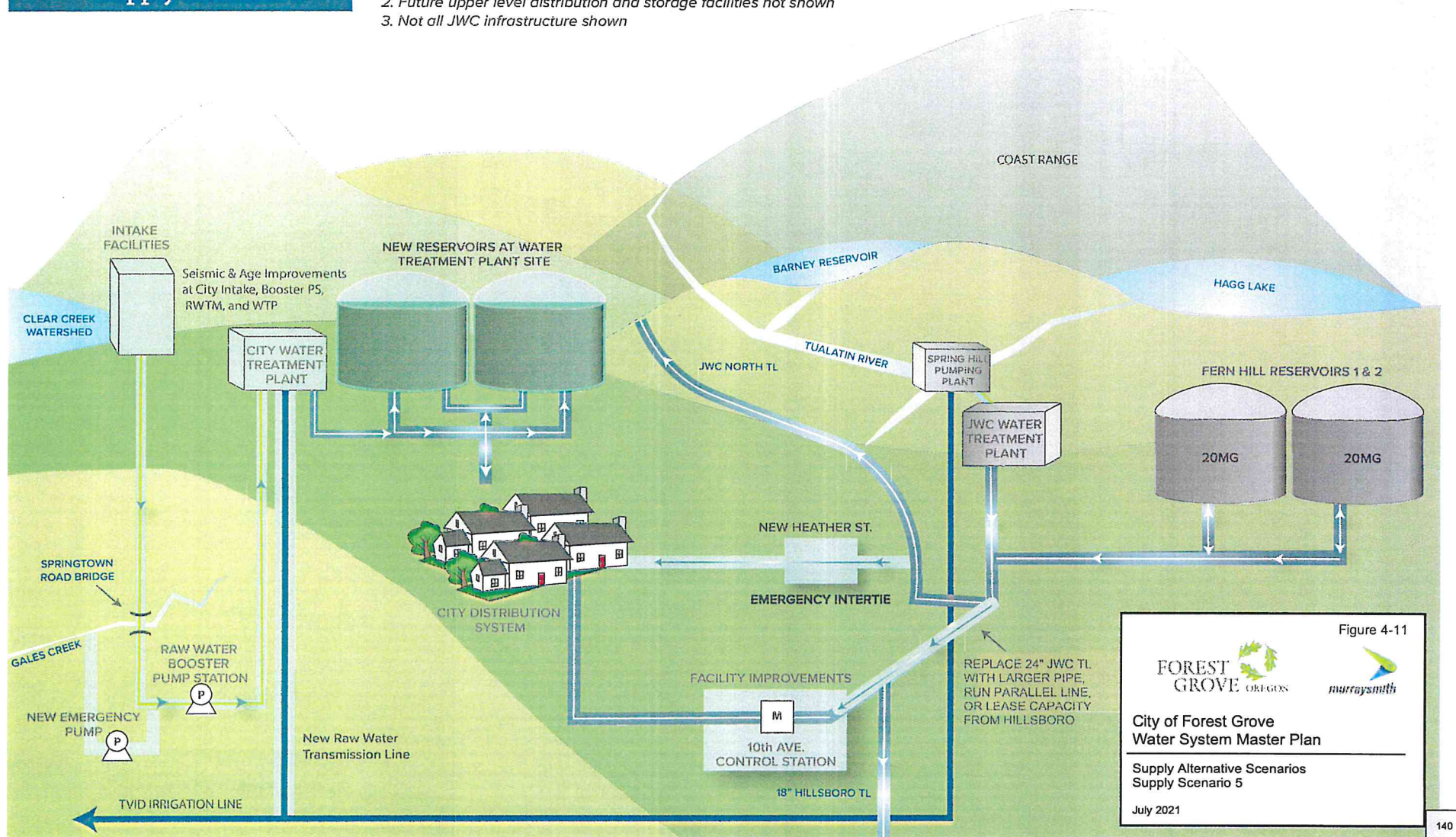


Figure 4-11



City of Forest Grove
Water System Master Plan

Supply Alternative Scenarios
Supply Scenario 5

July 2021

Section 5

Section 5

Distribution System Analysis

5.1 Introduction

This section presents an analysis of the City's water distribution system based on criteria outlined in **Section 3**. The water demand forecasts summarized in **Section 2** are used in conjunction with analysis criteria to assess water system performance including service pressures, storage and pumping capacity, and emergency fire flow availability. This section provides the basis for the recommended CIP presented in **Section 7**.

5.2 Service Pressure and Zone Analysis

5.2.1 Existing Conditions

Under existing PHD conditions, the City's pressure zones, described in **Section 1**, provide adequate minimum service pressure of at least 30 psi throughout the distribution system. Distribution service pressures can exceed the maximum recommended 80 psi upper pressure limit in some low-lying areas of the 368 Zone, particularly when the 10th Avenue Control Station is used to fill the City's 5 MG Reservoir. High system pressures are also seen along zone boundaries, particularly at lower elevations of the 540 Zone. Small areas of higher pressures in the distribution system are expected, particularly in steep terrain where large differences in topography over short distances make it impractical to serve customers at a narrower range of service pressures. Customers would typically be fitted with individual PRVs to ensure adequate pressure.

5.2.2 Service Area Expansion

As described in **Section 2.1.2**, the City is planning for growth primarily in three areas northwest of the current city limits: the Purdin Road UGB Area, the David Hill UGB Area, and the DHURA as shown on Plate 1 in **Appendix A**. The Purdin Road and David Hill UGB Areas are expected to be developed by within the next 20 years, while the DHURA is expected to begin development sometime after. Future service to the DHURA is beyond the 20-year planning horizon for this WSMP and therefore will only be discussed in the context of serving other areas within the UGB.

Most development in the David Hill UGB and Purdin Road UGB Areas is expected to be residential, with some neighborhood mixed use that includes some retail and office space adjacent to the existing service area near the intersection of David Hill Road and Highway 47 and the intersection of David Hill Road and Thatcher Road. Development areas will be looped into existing pressure zones, where applicable. The Purdin Road UGB will be served entirely by the existing 368 Zone. The David Hill UGB will be primarily looped into the existing 368, 435, and 540 Zones with a small

portion to be served by the future 710 Zone. The DHURA will be served by the future 710 and 880 Zones and looped into the existing zones where applicable.

5.3 Storage Analysis

Using the existing and future demands discussed in **Section 2** of this report, the operational, emergency, fire, and total required storage for the water system was calculated using the storage criteria discussed in **Section 3**.

5.3.1 Existing Storage Volumes

The City has existing storage in the 5 MG Reservoir at the City WTP, the David Hill Reservoir, and in the JWC Fern Hill Reservoirs. **Table 5-1** illustrates the available storage for all facilities.

- **5 MG Reservoir** - 5.0 MG of available storage. This reservoir also provides chlorine contact time for the City WTP. City staff report a reservoir water depth of 10.58 feet, approximately 1.6 MG, is required for sufficient chlorine contact time as determined by a 2017 tracer study. This volume does not need to be in addition to other storage requirements as long as operating levels do not regularly drop below this minimum.
- **David Hill Reservoir** - 1.0 MG of available storage.
- **JWC Fern Hill Reservoirs** – 3.2 MG of available storage. The City owns 13.33% (5.33 MG) of the total 40 MG capacity in the JWC Fern Hill Reservoirs. JWC operations allocate 40% of the total storage to JWC operations, with the remaining 60% available to Cities by ownership percentage, resulting in 3.2 MG of storage available to Forest Grove.

Table 5-1 | Existing Storage Volumes

Facility Name	Owner	Available Capacity (MG)	Zones Served by Gravity
5 MG Reservoir	City	5.0	368
David Hill Reservoir	City	1.0	540, 435, Gales Creek Svc Area
Fern Hill Reservoirs	JWC	3.2	368

Note:

1. The 5 MG Reservoir storage capacity in the 2010 Water System Plan was listed as 4.27 MG. Based on calculations from the original 1980 design drawings, the City's 5 MG Reservoir has a storage volume of closer to 5.2 MG. Due to high uncertainty, the reservoir will be assumed to have a capacity of 5 MG for this analysis.
2. The two Fern Hill Reservoirs in total contain up to 40 MG. The City owns 13.33% (5.33 MG) of which 60% (3.2 MG) is available to the City.

5.3.2 Operational Storage Required

As discussed in **Section 3**, operational storage is calculated as 25 percent of MDD. Pressure Zone 368 is served by operational storage in the 5 MG Reservoir at the City WTP and by the JWC Fern Hill Reservoirs. The 435, 540 Zones, and GCSA are served by operational storage within the David Hill Reservoir. The proposed 710 and 880 Zones are assumed to have operational storage within a

future, higher elevation reservoir. **Table 5-2** shows the required operational storage for the pressure zones served by each storage facility.

Table 5-2 | Operational Storage Required

Zone 368						
Year	2021	2026	2031	2041	2071	
MDD (mgd)	5.73	6.20	7.00	8.00	8.82	
Operational Storage Required (MG)	1.43	1.55	1.75	2.00	2.20	
Zone 435, 540, GCSA						
Year	2021	2026	2031	2041	2071	
MDD (mgd)	0.44	0.44	0.60	0.77	1.05	
Operational Storage Required (MG)	0.11	0.11	0.15	0.19	0.26	
Zone 710, 880						
Year	2021	2026	2031	2041	2071	
MDD (mgd)	-	-	-	0.03	0.17	
Operational Storage Required (MG)	-	-	-	0.01	0.04	

Note:

1. Required operational storage equal to 0.25xMDD. Storage volumes are given to the nearest hundredth (10,000 gallons) and rounding differences are present.
2. Construction of a new reservoir for the 710 and 880 zone will likely be tied to development of the DHURA which is likely to occur more than 20 years from now.
3. Development within the 710 pressure zone in the David Hill UGB will be provided by a constant pressure pumped system, until a future reservoir is constructed to serve the 710 and 880 pressure zones.

5.3.3 Emergency Storage Required

As described in **Section 3.5** emergency storage is required in the event of a loss of supply. Emergency storage is calculated as 100 percent of MDD in City and JWC owned storage. This is an increase from the City's 2010 Water System Plan that used 75 percent of MDD. **Table 5-3** summarizes the emergency storage required by zone.

The 368 Zone is served by gravity from the JWC supply. Therefore, storage in the JWC Fern Hill Reservoirs and the City's 5 MG Reservoir both provide emergency storage in the 368 Zone. The 435 and 540 Zones and GCSA have emergency storage within the David Hill Reservoir. The proposed 710 and 880 Zones are assumed to have emergency storage within a future, higher elevation reservoir.

Table 5-3 | Emergency Storage Required

Zone 368						
Year	2021	2026	2031	2041	2071	
MDD (mgd)	5.73	6.20	7.00	8.00	8.82	
Emergency Storage Required (MG) - 1xMDD	5.73	6.20	7.00	8.00	8.82	
Zone 435, 540, GCSA						
Year	2021	2026	2031	2041	2071	
MDD (mgd)	0.44	0.44	0.60	0.77	1.05	
Emergency Storage Required (MG) - 1xMDD	0.44	0.44	0.60	0.77	1.05	
Zone 710, 880						
Year	2021	2026	2031	2041	2071	
MDD (mgd)	-	-	-	0.03	0.17	
Emergency Storage Required (MG) - 1xMDD	-	-	-	0.03	0.17	

Note:

1. Construction of a new reservoir for the 710 and 880 zones will likely be tied to development of the DHURA which is likely to occur more than 20 years from now.
2. Development within the 710 pressure zone in the David Hill UGB will be provided by a constant pressure pumped system, until a future reservoir is constructed to serve the 710 and 880 pressure zones.

5.3.4 Fire Storage Required

Storage reservoirs must provide sufficient fire storage volume to supply the largest required fire flow in the zone. For this analysis, required fire flow for each zone is selected based on land use as described in **Section 3**.

Pressure Zone 368 has commercial and industrial customers within the zone boundary. Commercial and industrial customers typically require a higher fire flow rate and longer duration than residential properties. A flow rate of 3,000 gpm at a duration of four hours was assumed for the 368 Zone, consistent with 2019 OFC guidelines for maximum flow from a public water system and City Fire Marshal direction.

Pressure Zones 435, 540, and GCSA are primarily residential. Residential customers require a lower fire flow rate and shorter duration, typically 1,000 gpm for one hour. Oregon House Bill (HB) 2001 Middle Housing, passed in 2019, allows for duplex, triplex, and quadruplex housing within single family residentially zoned areas. This type of housing is considered medium density and has a higher fire flow requirement (2,000 gpm). Therefore, Zones 435, 540, and GCSA are assumed to have a fire flow requirement of 2,000 gpm for two hours.

Table 5-4 shows the total fire storage required based upon the suggested flow rates and durations for the pressure zones. It was assumed that the 435, 540 Zones, and GCSA will be served by the existing 1 MG David Hill Reservoir, and the proposed 710 and 880 Zones will be served by a future reservoir. This analysis assumes only one fire would occur at a time within an area served by a single reservoir.

Table 5-4 | Fire Storage Required

Zone 368		
Fire Flow Req (gpm)	Fire Flow Duration (hrs)	Fire Flow Storage Required (MG)
3000	4	0.72
Zone 435, 540, GCSA		
Fire Flow Req (gpm)	Fire Flow Duration (hrs)	Fire Flow Storage Required (MG)
2000	2	0.24
Zone 710, 880		
Fire Flow Req (gpm)	Fire Flow Duration (hrs)	Fire Flow Storage Required (MG)
2000	2	0.24

Note:

1. Construction of a new reservoir for the 710 and 880 zones will likely be tied to development of the DHURA which is likely to occur more than 20 years from now.
2. Development within the 710 pressure zone in the David Hill UGB will be provided by a constant pressure pumped system, until a future reservoir is constructed to serve the 710 and 880 pressure zones.

5.3.5 JWC Contractual Storage Required

As described in **Section 3.5**, the City's agreement with the JWC partners requires the City to maintain system-wide storage capable of providing three days of the average daily finished water supplied to the City by the JWC system. The JWC requires this storage to minimize fluctuations in demands placed on the JWC treatment and transmission facilities. The City calculated this demand as the difference between projected ADD calculated in **Section 2** and projected City finished water production based on WTP production limitations during non-regulated season and raw water supply during the regulated season.

Total storage includes City storage facilities and the City's 3.2 MG Fern Hill storage capacity ownership. The Fern Hill storage is considered available storage to meet this requirement because the JWC does not allow the reservoir levels to decrease to a point where the capacity would not be available to the City. With the 2020 update to the 10th Avenue Control Station valves, Fern Hill water is available on demand. System-wide JWC contractual storage criteria:

- **Criteria 3** - JWC contractual guidelines, three times the average daily finished water supplied to the City by the JWC system.

Table 5-5 shows the calculated system-wide storage necessary to comply with JWC requirements.

Table 5-5 | JWC System-wide Storage Required

	2021	2026	2031	2041	2071
ADD (MGD)	3.27	3.52	4.03	4.68	5.33
Projected portion of ADD Supplied by Forest Grove WTP (MGD) ¹	1.96	1.96	1.96	1.96	1.96
Projected Portion of ADD Supplied by JWC (MGD)	1.31	1.56	2.07	2.72	3.37
JWC Storage Required (MG) ²	3.93	4.68	6.21	8.16	10.12

Note:

1. City provided data for the projected portion of ADD supplied by City WTP.
2. Three times the average daily finished water supplied to the City by the JWC system.

5.3.6 Total System Storage Analysis

Total required system storage is the sum of operational (OS), emergency (ES) and fire storage (FS) components for zones served by each facility. In addition, the City's agreement with the JWC requires a minim total system storage. Total required system storage assumes that Pressure Zone 368 is served by both the 5 MG Reservoir and the City's owned capacity in the JWC Fern Hill Reservoirs. The remaining pressure zones (existing and proposed) are assumed to be served by the 1 MG David Hill Reservoir and future 710 Reservoir. The JWC storage requirements are applied to the entire Forest Grove system, combined.

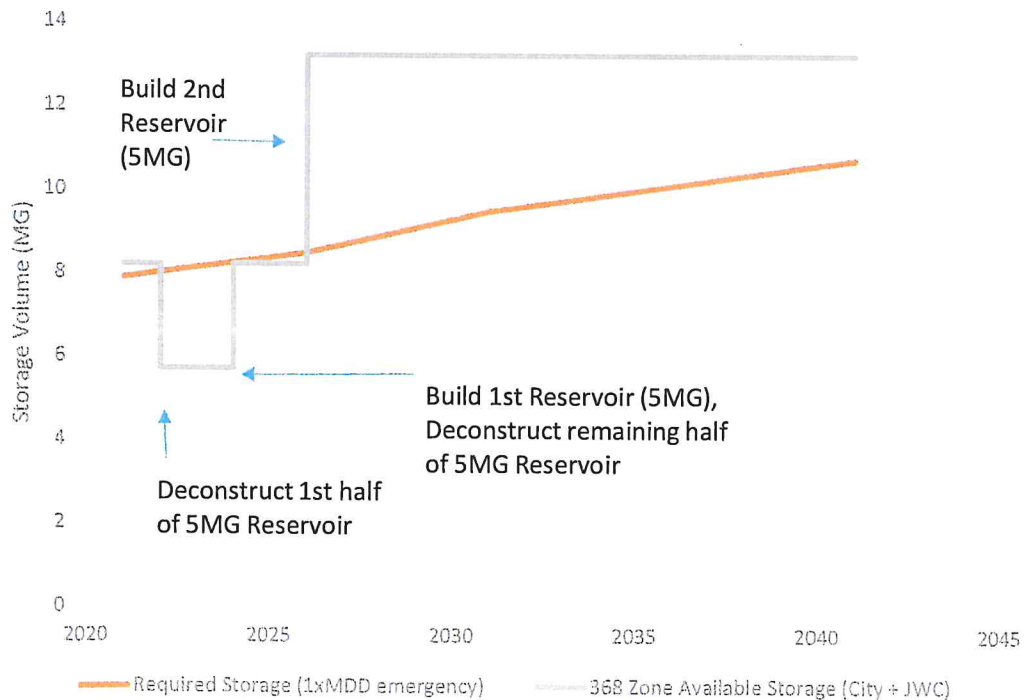
5.3.6.1 Storage Analysis Findings

Additional storage is required at all zones within 20 years. **Table 5-6** and **Figure 5-2**, **Figure 5-3**, and **Figure 5-4** summarize the storage required by zone. **Table 5-7** and **Figure 5-5** summarizes total system storage needs including JWC requirements and includes proposed additional storage. It was assumed that new storage would be City owned and not through the JWC system.

The 368 Zone is currently barely deficient and will require an additional 3.06 MG in 20 years, and 4.2 MG in 50 years. To meet this deficit, twin 5 MG reservoirs are proposed to replace the existing 5 MG reservoir located at the City WTP. Additionally, the upper zones (435, 540, and GCSA) will reach a storage deficit in 10 years, and by 50 years require an additional 0.56 MG. Pumping and transmission improvements will enable the upper zones to access some of the 368 Zone storage, offsetting the need for additional storage at the David Hill Reservoir. The existing 5 MG Reservoir is critical to current City WTP operations, as it sets the hydraulic grade for the 368 Zone which serves most City water customers and acts as terminal storage for the JWC supply. Operation of half of the existing reservoir could be maintained while the first half is deconstructed, and the first of two new twin 5 MG reservoirs is built. Once finished, the second half of the existing reservoir could be demolished, and the second 5 MG reservoir constructed. **Figure 5-1** illustrates one potential construction phasing of the deconstruction of the existing 5 MG Reservoir by half, and the construction of two Reservoirs. Timing shown may not be feasible given construction limitations. With this phasing, short term deficits will exist and the City may be more vulnerable to supply interruptions.

A 0.5 MG 710 reservoir is recommended to serve high elevation customers, constructed as development requires. This reservoir also provides a benefit to customers in the 540, 435, and GCSA zones as excess storage in this reservoir can be accessed by those customers by gravity. In the short term, small developments at the 710 level may be served by constant pressure pumping from the 540 Zone, as described in the next section. Long term, however, a reservoir is recommended to best serve these customers. Timing on this reservoir is primarily dependent on development.

Figure 5-1 | Phased Construction of 368 Zone Storage



Note:

1. This is only one possible construction schedule. Actual construction timeline will vary.

Table 5-6 | Storage Requirements and Deficit by Pressure Zone (MG)

Year	Demand (MG)		Existing Storage (MG)		Required Storage (MG)				
	Avg (ADD)	Max (MDD)	City	JWC	Operating (OS)	Emergency (ES)	Fire (FS)	Total Storage	Surplus/ (Need)
368									
2021	3.03	5.73	5	3.2	1.43	5.73	0.72	7.88	0.32
2026	3.28	6.20	5	3.2	1.55	6.20	0.72	8.47	(0.27)
2031	3.72	7.00	5	3.2	1.75	7.00	0.72	9.46	(1.26)
2041	4.27	8.00	5	3.2	2.00	8.00	0.72	10.72	(2.52)
2071	4.72	8.82	5	3.2	2.20	8.82	0.72	11.74	(3.54)
435, 540, GCSA									
2021	0.23	0.44	1	0	0.11	0.44	0.24	0.79	0.21
2026	0.23	0.44	1	0	0.11	0.44	0.24	0.79	0.21
2031	0.31	0.60	1	0	0.15	0.60	0.24	0.99	0.01
2041	0.39	0.77	1	0	0.19	0.77	0.24	1.20	(0.20)
2071	0.53	1.05	1	0	0.26	1.05	0.24	1.55	(0.55)
710, 880									
2021	-	-	0	0	-	-	-	-	-
2026	-	-	0	0	-	-	-	-	-
2031	-	-	0	0	-	-	-	-	-
2041	0.01	0.03	0	0	0.01	0.03	0.24	0.27	(0.27)
2071	0.08	0.17	0	0	0.04	0.17	0.24	0.45	(0.45)

Note:

1. Storage calculations in the 368 zone include 3.2 MG City-owned storage capacity in JWC Fern Hill Reservoirs.
2. Negative values are shown in parentheses and indicate a deficit.
3. Zones 710 and 880 are proposed to serve future development and have no existing storage.
4. Construction of a new reservoir for the 710 and 880 zone will likely be tied to development of the DHURA which is likely to occur more than 20 years from now.
5. Development within the 710 pressure zone in the David Hill UGB will be provided by a constant pressure pumped system, until a future reservoir is constructed to serve the 710 and 880 pressure zones.

Figure 5-2 | 368 Zone Storage Requirements

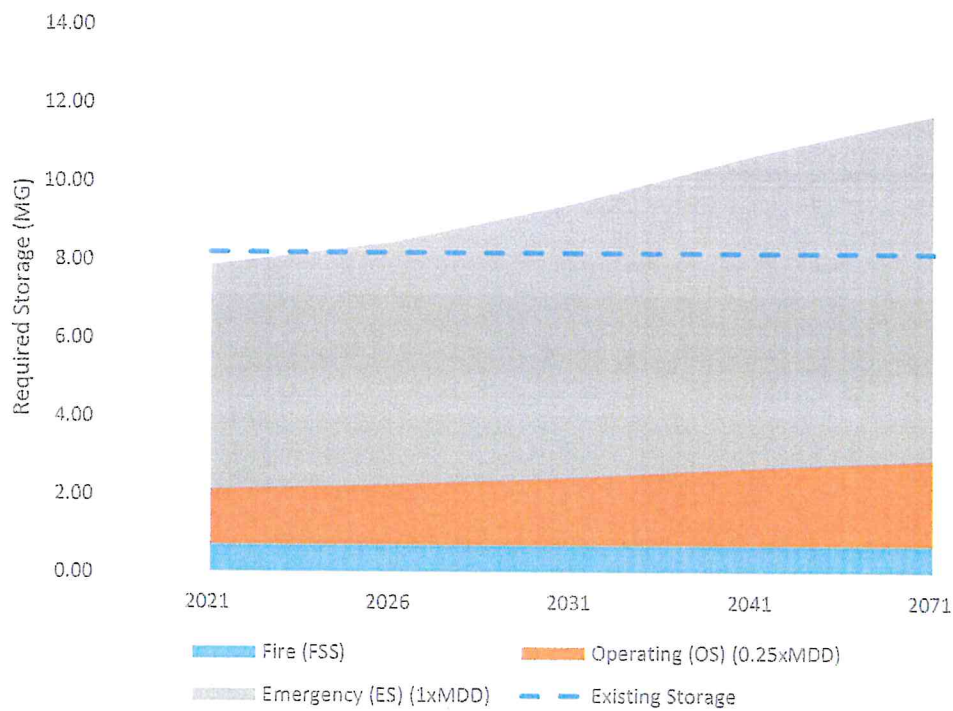


Figure 5-3 | 435, 540, and GCSA Zone Storage Requirements

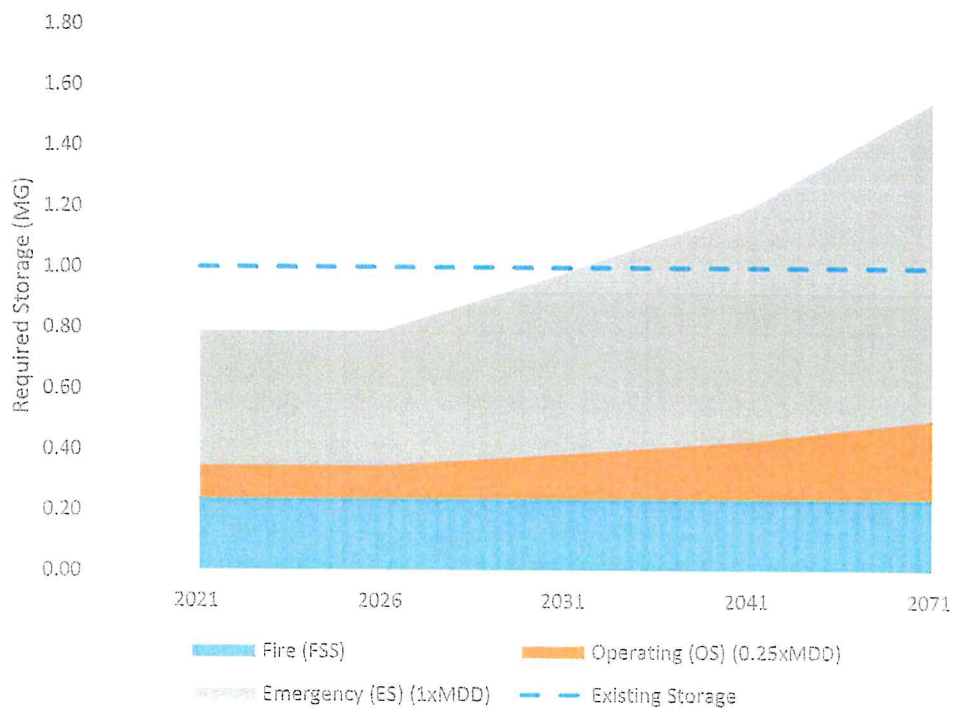
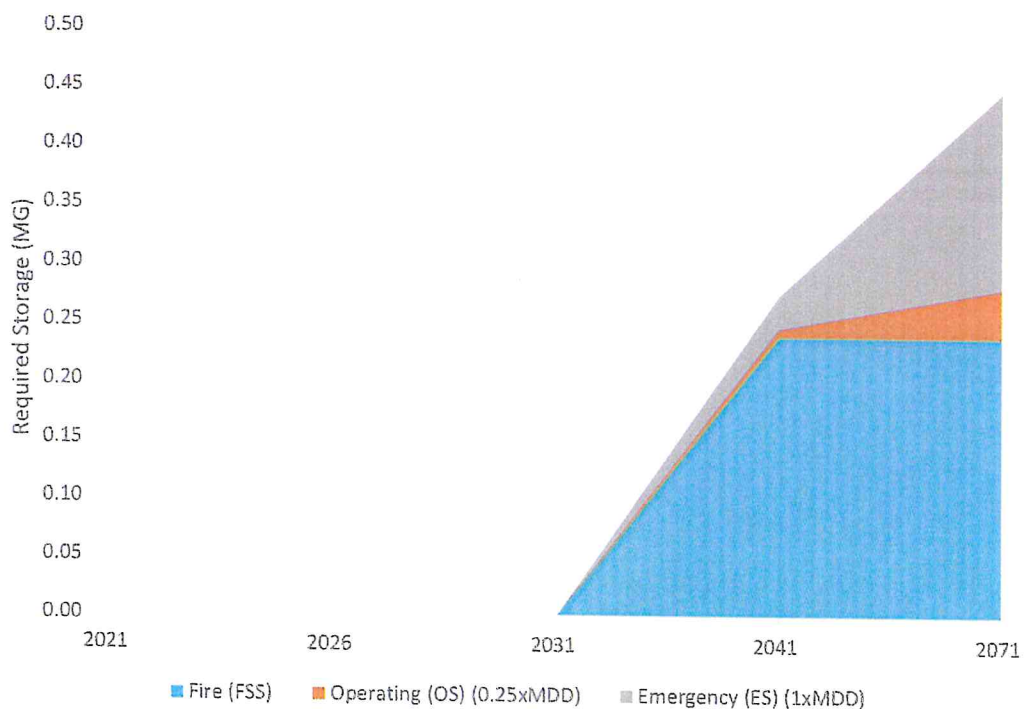


Figure 5-4 | 710 and 880 Zone Storage Requirements



Note:

1. No existing 710 or 880 storage facilities. Prior to construction of 710 Reservoir, supply to be provided by David Hill Reservoir.

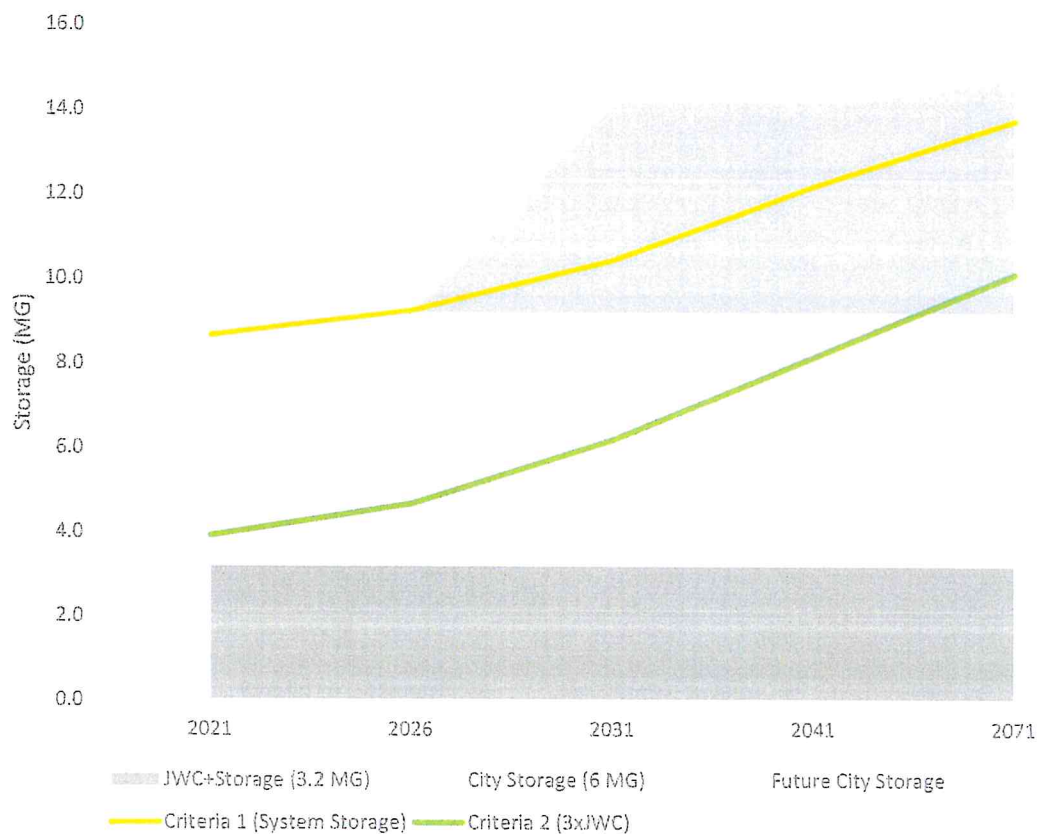
Table 5-7 | Total Storage Deficiencies

Year	Existing Storage (MG)		Criteria 1 – System Storage Requirements (MG)		Criteria 2 – JWC In-System Storage (MG)	
	City	JWC	Total Required (Table 5-6)	Surplus/ (Need)	Total Required (Table 5-5)	Surplus/ (Need)
2021	6.00	3.20	8.67	0.53	3.92	5.28
2026	6.00	3.20	9.26	(0.06)	4.68	4.52
2031	6.00	3.20	10.45	(1.25)	6.20	3.00
2041	6.00	3.20	12.19	(2.99)	8.16	1.04
2071	6.00	3.20	13.74	(4.54)	10.12	(0.92)

Note:

1. Negative values shown in parentheses indicate a deficit.

Figure 5-5 | Total Storage Deficiencies and Proposed Storage



Note:

1. City Storage includes both the 5 MG Reservoir and the 1 MG David Hill Reservoir.
2. Future City Storage includes a second 5 MG Reservoir, in addition to the replacement of the existing 5 MG Reservoir, and a new 0.5 MG 710 Reservoir.

5.4 Pumping Analysis

5.4.1 Capacity

As presented in **Section 3**, the City's required pumping capacity varies depending on the water demand, volume of available storage, and the number of pumping facilities serving each pressure zone. Required firm capacity is defined as a station's total pumping capacity with the largest pump out of service. Pumping capacity is evaluated for these two configurations.

- **Pumping to storage**
 - Required firm capacity (largest pump out of service) = MDD for zones served
 - Applies to:
 - David Hill PS and Watercrest PS
 - Proposed future 710 Zone PS after a proposed 710 reservoir is constructed

- **Constant pressure pumping – sole supply to customers**
 - Required firm capacity = PHD for zones served + largest required fire flow
 - Applies to proposed service areas above the existing 540 Zone, including:
 - proposed future 710 Zone prior to proposed 710 reservoir construction
 - proposed 880 Zone

Existing and projected future pumping capacity requirements are summarized in **Table 5-8**.

Table 5-8 | Pumping Capacity Analysis

Pump Station Name	Service Type	Criteria	Existing Capacity (gpm)	Zones Served	Year	Required Capacity (gpm)	Surplus/ (Need) (gpm)
Watercrest & David Hill	To Storage	MDD	1,080 Total 680 Firm	540, 435, GCSA, Future 710 and 880	2021	307	373
					2026	308	372
					2031	415	265
					2041	554	126
					2071	843	(163)
Future 710 (pre-reservoir)	Constant Pressure Supply	PHD + 2,000 gpm max fire flow	NA	Future 710 and 880	2021	NA	NA
					2026	2,000	(2,000)
					2031	2,000	(2,000)
					2041	2,039	(2,039)
					2071	2,232	(2,232)
Future 710 (post-reservoir)	To Storage	MDD	NA	Future 710 and 880	2021	-	-
					2026	-	-
					2031	-	-
					2041	19	(19)
					2071	116	(116)
Future 880 (post-reservoir)	Constant Pressure Supply	PHD + 2,000 gpm max fire flow	NA	Future 880	2021	-	-
					2026	-	-
					2031	-	-
					2041	-	-
					2071	2,070	(2,070)

Note:

1. Negative values shown in parentheses indicate a deficit.
2. Watercrest PS is a single pump at 280 gpm capacity. David Hill PS has two pumps at 400 gpm each. Firm capacity in this scenario assumes the largest pump of the three available pumps is out of service, one pump is active at each station.
3. Pump stations must provide adequate supply for all zones where one zone acts as a source for another. While the Watercrest and David Hill Pump Stations only directly supply the 540 Zone, they must also provide MDD for higher zones which are supplied through pumping or PRVs from the 540 Zone.
4. It is assumed that the 880 PS draws suction supply from the 710 Zone. Prior to construction of the future 710 Reservoir, the 710 PS will be required to simultaneously provide PHD and fire flow for both the 710 and 880 Zones. The timing of 710 Reservoir construction is unknown, therefore 880 Zone pumping demands are shown under both operating conditions (with 710 Reservoir and without) for all years.

5.4.2 Upper Zone Supply

Pumping is required for service to the City's existing upper zones (above 368 Zone). Currently, the City relies on the Watercrest PS to supply the 540 and 435 Zones and GCSA, with backup supply from the David Hill PS. Additional demand will be placed on these pump stations as the City expands into the David Hill UGB and DHURA areas.

As shown in **Table 5-8**, there is no expected pumping capacity deficit to upper zones within 20 years. However, there is currently no provision for back-up power at the David Hill Pump Stations making it vulnerable to a power outage. The City has indicated the Watercrest pump station is backed up by the emergency generator at the City WTP. It is recommended that the City maintains back-up power for at least one of the pump stations, if not both, so the David Hill Reservoir can continue to be filled during a power outage. This will be particularly important as development accelerates in the David Hill area. Increased water demand from future development here will be reliant on these pump stations and the David Hill Reservoir for water service.

The Watercrest Pump Station operates with a single pump. It is recommended that the City evaluate upgrading equipment at this pump station to include a redundant pump. David Hill Pump Station may be considered the redundant pump for Watercrest. In this case, the David Hill Pump Station should be exercised regularly to confirm it will be ready to operate in case of a mechanical issue at the Watercrest Pump Station.

5.4.3 Future 710 and 880 Zone Supply

To provide adequate service pressure to customers, the David Hill UGB area will require a maximum HGL of 710 feet, while the DHURA will require a maximum HGL of 880 feet. The City is currently in the preliminary planning phase for development of the UGB area. The DHURA is not expected to develop within the next 20 years. There are several water service options to meet this uncertain development timeframe.

The proposed 710 service area within the UGB is limited in size and thus a small constant pressure pump station, located near the existing David Hill Reservoir, can effectively serve areas between approximately 480 feet and 600 feet at an HGL of 710 feet. An upper-level reservoir could later be constructed at this 710-foot HGL to provide gravity supply to the 710 Zone and the constant pressure pump station could transition to pump to storage. The highest elevations in the DHURA could then be served by a new constant pressure pump station at an approximate HGL of 880 feet. This new pump station would pull suction supply from either the 710 Reservoir, or the existing David Hill Reservoir, depending on the location of future development and the proposed 710 Reservoir.

Prior to construction of the 710 Reservoir, the 710 PS would need to provide increased capacity to supply peak hour and fire flow demands without the benefit of gravity storage. Once the 710 Reservoir is constructed, pumping capacity requirements will decrease as the reservoir will provide fire flow capacity. Both pump station operational conditions (pre- and post-710 Reservoir) are

provided in **Table 5-8**. As the timing of 710 Reservoir construction is unknown, both operational conditions are shown for the 710 PS for the entire planning period. Required pumping capacity shown in **Table 5-8** is based on projected demands for both the 710 and 880 pressure zones over the 20-year planning horizon consistent with demand projections in **Section 2**. The 50-year planning horizon is also shown for reference. Ultimate design capacity for a proposed 710 PS will be determined by the actual service area selected and refined demand projections developed during the pre-design process. It is recommended the proposed constant pressure pump station be designed with on-site back-up power with automatic transfer switches.

5.4.4 Future Service Elevations between Zones

As described in **Section 1.4** and **5.2.2**, proposed future pressure zone HGLs were established based on existing ground elevations taken from topographic mapping and service pressure criteria documented in **Section 3**. Pressure zone boundaries and HGLs are chosen to serve the widest range of customer elevations with the City's future service area with the minimum number of new zones. This approach maximizes distribution system looping for capacity and water quality and minimizes the need for new facilities such as reservoir and pump stations. This can also leave a narrow band of elevation in undeveloped areas where future customers may fall between two zones, receiving higher than normal pressure from the higher HGL zone and lower than normal pressure from the lower HGL zone.

Existing ground elevations in the David Hill UGB and DHURA include a narrow band between 440 and 480 feet which falls between zones. Customers up to 440 feet are served by the David Hill Reservoir and existing 540 Zone. Customer above 480 feet are served from the proposed 710 Zone to be supplied by a proposed constant pressure pump station in the short term and a future 710 Reservoir in the long term. Service to future customers between the 540 and 710 zones should be evaluated at the time a site plan is proposed for the development. Actual water service elevations will be dependent on site grading and structure placement on each developed property. If service elevations remain in the 440 to 480-foot range between zones, the following service options should be considered to supply these customers with an HGL of approximately 600 feet.

- **PRVs** – water supplied from the proposed 710 Zone routed through pressure reducing valves on individual services as needed or a single PRV on a distribution main serving multiple customers in this range
- **Optimize 710 Pump Station** – a constant pressure pump station proposed to supply an approximate 710 HGL to future 710 Zone customers adjacent to this elevation range could be optimized using variable frequency drives (VFDs) to serve a broader range of elevations or a narrow set of elevations most likely to develop prior to 710 Reservoir construction. VFDs are already required for constant pressure pumping so this approach does not add mechanical cost to the proposed pump station

5.5 Distribution Capacity and Hydraulic Performance

5.5.1 Hydraulic Model

A steady-state hydraulic network analysis model was used to evaluate the performance of the City's existing distribution system and evaluate proposed piping improvements based on hydraulic performance criteria described in **Section 3**. The purpose of the model is to determine pressure and flow relationships throughout the distribution system for average and peak day water demands under existing and projected future conditions. Modeled pipes are shown as "links" between "nodes" which represent pipeline junctions or pipe size changes. Diameter, length, and head loss coefficients are specified for each pipe and an approximate ground elevation is specified for each node.

The hydraulic model was developed for this WSMP using the InfoWater modeling software platform with GIS water system mapping and operations data provided by the City. Model software selection is documented in **Appendix F**. The model was calibrated using data from fire hydrant flow tests conducted specifically for model calibration. Model analysis scenarios were created to evaluate existing and projected 20-year demands. A complete description of calibration and results is available in **Appendix G**.

5.5.2 Modeled Water Demands

5.5.2.1 Existing Service Area

Existing water demands are assigned to the model geographically based on customer billing address and billed water consumption. Future residential/multifamily demand in the existing water service area is assigned by scaling up the existing demand distribution. Future demand in the existing system due to development of non-residential areas identified in the EOA were assigned to adjacent junctions. Future demand in new developments are uniformly distributed across new junctions, based on the areas projected demand.

5.5.3 Model Calibration

Model calibration typically involves adjusting the model parameters such that pressure and flow results from the model more closely reflect field pressures throughout the City's distribution system. This calibration process tests the accuracy of model pipeline friction factors, demand distribution, valve status, network configuration, and facility parameters such as reservoir elevations and pump curves. The required level of model accuracy can vary according to the intended use of the model, the type and size of water system, the available data, and the way the system is controlled and operated.

To calibrate the model, pressure and flow measurements are recorded at chosen fire hydrants throughout the distribution system during flow testing. Fire flow testing "stresses" the system by flowing a hydrant and monitoring system pressure drops due to that flow. Boundary condition

data, such as reservoir levels and pump on/off status, must also be known to accurately model the system conditions during the time of the flow test. Flow testing was performed in November of 2018, and February of 2019.

5.5.3.1 10th Avenue Control Station Assumptions

Supply from the JWC is currently only available through the 10th Avenue Control Station. The station control valves were replaced in July 2020 with dual purpose flow and pressure control valves, typically operated under pressure control. Prior to 2020, the station had flow control valves with mechanical pressure modes. For analysis purposes, the valves are modeled as pressure reducing valves at 80 PSI when supplying the system, or 40 PSI when operating as emergency supply only. Although this is not how the Control Station was operated or modeled during calibration, this assumption does not significantly impact calibration results and is representative of current operations.

For any water system, a portion of the data describing the distribution system will be missing or inaccurate, or the system operation will change with future development, and assumptions will be required. This does not necessarily mean the accuracy of the hydraulic model will be compromised, as is the case for the 10th Avenue Control Station. Models that do not meet the highest degree of calibration can still be useful for planning purposes.

5.5.3.2 Steady State Calibration Results

The model calibration's confidence level was evaluated based on the difference between modeled and field-measured pressure drops during fire hydrant flow testing, measured in psi, as summarized in **Table 5-9**. Overall system calibration confidence is considered medium to high.

Table 5-9 | Calibration Results Averaged by Zone

Zone	Static Pressure Percent Error	Residual Fire Flow Pressure Difference (PSI)	Confidence Level
368 - Average	5%	-5	Medium/High
368 - JWC Supply	5%	-4	Medium/High
368 - WTP Supply	5%	-6	Medium/High
435	5%	-5	Medium/High
540	<1%	-5	High
Gales Creek ¹	N/A	N/A	N/A
435 – Valley Crest Way PRV ²	N/A	N/A	N/A

Note:

1. No flow tests recorded in the GCSA.
2. Small subzone supplying <20 homes. No flow tests conducted here.
3. Complete results available in the Calibration Memo, included in **Appendix G**.

5.5.4 Fire Flow Analysis

Fire flow scenarios test the distribution system's ability to provide required fire flows at a given location while simultaneously supplying MDD and maintaining a minimum residual service pressure of 20 psi at all services. Required fire flows are assigned based on the zoning surrounding each hydrant as summarized in **Section 3**. Deficiencies within 10% of the required flow are assumed within the error range of the model. Gales Creek was not evaluated.

The system was analyzed under existing MDD and projected 20-year (2041) MDD conditions. Only areas within the UGB were assumed to be developed and have water demand within 20 years, consistent with future demand projections described in **Section 2**.

5.5.4.1 Operating Conditions

5.5.4.1.1 Heather Street Control Station (NTL Emergency Fire Flow Connection)

The City is currently designing an emergency intertie station, the Heather Street Control Station, with the 72-inch JWC NTL which passes through the western boundary of the City water service area. This control station will have combination pressure and flow control valves like those at the 10th Avenue Control Station. As described in **Section 4**, the City does not own capacity in the 72-inch JWC NTL and will be leasing capacity from other JWC partners on an emergency basis. For this analysis, it is assumed that this connection is available under future emergency conditions and is operated based on pressure. The pressure is set low enough (40 PSI) so that the valve does not open under non-emergency conditions.

5.5.4.1.2 10th Avenue Control Station

For this analysis, it is assumed that this connection will be operating on pressure control and therefore will be available to supply fire flow, even if the primary system supply is the WTP. The station control valves will open under low pressure (similar 40 PSI setting as Heather St Control) even if the system is being supplied primarily by the City's WTP during the event.

5.5.4.1.3 System Storage

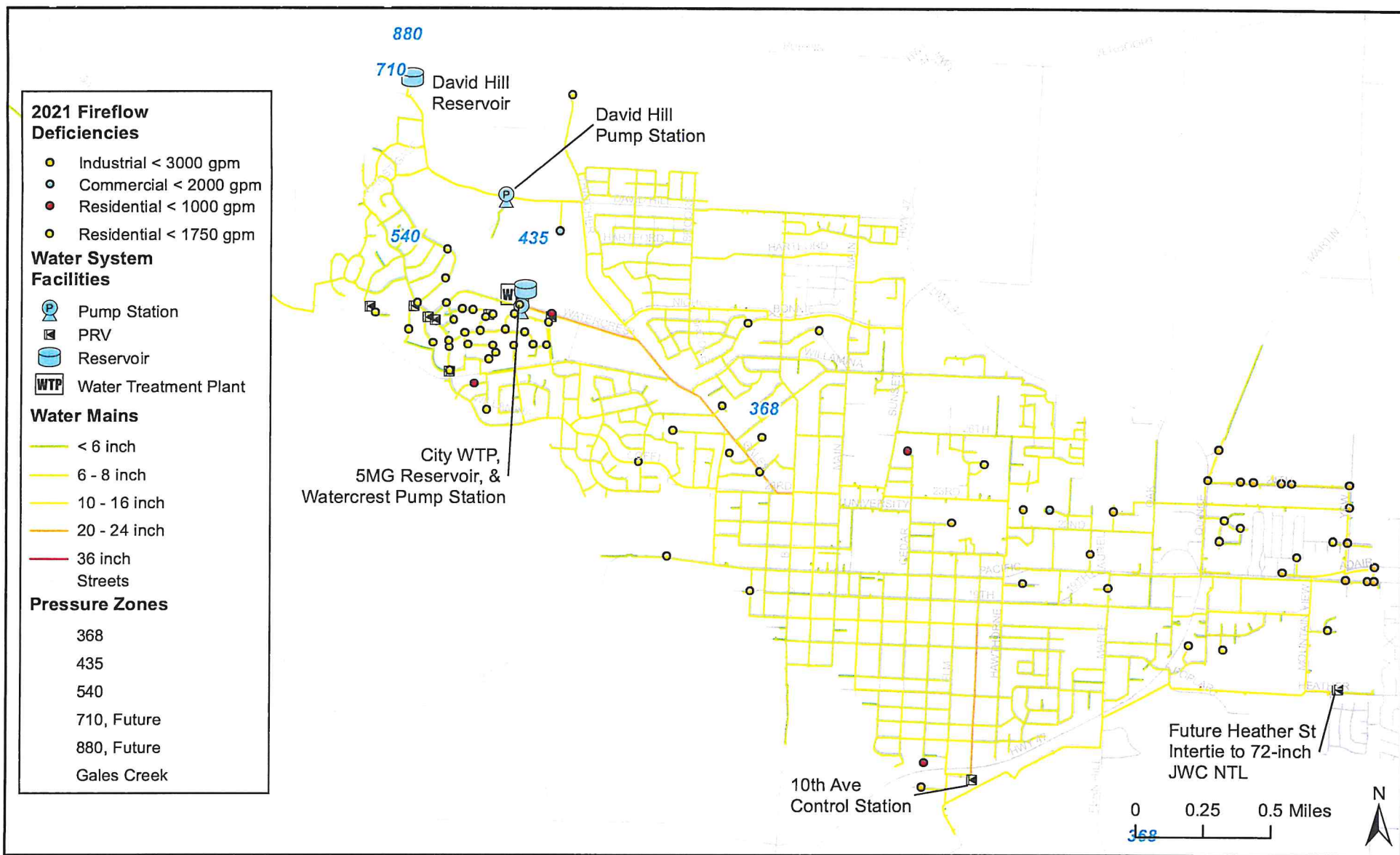
The David Hill and 5 MG Reservoirs are assumed to be operating at 50% full. This is a slightly more conservative estimate of all operational and fire storage depleted and only emergency storage capacity available. Emergency storage is assumed to be 1xMDD. It is assumed the 5 MG Reservoir is replaced with two, 5 MG Reservoirs. JWC storage is included in the 368 Zone requirements. Pumping from the twin 5 MG Reservoirs will be available to meet future 540 Zone emergency storage. However, in a more conservative estimate, it was assumed no pumping available.

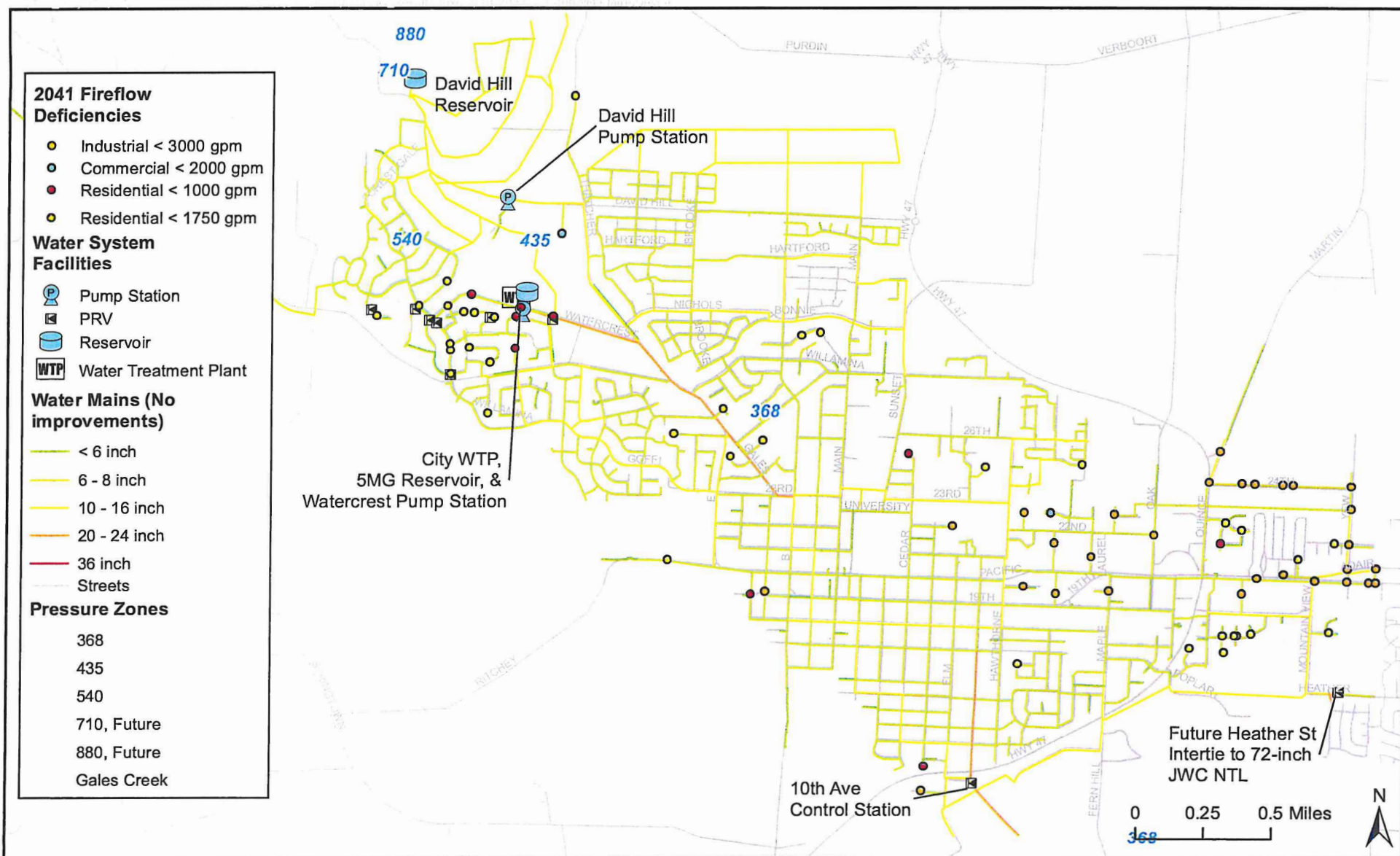
5.5.4.2 Fire Flow Analysis Results

The City's distribution system is generally well looped with multiple PRVs or supplies serving each pressure zone. Adequate fire flow is generally available under 2021 MDD conditions throughout

the existing distribution system with slightly less flow available at the boundary between pressure zones for fireflow demands less than 3,000 gpm. For industrial fire flows (3,000 gpm), especially in the northeast corner of the system, fireflow is limited, primarily due to pipe size restrictions. **Figure 5-6** illustrates fire flow deficiencies under 2021 MDD.

These deficiencies are exacerbated under 2041 MDD conditions. Transmission upsizing between the JWC control valves and the City WTP improve most deficiencies and isolated piping upsizing or system looping address most of the remaining deficiencies. Additional improvements are listed in **Section 7**. **Figure 5-7** illustrates fire flow deficiencies under 2041 without system improvements. Additional fire flow availability maps are included in **Appendix J, System Wide Fire Flow Availability**.





5.5.5 JWC Supply Transmission to 5 MG Reservoir

5.5.5.1 Model Results

As previously discussed, the City relies on the existing 10th Avenue Control Station to provide adequate supply from the JWC to meet peak summer season demands and maintain the water level in the 5 MG Reservoir. Finished water stored in the 5 MG Reservoir should also provide operational storage to set the HGL and maintain system pressures in the 368 Zone during fluctuations in demand throughout the day. JWC flow through 10th Avenue is transmitted to the City's 5 MG Reservoir through the distribution system. Hydraulic modeling of JWC supply during peak demands indicates:

- **368 Zone HGL** - The 10th Avenue Control Station pressure control valves are maintaining zone pressure during peak demand, rather than the 5 MG Reservoir.
- **368 Zone Service Pressure** – To refill the 5 MG reservoir during high demand, the pressure at the control valves also needs to increase. These higher flow rates create excessive distribution system pressures over 100 psi for the lowest elevation customers in the 368 Zone which are also closest to the Control Station.

These model findings are consistent with water utility staff observations of system pressures and reservoir filling from the JWC supply through 10th Avenue Control Station.

5.5.5.2 System Concerns

Model results described in the prior section suggest a few vulnerabilities in the City's existing JWC supply and distribution system.

1. **Undersized distribution mains** - Portions of the distribution system between the 10th Avenue Control Station and 5 MG Reservoir are undersized, limiting available flow. This may inhibit the City's ability to refill the reservoir quickly from JWC supply.
2. **5 MG Reservoir draw down** - The existing 5 MG Reservoir has a narrow hydraulic operating range (draw down) meaning the existing reservoir water level cannot be lowered very much without having inadequate pressure at the highest elevations of the 368 Zone closest to the City WTP. It is anticipated that this issue will become more pronounced as demands grow and the existing reservoir volume does not meet required storage capacity as shown in Table 5-6.
3. **Low elevation and high pressure near JWC supply point** - 368 Zone customers near the 10th Avenue Control Station are at the lowest elevations in the City system. Thus, service pressures are already on the high end of the normal range. This means that with existing infrastructure, even small increases in pressure due to higher JWC flows, as noted above in System Concern 1, will more easily exceed the normal service pressure range which could lead to customer plumbing fixture damage from overpressure.

5.5.5.3 Mitigation Strategies

To mitigate system concerns presented in the prior section, the City could implement one of the following strategies. Strategy 2, replace the 5 MG Reservoir at the same overflow elevation and upsize transmission, is the preferred strategy as it limits system changes and improves distribution transmission as well.

- **Strategy 1** - Replace the 5 MG Reservoir at the same overflow elevation and move the 368 Zone upper service elevation boundary down to a lower elevation. This would add customer demand to upper zones and allow a reduced HGL in the 368 Zone and more draw down in the new reservoir at the WTP site. This strategy would require more capacity in pumping and storage for upper zones.
- **Strategy 2** – Replace the 5 MG Reservoir at the same overflow elevation and upsize transmission from 10th Avenue Control Station to the 5 MG Reservoir. Upsizing transmission along this route to 20 inches allows for continued operations with a reservoir overflow of 368 feet. High pressures will remain a concern at low elevations in the 368 Zone during high supply but can be mitigated with controlled reservoir operations and slower reservoir filling rates. For some of the lowest elevation customers, individual PRVs are recommended, if they do not already exist.

5.5.5.4 Heather Street Control Station Flows

As discussed in **Section 4**, the City is currently designing an emergency intertie with the 72-inch JWC NTL called the Heather Street Control Station near Heather Street and Mountain View Drive at the east end of the City system. Hydraulic challenges at the Heather Street JWC supply connection are similar to those system concerns described in **Section 5.5.5.2**. The area around Heather Street has some of the lowest elevations in the system which receive service pressure on the high end of the normal range. Modeling indicates that higher flow rates, over approximately 2,250 gpm, through the proposed intertie will drive pressures over 100 psi locally. Several operating scenarios were modeled for the proposed Heather Street Control Station under existing MDD. Modeling scenarios included upsized distribution mains to the 5 MG Reservoir, testing fixed control station flow rates, and testing pressure constraints. The results are summarized in **Table 5-10**.

Upsizing existing distribution mains from the Heather Street Control Station to provide a continuous 20-inch diameter transmission route to the 5 MG Reservoir linked into the existing system appears to provide the best benefit by both minimizing pressure increases and maximizing flows. However, at very high flows, building a separate 24-inch transmission may mitigate some distribution system overpressurization for customers near the Heather Street Intertie, when compared with a 20-inch connected alternative.

Table 5-10 | Heather Street Control Station Flow Analysis

Distribution Piping Improvements	Limit flow velocity to 14 fps or 7,000 gpm		Available Flow at Heather Street (gpm)	
	Available Flow at Heather Street (gpm)	Pressure at Heather Street (psi)	Pressure limited to 100 psi	Pressure limited to 85 psi
No changes, existing distribution	3,500	120	2,250	500
24-inch dedicated transmission to 5 MG Reservoir	7,000	100	7,000	50
Continuous 20-inch, replace all existing transmission <20-inch diameter to 5 MG Res	7,000	117	5,000	1,000

5.6 Distribution System Water Quality

The City meets all current drinking water quality regulations. The following summary includes microbial contaminants (Total Coliform Rule), lead and copper (Lead and Copper Rule) and disinfection by-products (Stage 2 Disinfectants and Disinfection Byproducts Rule) which may be exacerbated or originate in the distribution system.

5.6.1 Total Coliform Rule Compliance

The City is currently meeting all applicable requirements for the Total Coliform Rule. It is important to maintain active circulation of water throughout the distribution system, in both pipes and reservoirs to retain a chlorine residual. The absence of chlorine residual and accumulation of sediments contribute to bacterial growth, which in turn can result in failure to comply with this rule. As of December 1, 2020, the City tests 30 routine coliform samples per month.

5.6.2 Lead and Copper Rule Compliance

Under the Lead and Copper Rule drinking water providers are required to test for lead in the distribution system and manage the hydrogen potential (pH) of water supplies to reduce corrosion of pipes and fixtures which can release lead into drinking water. Forest Grove is in compliance with the Lead and Copper Rule. The JWC WTP uses caustic soda to raise the pH of treated water supplied to City customers and reduce corrosion. The City tests for lead at 30 customer taps on a 3-year cycle. In 2020 testing of 30 test sites, 17 showed no lead detected and all were less than 0.0072 milligrams per liter (mg/L), well below the regulated action level of 0.015 mg/L. Copper testing showed similarly low levels in all 30 tests. There are no concerns with future compliance with the Lead and Copper Rule.

5.6.3 Stage 2 Disinfectants and Disinfection Byproducts Rule (D/DBPR) Compliance

Disinfection byproducts (DBP) form when disinfectants, like chlorine used to kill harmful bacteria and reduce water borne illness, react with naturally occurring compounds in the source water. All commonly used disinfectants form DBPs. Research has linked high concentrations of DBPs to increased risk of cancer. DBPs are regulated to a maximum contaminant level (MCL) which is considered safe. Currently, the City conducts quarterly sampling for DBPs at two sample sites, both of which are currently in compliance. City testing consistently shows trihalomethanes (THM) levels at less than one third to one quarter of the MCL and haloacetic acids (HAA5) levels less averaging less than two thirds of the MCL.

Section 6

Section 6

Seismic Resiliency Plan Summary

6.1 Introduction

This section presents a summary of the September 2020 Forest Grove Water System Seismic Resiliency Plan (SRP, InfraTerra 2020) included in **Appendix H**. The SRP fulfills the seismic requirements for Water Master Plans in OAR 333-061-0060(5) (J) and recommends mitigation measures that can be implemented over the next 50 years to improve seismic resilience of the water system. The findings and recommendations listed in this section are summarized from InfraTerra's SRP and not from work performed by Murraysmith.

Findings and recommendations from the SRP are also referenced in **Section 4** and **Section 5** of this WSMP. **Section 7** includes seismic mitigation projects recommended in the SRP.

6.2 Performance Objectives

Seismic performance objectives developed for the City water system are guided by the ORP which was developed by the Oregon Seismic Safety Policy Advisory Commission (OSSPAC) under the 2011 House Resolution 3 by the Oregon House of Representatives. The ORP sets policy direction for owners of infrastructure to protect lives and maintain economic and commercial activity following a Moment Magnitude 9.0 (M9) earthquake on the Cascadia Subduction Zone (CSZ).

Recognizing the high cost of infrastructure improvements, the ORP recommends a phased approach for improving seismic resilience. The approach includes identification and hardening of key supply, transmission, and distribution facilities (backbone) so that water is available for critical needs such as fire suppression, health and emergency response, and drinking water at key distribution points immediately after the earthquake while damage to the rest of the water system is repaired. The identified backbone for the City water system includes:

- RWTM – supply to City WTP
- City WTP
- 5 MG Reservoir at City WTP
- 24-inch JWC TL
- David Hill Reservoir
- Key water distribution mains to provide city-wide coverage

The SRP analysis estimates that in its present state, the City's backbone would be operable within 2 weeks to 3 months and the distribution system operable within 3 to 6 months following a CSZ M9 event. See **Table 6-1** excerpted from the SRP Figure 29 Existing Estimated Recovery Time.

Table 6-1 | ORP Repair and Recovery Estimates

CSZ M _w 9.0 Event Occurs		Timeline						
ORP Category	CFG Assets	0 - 24 hours	1 - 3 days	3 - 7 days	1 - 2 weeks	2 weeks - 1 month	1 - 3 months	3 - 6 months
Potable water available at supply source (WTP, wells, impoundment)	1. RWTM from Stringtown Bridge to WTP 2. WTP facilities supporting treatment function 3. 24-inch JWC TL	20 - 30% operational	50 - 60% operational		80 - 90% operational	CFG 90% Recovery Time Est. Range		
Main transmission facilities, pipes, pump stations, and reservoirs (backbone) operational	1. First-tier backbone distribution pipelines 2. 5MG reservoir at WTP	80 - 90% operational				CFG 90% Recovery Time Est. Range		
Water supply to critical facilities available	1. All backbone pipelines 2. David Hill Reservoir	50 - 60% operational	80 - 90% operational			CFG 90% Recovery Time Est. Range		
Water for fire suppression--at key supply points	1. FGFR fire department capability to utilize alternative water sources to suppress fires 2. David Hill Reservoir continued operation 3. 5MG WTP Reservoir continued operation	80 - 90% operational					CFG 90% Recovery Time Est. Range	
Water for fire suppression--at fire hydrants	1. All pipelines required to supply hydrants (most of distribution system)			20 - 30% operational	50 - 60% operational	80 - 90% operational	CFG 90% Recovery Time Est. Range	
Water available at community distribution centers/points	1. Backbone distribution pipelines		50 - 60% operational	80 - 90% operational	CFG 90% Recovery Time Est. Range			
Distribution system operational	1. All transmission and distribution pipelines 2. All pump stations		20 - 30% operational	50 - 60% operational	80 - 90% operational		CFG 90% Recovery Time Est. Range	

6.3 Seismic Hazard Mapping

The most significant seismic hazard to the City is from a major CSZ earthquake. The geologic record shows an average recurrence interval of 500 to 530 years for an M8 or greater earthquake, and an average recurrence interval of about 240 years for smaller (M7 to M8) earthquakes in the CSZ. Recent research predicts a 16 to 22 percent probability of an M8.5 earthquake occurring on the CSZ within the next 50 years (Goldfinger et al., 2016).

In addition to the CSZ, the City may also be impacted from an earthquake on the local Gales Creek fault located approximately 2 miles to the west. The fault runs in a northwesterly direction, parallel to Gales Creek. According to the United States Geological Survey (USGS), the fault can produce an M6.8 earthquake and assign it a recurrence interval of 64,000 years. Research into the frequency of past fault ruptures and the activity of the Gales Creek fault was still underway at the time of the writing of this report. Once a better understanding of the seismic activity of the Gales Creek fault is obtained, its impact on the City's water system should be assessed.

The SRP includes earthquake hazard maps for the City's service area which show peak ground acceleration (PGA), peak ground velocity (PGV), liquefaction susceptibility, permanent ground deformation (PGD) for liquefaction-induced lateral spread, PGD for liquefaction induced settlement, and PGD for seismically-triggered landslides. Maps were developed using both publicly available and project specific data.

6.3.1 Ground Shaking Hazard

Ground shaking potential was estimated from information provided in the ORP and published by the Oregon Department of Geology and Mineral Industries (DOGAMI). Key measures of ground shaking are PGA and PGV. Due to its proximity to the City, PGA estimates for an M6.8 earthquake on the Gales Creek fault are higher but less likely than PGA from a more distant but stronger M9 CSZ event.

6.3.2 Liquefaction Hazard

Liquefaction occurs in loosely deposited saturated granular soils. Such soils, when subjected to earthquake ground shaking that is strong enough or repeated long enough, lose their ability to support structures due to the loss of soil structure and frictional resistance within the soil. Liquefied soil acts like a fluid and can flow resulting in lateral spread deformations and differential settlement. According to the SRP, "PGD from liquefaction is the primary cause of damage to water systems in large earthquakes" (SRP, page 25).

Observations from geologic site reconnaissance and publicly available data including geotechnical borings and reports from prior Oregon Department of Transportation (ODOT), DOGAMI, Oregon Water Resources Investigations, and geotechnical reports provided by the City were used to develop liquefaction susceptibility and PGD maps. Maps provided in the SRP show that the liquefaction hazard within the City is very little to moderate (See SRP Plates 9 and 10) and only

areas along Gales Creek and other streams are susceptible to lateral spread hazard (See SRP Plates 11 and 12).

PGD resulting from liquefaction can be either lateral spreading or settlement. Lateral spreading generally occurs on slopes or riverbanks and ranges between a few inches and several feet. Settlement occurs due to several mechanisms and is more typically on the order of a few inches. According to the SRP, “except for locations along the RWTM and the JWC pipelines, lateral spread hazard in the City is low. The liquefaction-induced settlement estimates are also relatively small (generally less than 3 inches)” (SRP, page 28).

6.3.3 Earthquake-Triggered Landslides

Earthquake-triggered landslides are likely to occur on slopes, particularly in areas of prior landslides. According to the SRP, “the overall risk to the City’s infrastructure from seismically-induced landslides is low, except in the Clear Creek watershed area and near the Raw Water Pump Station off Gales Creek Road” (SRP, page 29).

6.4 Seismic Vulnerability Assessment

The SRP included assessment of the seismic vulnerability of the City’s water system assets including pipelines, reservoirs, WTP facilities, pump stations, and the public works facility.

6.4.1 Pipelines

Transmission and distribution pipelines required to meet the most critical post-earthquake needs were identified as backbone with the remainder designated as distribution. The backbone system was further prioritized into first tier (high priority lines to key facilities and potential emergency distribution sites) or second tier (connection to the David Hill Reservoir, for instance). Conservative estimates of pipe repairs in an M9 CSZ event were based on seismic hazard mapping and pipeline construction such as pipe material and joint type. Estimated pipeline repairs are shown in **Table 6-2**. According to the SRP, most repairs are located in liquefaction areas and are clustered in older, cast iron pipes.

Table 6-2 | Summary of Best Estimate All Pipeline Repairs

Table 12: Summary of Best Estimate All Pipeline Repairs (M9 CSZ Earthquake)							
Repair Estimates	Backbone System						Non-Backbone Distribution System
	Transmission			Distribution			
	First-Tier	Second-Tier	24-inch JWC TL	First - Tier	Second-Tier	Future	
Median Estimate	2	11	10	29	6	2	213
Upper Estimate ¹	6	32	28	84	17	7	616
Lower Estimate ²	1	4	3	1	2	1	74
1 - Upper estimate represents median + 1 lognormal standard deviation							
2 - Lower estimate represents median - 1 lognormal standard deviation							

6.4.2 Reservoirs

Reservoir seismic assessments considered ground shaking, liquefaction-induced lateral spreading and ground settlement, and slope stability. The assessments were based on available existing data. No new geotechnical investigations were performed for this assessment.

The 5 MG WTP Reservoir is “underlain by stiff clean to sandy clays that are not susceptible to liquefaction” (SRP page 40). However, the SRP indicates that the fill slope between the WTP and the reservoir could deform about 2 inches in an M9 CSZ event. A structural assessment of the reservoir identified seismic deficiencies in the roof support columns, central wall, and perimeter walls. The SRP recommends the reservoir be seismically upgraded or replaced.

The David Hill Reservoir is “underlain by stiff silt over siltstone, and is not susceptible to liquefaction” (SRP page 41). Photographs and DOGAMI mapping show recent history of local landslides, particularly in “man-made cuts and over-steepened slopes constructed as part of the road bench above the reservoir” (SRP page 41). The SRP indicates the slope may be unstable, particularly during wet conditions, and could damage piping that cross the deformation zone. A structural assessment of the reservoir shows that the “bending moment capacity of the perimeter walls is exceeded for seismic loading” (SRP page 42). The SRP recommends a more detailed seismic analysis of the David Hill Reservoir, and if analysis indicates vulnerabilities, then the reservoir should be seismically upgraded.

6.4.3 Other Facilities

6.4.3.1 Water Treatment Plant

The SRP findings indicate the WTP site is not susceptible to liquefaction and adjacent slopes are unlikely to be impacted by significant landslide activity in an M9 CSZ event. The WTP buildings were evaluated using ASCE 41-17 standard. The SRP indicates all WTP structures essential for plant operation meet the Immediate Occupancy performance criteria.

6.4.3.2 Pump Stations

The SRP findings show that the pump station sites (David Hill, Watercrest, and Raw Water) do not have a liquefaction or landslides hazard. Minor seismic vulnerabilities were indicated at the David Hill Pump Station including potential cracking near the door in the east wall, but the building meets Immediate Occupancy performance level of ASCE 41-17. No significant seismic vulnerabilities were identified for the Watercrest or Raw Water Pump Stations.

This means that while minor structural and non-structural repairs might be appropriate, these repairs would generally not be required before reoccupancy, and the WTP facilities will be available for continued plant operation.

6.4.3.3 Public Works Facility

The SRP findings indicate the Public Works Facility may be susceptible to liquefaction, with liquefaction-induced PGD of approximately 2 inches. Structures at the site were evaluated independently to assess their seismic vulnerability. According to the SRP, the covered storage structure “could be at risk of significant lateral deformations and structure damage, leading to potential collapse” (SRP page 48). Additionally, the SRP recommends more detailed structural assessment to evaluate the office building and machine shop and the equipment building for the ASCE 41-17 Immediate Occupancy performance level. SRP finds that the supply storage building is expected to meet Immediate Occupancy performance level.

6.4.3.4 10th Avenue Control Station

The SRP findings indicate that the 10th Avenue Control Station site may be susceptible to liquefaction. It is also indicated that while collapse and life safety risk may not be concerns at the structure, a “detailed evaluation of the liquefaction hazard and structural response [should] be performed to meet ASCE41-17 Immediate Occupancy performance level” and that “flexibility be provided to the rigid pipe to wall and pipe to slab penetrations” (SRP page 49).

6.4.3.5 RWTM and Stringtown Bridge

The 16-inch RWTM is suspended by steel rods from the Stringtown Bridge where it crosses Gales Creek. According to the SRP, the bridge piers are likely founded on rock below alluvial soils that are susceptible to liquefaction. The SRP states that “up to 3 feet of liquefaction-induced lateral spreading may occur in an M9 CSZ earthquake” (SRP page 49). The SRP recognizes that while potential cracking of the reinforced concrete may not directly affect the pipelines, liquefaction-induced lateral spread is a seismic risk to the bridge. The Stringtown Bridge was assigned to Group 2B during a 1995 seismic vulnerability study by Washington County. This Group 2B designation means the bridge has three substructure deficiencies. The SRP recommends that the City consider “securing its pipeline either through retrofit of the bridge or separating the pipeline from the bridge and designing the pipeline to withstand liquefaction and ground shaking” (SRP page 49).

6.5 Post-Earthquake Repair

After a seismic event, the City will need to quickly assess the system condition and initiate repairs. If the water system needs repairs, it is likely other critical infrastructure is also damaged. This could mean communication channels are blocked, roadways are damaged so staff and equipment cannot access the system, or City supervisory control and data acquisition (SCADA) infrastructure is damaged and cannot be relied on. The City should develop and practice a post-seismic plan to help facilitate communication, operations, and repairs.

Community partners may be able to assist in an emergency. Oregon Water/Wastewater Agency Response Network (ORWARN) is a network of water and sewer agencies that provide voluntary assistance to each other during an emergency. It is anticipated that after a CSZ event other local

providers will likely also be dealing with an immediate emergency and thus unable to assist. The SRP recommends looking into the interstate Emergency Management Assistance Compact (EMAC) at the state level for more widespread assistance.

Assuming the City has adequate staff and access to begin repairs, the SRP estimates that repairs can take anywhere from a few hours for pipes less than 12 inches in diameter, to more than a day for larger pipes. When applying this repair time to over 20 median estimated repairs in the backbone and significantly larger number of repairs in the distribution system the timeline to return to normal operations quickly balloons to days or weeks. To help facilitate this, the SRP recommends the City establish a post-earthquake pipeline repair protocol (SRP, page 52).

The suggested repair protocol may include steps for pipe material acquisition and additional resources. The City owns an array of repair equipment including “one backhoe, one excavator, two hydro-excavators, and one water service pickup truck to support the hydro-excavator” (SRP, page 50). The SRP found that “at present, the City does not have sufficient stockpile to repair all of the estimated pipeline damage” (SRP, page 50). Stockpiling all possibly needed materials is impractical due to “space restrictions and damage/deformation that can occur over time” (SRP, page 51). These challenges should be weighed with the likely challenges in supply chain following a seismic event due to high demand, disruptions in transportation or production, and time.

6.6 Mitigation Options and Recommendations

According to the SRP, the overall seismic risk is moderate, yet the risk of service interruption is high. If a CSZ earthquake were to strike today, the SRP estimates that it would take between three and six months to return to 90 percent of normal operations, assuming the damage to 5 MG Reservoir does not result in the uncontrolled release of stored water. If the damage to the 5 MG Reservoir is catastrophic, the repair time will increase significantly. The three to six month time frame is more than the ORP suggested timeframe of two weeks to one month to restore operations to 90 percent of all the ORP categories listed in **Table 6-1**.

Improving the seismic resilience of the entire system can be cost and time prohibitive, so the SRP focused on an approach to reduce costs and at the same time achieve as many of the critical ORP goals as possible. The SRP provides two packages of mitigation options, a lower cost Option 1 designed to achieve ORP goals for the first-tier backbone and critical water supply elements and a higher cost Option 2, which is an extension of Option 1 by including upgrades for most vulnerable elements of the second-tier backbone to provide additional redundancy. The SRP recognizes that neither option will fully satisfy all the ORP goals but these upgrades, coupled with careful emergency operations planning, will significantly improve the resiliency of the City’s water system.

The SRP presents a cost-effective solution to improve recovery by targeting the most vulnerable pipe materials and highest hazard areas. These recommendations will improve the likelihood that water is available for emergency use and firefighting immediately following the earthquake and reduce the time to restore the non-backbone water distribution system so water is available for daily use and economic activity.

This WSMP CIP includes recommendations from Option 1 and Option 2 of the SRP as planned improvements that can be performed using a two-phase approach. Phase 1 of the improvements are the same as SRP's Option 1 and focus on the first-tier backbone pipelines and infrastructure so that 80 to 90 percent of the first-tier backbone system is operable within 24 hours. Phase 2 includes the additional recommended improvements included in the SRP's Option 2 and addresses upgrades to the second-tier backbone system by replacing 15.5 miles of cast iron pipeline. Phase 2 improvements will meet all the ORP Goals to be 80 to 90 percent operational, except for goals related to the non-backbone water distribution system. To meet all the water system goals of the ORP, an additional 25.1 miles of existing ductile iron pipe would have to be replaced with seismically resistant pipe, which is likely cost prohibitive. The recommended phased approach will achieve many, but not all, of the ORP water system goals and when coupled with emergency operations planning will significantly improve the City's water system seismic resiliency.

6.6.1 Phase 1 Mitigation

The SRP recommends the City take the following steps to address Backbone vulnerabilities.

- Portable or permanent emergency pumping equipment to withdraw water from Gales Creek at Stringtown Bridge including backup power
- Geotechnical study to identify sections of the RWTM from Stringtown Road Bridge to the WTP
- Seismic upgrades of the RWTM between Stringtown Road Bridge and WTP based on the results of the Geotechnical Study. This could include approximately 1.2 miles of pipe susceptible to liquefaction and approximately 500 feet within Forest Glen Park to avoid a historic landslide area
- Backup power to existing Raw Water Pump Station
- Seismic upgrade/replace 5 MG Reservoir at City WTP site
- Assess and upgrade, if needed, anchorage of emergency generator electrical cabinets.
- Replace 4 miles cast iron pipes in the first-tier backbone with seismically resilient pipe.
- Detailed structural analysis of the Public Works Office Building to assess Life Safety performance criteria and to assess mechanical equipment and electrical panel anchorage
- Install isolation valves along backbone.

6.6.2 Phase 2 Mitigation

Once the Phase 1 mitigations are complete, Phase 2 includes the following improvements to further increase the resiliency of the water system.

- Replace 0.8 miles cast iron pipe within the second-tier backbone with seismically resilient pipe.
- Geotechnical study to identify sections of the RWTM from Clear Creek Watershed to the Stringtown Road Bridge
- Replace RWTM from Watershed to Stringtown Road Bridge, based on the findings of the Geotechnical study. This could include approximately 1.9 miles of pipeline from Clear Creek to the Gales Creek Cemetery and approximately 3.7 miles of pipeline between the Gales Creek Cemetery and the Stringtown Road Bridge.
- Detailed structural study of the existing Stringtown Road Bridge (County owned asset) and alternative analysis comparing the seismic improvement costs for the Stringtown Road Bridge and alternative methods evaluation for the RWTM to cross Gales Creek. Then modify the RWTM crossing of Gales Creek based on the findings of the alternatives analysis.
- Replace 1.3 miles of the 24-inch JWC TL with seismic resistant pipe including pipeline flexibility at 10th Avenue Control Station building penetrations. Perform geotechnical investigations to potentially reduce the replacement length.
- Detailed evaluation of liquefaction hazard and structural response of the 10th Avenue Control Station and perform as-needed improvements to meet ASCE 41-17's Immediate Occupancy performance objectives.
- Backup power added to the David Hill Pump Stations
- Seismic assessment at David Hill Reservoir
- Replace 15.5 miles cast iron pipe in the non-backbone distribution system.
- Isolation valves should be added throughout the system to help isolate leaks and pipeline failures post seismic event.

6.6.3 Additional Actions

The SRP also recommended the following additional action items to address system and operational deficiencies.

- Develop a long-term pipeline replacement program for non-cast iron pipelines that prioritize mains in terms of liquefaction severity, age, and corrosion.

- Stockpile repair resources for 10 workdays worth of repairs.
- Establish material procurement protocols and on-call contracts with suppliers.
- Develop repair protocols for rapid reimbursement from FEMA.
- Develop EMAC with State of Oregon for mutual aid from other states.
- Emergency response training and protocols
- Programs to evaluate and test emergency response equipment
- Develop and maintain utility maps with locations of pipeline repairs.

6.7 Summary

The SRP concluded that while seismic risk in the event of a CSZ M9 event in the City is moderate, the risk of service interruption is high. The RWTM supplying the City's WTP is at risk, particularly due to landslide along the river valley. City facilities will likely be affected to various degrees. Pipelines, particularly aging cast iron pipes, are at high risk of failure. To address these deficiencies, system improvements should be made, first addressing the first-tier backbone and then the rest of the system.

Section 7

Section 7

Capital Improvement Program

This section presents recommended improvements for the City's water system based on the analysis and findings presented in **Section 4**, **Section 5**, and **Section 6**, and projects identified in the City's current water CIP projects list. The CIP presented in **Table 7-1** summarizes recommended improvements and provides an approximate timeframe for each project. Proposed improvements are illustrated in **Figure 7-1**, and individual project sheets are included in **Appendix I**.

7.1 Project Cost Estimates

An estimated project cost has been developed for each recommended improvement consistent with previously identified projects from the City's current CIP and current preliminary design work, as applicable. Cost estimates represent opinions of cost only, acknowledging that final costs of individual projects will vary depending on actual labor and material costs, market conditions for construction, regulatory factors, final project scope, project schedule and other factors. The Association for the Advancement of Cost Engineering International (AACE) classifies cost estimates depending on project definition, end usage and other factors. The cost estimates presented here are considered Class 5 with an end use being a study or feasibility evaluation and an expected accuracy range of -50 percent to +100 percent. As the project is better defined, the accuracy level of the estimates can be narrowed.

Since construction costs change periodically, an indexing method to adjust present estimates in the future is useful. The Engineering News-Record (ENR) Construction Cost Index (CCI) is a commonly used index for this purpose. For purposes of future cost estimate updating; the current ENR CCI for Seattle, Washington is 13,165 (June 2021).

7.2 Timeframes

A summary of all improvement projects and estimated project costs is presented in **Table 7-1**. This CIP table provides for project sequencing by showing prioritized projects for the following timeframes.

- 0 to 5-year timeframe - recommended completion through 2027
- 6 to 10-year timeframe - recommended completion between 2027 and 2032
- 11 to 20-year timeframe - recommended completion between 2033 and 2042
- 20+ year timeframe – recommended completion after 2042

Table 7-2 provides a detailed yearly breakdown of the first five years of the CIP.

7.3 Supply

7.3.1 City Supply Projects

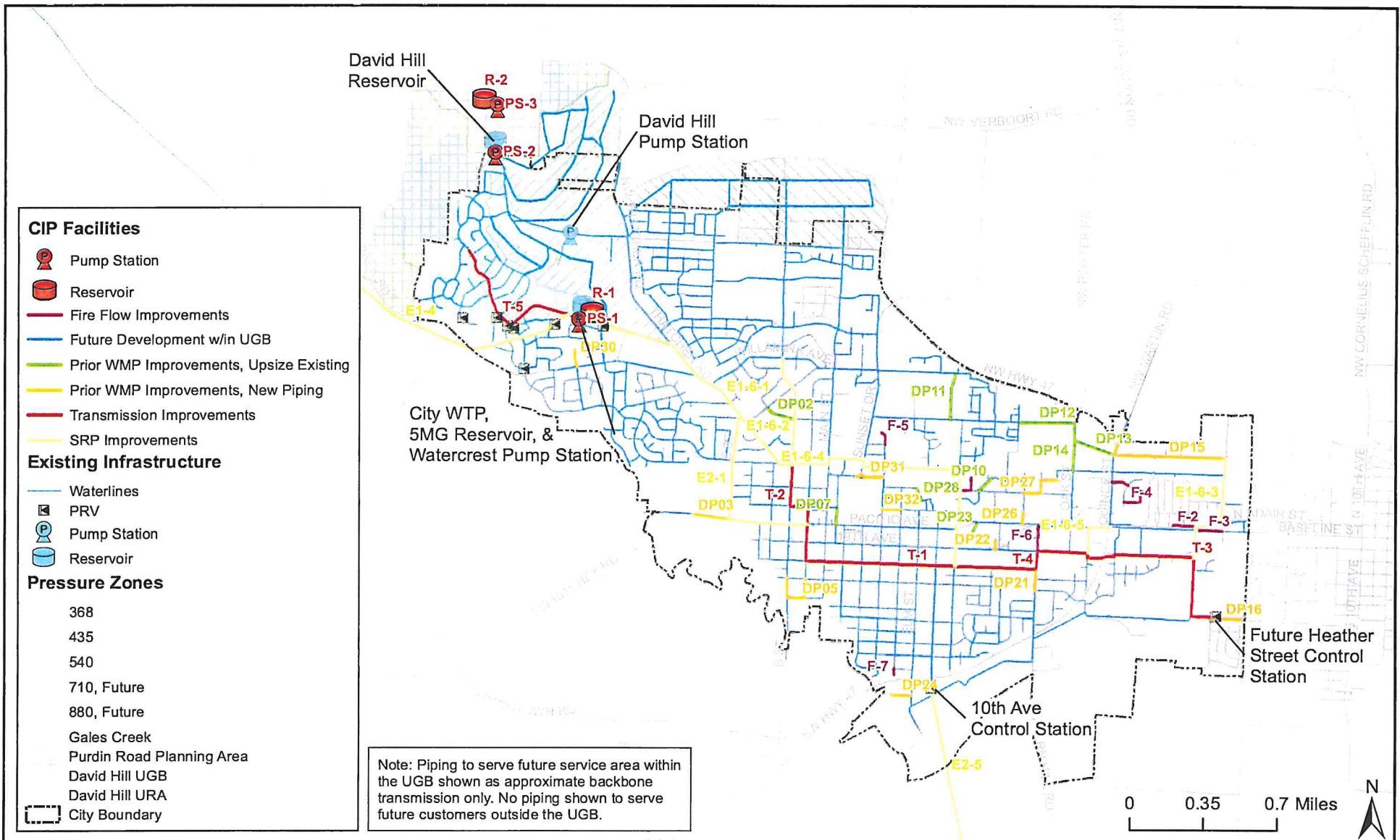
The City will need to consider additional supply within the near future. To address these concerns, several projects are included in the CIP.

- The City needs to complete a Water Supply Study to make an informed decision on the best long-term supply strategy and fill the remaining information gaps. As part of this analysis, the need for and timing of projects related to supply will be confirmed. The City should complete a facility assessment at the City WTP to understand upgrades, replacements, and limitations of future service. This will be valuable for performing cost/benefit analyses of supply alternatives that include the City WTP.
- No matter which alternative is selected, the City should develop reliable and resilient transmission for their full JWC treatment ownership. In the short term, this means pursuing leasing rights from the City of Hillsboro in the existing 24-inch JWC TL greater than the existing 6.1 MGD ownership. Long term, the City should replace the 24-inch JWC TL with seismically resilient transmission. This transmission line should be sized for future needs, including the potential for increased JWC treatment capacity. This project is included under Seismic Improvements Phase 2 (E2-5) but phased for the next 0-5 years.
- The City also will likely need to plan for implementing the Barney Reservoir capacity buyback from TVWD within 50 years, depending on future reservoir operations, drought conditions, and demands. The request process can take four years to complete.
- A streamflow gauging station is required on Gales Creek as a condition of T-11677 to transfer the POD from Gales Creek to Springhill Pump Station, if taking water from June 1 to September 30.

7.3.2 Joint Water Commission (JWC)

To maintain the City's primary supply from the JWC, on-going investment is needed. The JWC partners are currently planning on the following investments.

- Various JWC on-going shared-cost upgrade and replacement projects including seismic mitigation at the existing WTP, on-site electrical, building, and security capital maintenance, as well as asset management
- JWC WTP upgrades to be completed in 2023 to realize full capacity of the WTP



- Seismic retrofit to the existing Scoggins Dam, which provides raw water storage in Hagg Lake from Scoggins Creek to supply the JWC WTP during low summer flows in the Tualatin River. The United States Bureau of Reclamation owns the dam and is pursuing funding under the federal Safety of Dams program. Additional funding would be split between the repayment partners including the Cities of Hillsboro, Beaverton, and Forest Grove, Clean Water Services (CWS), and TVID.

7.4 Storage Reservoirs

As presented in **Section 5**, the City will need additional storage at all levels within 20 years. The age and condition of the City's primary storage facility (the 5 MG Reservoir at the City WTP) requires replacement soon.

7.4.1 Two 5 MG Reservoirs at the Existing City WTP Site

The existing 5 MG Reservoir located at the City's WTP site is failing, does not meet seismic standards, and needs to be replaced. Two 5 MG Reservoirs are proposed to replace the 5 MG Reservoir onsite, with phased construction to allow for continued operations and development timing of the second reservoir (likely within the next 10 years, see **Figure 5-1** for one example of construction phasing – may not represent actual time needed for demolition and construction, to be reviewed during pre-design).

7.4.2 710 Reservoir

A 710 reservoir is proposed to serve future customers located above existing service elevations. The construction of the single, 0.5 MG reservoir can be phased with development. Temporary service to customers prior to reservoir construction can be achieved via a closed zone pump station, described further below. This reservoir size should be verified in design when development occurs.

7.5 Pump Stations

7.5.1 Upgrade Watercrest Pump Station

Although the pumping capacity analysis in **Table 5-8** indicates a capacity deficiency in existing stations after the 20-year planning horizon, it is recommended the City plan for upgrading existing pumping to the upper zones. This could occur through improvements to either the Watercrest PS or the David Hill PS. Costs shown in the CIP assume upsizing of the Watercrest PS. This station will operate more with additional demand at the top of the hill. In addition to station upgrades, transmission upgrades may also be required to accommodate increased flows.

7.5.2 New 710 Pump Station

A constant pressure 710 PS is recommended to be constructed with development of the upper zone. Once the 710 reservoir is built, this station can transition to pumping to storage, and no longer needs to provide fire flow capacity.

7.5.3 New 880 Pump Station

It was assumed areas above the proposed 710 pressure zone would develop once the 710 reservoir is constructed. To serve these customers, a new 880 closed zone PS should be constructed, similar to how the 710 PS will operate prior to construction of the 710 reservoir. Suction supply is assumed from the 710 reservoir, as it is not recommended to operate two closed zone pump stations in series.

7.6 Distribution Mains

7.6.1 Fire Flow Improvements

The City has known fire flow limitations in the industrial area in the northeast of town. The Heather Street Control Station and upsized transmission to the Heather Street Control Station and the 10th Avenue Control Station will mitigate many of these deficiencies. Limited improvements are recommended throughout the rest of the system to address fire flow deficiencies.

7.6.2 Transmission Improvements

Three transmission improvement projects are recommended.

- **10th Avenue Transmission:** improves WTP reservoir filling, fire flow transmission, and supply from Heather Avenue
- **Heather Avenue Transmission:** potential limitations for railroad and highway crossings, important if the City anticipates regular use of the Heather Street Control Station
- **Upper Zone Transmission from Watercrest PS** – existing 8-inch diameter main, this is a critical upsizing improvement for future supply to zones above existing 540 and tank filling from the Watercrest PS. If the David Hill PS is improved instead of the Watercrest PS, this improvement will not be required.

7.6.3 Piping Improvements Identified in the Prior WSMP

Piping improvements to address system looping and upsize existing piping were included from the prior WSMP. Construction of these projects is assumed to occur as required system looping to support local development or as opportunities arise to pair piping improvements with other utility projects.

7.7 Seismic Improvements

Overlapping sections of piping improvements suggested in both the SRP and other CIP projects (transmission improvements along 18th Ave, for example) were trimmed from the SRP projects so as not to double count.

7.7.1 Phase I

Phase I improvements were identified in the SRP and are intended to meet the ORP goal of 80 to 90 percent of the backbone operational within 24-hours of a seismic event. See **Section 6.6.1** for additional information. These projects are recommended to be completed within 0-5 years.

7.7.2 Phase II

Phase II improvements were identified in the SRP and are intended to meet the ORP goal of 80 to 90 percent of the entire system operational, except for goals related to the non-backbone water distribution system. To meet all the water system goals of the ORP, an additional 25.1 miles of existing ductile iron pipe would have to be replaced with seismically resistant pipe, which is likely cost prohibitive. The recommended phased approach will achieve many, but not all, of the ORP water system goals and when coupled with emergency operations planning, will significantly improve the City's water system seismic resiliency. See **Section 6.6.2** for additional information. Projects are recommended to be completed within 11-20 years, except for improvements to the JWC TL which is recommended for 0-5 years and discussed in the supply section.

7.7.3 Additional Actions

Additional recommended actions were identified in the SRP to mitigate seismic risk. See **Section 6.6.3** for additional description. These projects are generally either smaller projects or actions identified for the City to complete to aid in post disaster operations and planning. Projects are recommended to be completed within 0-5 years.

7.8 Planning Studies

7.8.1 System-wide Planning

The City will complete a rate study once this WSMP has been adopted. It is also recommended that the City continue to update the WSMP and Water Management and Conservation Plan (WMCP) every 10 years. An updated WSMP is required by the State of Oregon for a 20-year planning period. However, with potential changes to the City supply depending on findings of the WTP analysis and ongoing expansion of the City service area, it is prudent for the City to continue to regularly evaluate capital investment and prioritize needs for the water system and document this long-term water service strategy in the WSMP.

7.8.2 Emergency Water Supply Study

It is recommended the City complete an emergency water supply study to identify potential local sources of emergency water supply and develop a plan to implement development of, or access to, emergency water supply sources to mitigate for potential disruption of the City's primary water supplies in a regional emergency.

7.8.3 Develop New Engineering Standards

The City should consider updating the engineering standards to meet current seismic and resiliency criteria.

7.9 CIP Funding

The City may fund the water system CIP from a variety of sources, including governmental grant and loan programs, publicly issued debt, and cash resources and revenue. The City's cash resources and revenue available for water system capital projects include water rate funding, cash reserves, and system development charges (SDCs).

Generated through development and system growth, SDCs are typically used by utilities to support capital funding needs. The charge is intended to recover a fair share of the costs of existing and planned facilities that provide capacity to serve new growth.

As shown in **Table 7-1**, the City's proposed CIP includes significant investment, particularly in supply and storage improvements. This new capacity will serve growth while also providing more resilient water facilities that benefit all customers. An evaluation of water rates and SDCs in support of the water system CIP will be completed as follow-on work to this WSMP.

Table 7-1 | Capital Improvement Plan Summary

Improvement Category	Project No.	Project Title	CIP Cost Summary ¹					Purpose
			5-year 2022 to 2027	5 to 10-year 2028 to 2032	10 to 20-year 2033 to 2042	20-year +	20-year TOTAL	
Supply	S-1	Streamflow gauging station - Gales Creek	\$75,000				\$75,000	Requirement Growth, Reliability
	S-2	Barney Reservoir raw water capacity "buy-back" from TVWD				\$36,400,000		
	S-3	Long Term Water Supply Study and City WTP Facility Plan	\$400,000				\$400,000	
	<i>JWC Supply Projects - Forest Grove share</i>							
	S-4	JWC capital repair and replacement	\$1,100,000				\$1,100,000	Reliability
	S-5	Expansion projects - cathodic protection, Spring Hill Pumping Plant mitigation, disinfection facility, land purchase	\$900,000				\$900,000	Growth
	S-6	Minor capital projects - meters, equipment, building improvements	\$120,000				\$120,000	Reliability
	S-7	Scoggins seismic retrofit			\$2,040,000	\$8,160,000	\$2,040,000	Resilience
	S-8	WTP long-term seismic improvements			\$5,600,000		\$5,600,000	Resilience
		Supply Subtotal	\$2,595,000	\$-	\$7,640,000	\$44,560,000	\$10,235,000	
Storage Reservoirs	R-1	Replace existing 5 MG Reservoir at City WTP with two 5 MG Reservoirs (10 MG total)	\$11,300,000	\$11,300,000			\$22,600,000	Capacity, resilience, growth
	R-2	710 Reservoir (0.5 MG)			\$1,000,000		\$1,000,000	
		Storage Subtotal	\$11,300,000	\$11,300,000	\$1,000,000	\$-	\$23,600,000	Growth
Pump Stations	PS-1	Upgrade Watercrest Pump Station	\$1,200,000				\$1,200,000	Reliability
	PS-2	710 constant pressure Pump Station	\$900,000				\$900,000	Growth
	PS-3	880 constant pressure Pump Station			\$850,000		\$850,000	Growth
		Pump Stations Subtotal	\$2,100,000	\$-	\$850,000	\$-	\$2,950,000	
Piping Improvements	<i>Fire Flow Improvements</i>							
	F-1	Multifamily Residential - 22nd Ave - Garden Grove Apartments			\$260,000		\$260,000	Fire Flow
	F-2	Commercial - Pacific Ave - Best Western			\$260,000		\$260,000	Fire Flow
	F-3	Commercial - Pacific Ave - Mountain View Ln to Yew St			\$520,000		\$520,000	Fire Flow
	F-4	Residential - 23 rd Ave			\$350,000		\$350,000	Fire Flow
	F-5	Residential - Cedar St			\$90,000		\$90,000	Fire Flow
	F-6	Industrial - Maple St			\$250,000		\$250,000	Fire Flow
	F-7	Residential - Douglas St			\$40,000		\$40,000	Fire Flow
	<i>HDR Improvements - New Pipes</i>							
	HDR_DP02	Harvey Clarke Elementary			\$220,000		\$220,000	HDR New Pipes
	HDR_DP07	College Way connection from Pacific Ave			\$130,000		\$130,000	HDR New Pipes
	HDR_DP10	Bard Park connection			\$130,000		\$130,000	HDR New Pipes
	HDR_DP11	Firwood Ln			\$350,000		\$350,000	HDR New Pipes
	HDR_DP12	Oak St to Kingwood St connection			\$650,000		\$650,000	HDR New Pipes
	HDR_DP13	Oak St to Nehalem Hwy connection			\$460,000		\$460,000	HDR New Pipes
	HDR_DP14	Oak St to RR connection			\$240,000		\$240,000	HDR New Pipes
	HDR_DP23	19th Pl to Pacific Ave connector near Les Schwab			\$110,000		\$110,000	HDR New Pipes
	HDR_DP28	RR crossing from Green Ct to 22nd Ave			\$130,000		\$130,000	HDR New Pipes
	<i>HDR Improvements - Upsize Existing Pipes</i>							
	HDR_DP03	Tom McCall Upper Elementary			\$390,000		\$390,000	HDR Upsize

Improvement Category	Project No.	Project Title	CIP Cost Summary ¹					Purpose
			5-year 2022 to 2027	5 to 10-year 2028 to 2032	10 to 20-year 2033 to 2042	20-year +	20-year TOTAL	
	HDR_DP05	B St and 16th Ave			\$350,000		\$350,000	HDR Upsize
	HDR_DP06	A St between 16th and 17th Ave			\$150,000		\$150,000	HDR Upsize
	HDR_DP15	24th Ave east from Nehalem Hwy			\$1,210,000		\$1,210,000	HDR Upsize
	HDR_DP16	Heather St east			\$390,000		\$390,000	HDR Upsize
	HDR_DP17	NW Martin Rd connector			\$290,000		\$290,000	HDR Upsize
	HDR_DP21	Maple St from 17th Ave to 18th Ave			\$200,000		\$200,000	HDR Upsize
	HDR_DP22	19th Ave Safeway			\$80,000		\$80,000	HDR Upsize
	HDR_DP24	9th Ave from Elm St			\$180,000		\$180,000	HDR Upsize
	HDR_DP26	Laurel St north from Pacific Ave			\$100,000		\$100,000	HDR Upsize
	HDR_DP27	22nd Ave, Maple St, and 22nd Pl			\$350,000		\$350,000	HDR Upsize
	HDR_DP30	Buxton Ct			\$130,000		\$130,000	HDR Upsize
	HDR_DP31	University Ave from Cedar St to Sunset Dr			\$230,000		\$230,000	HDR Upsize
	HDR_DP32	21st Ave from Douglas St to Cedar St			\$150,000		\$150,000	HDR Upsize
	Transmission Improvements							
	T-1	10th Ave Transmission, upsize existing 12" transmission from 18th and Filbert St to 23rd and B St, 20"	\$3,050,000				\$3,050,000	Transmission
	T-2	10th Ave Transmission, upsize existing 16" from 23rd and B St to Pacific Ave and A St, 20"		\$1,440,000			\$1,440,000	Transmission
	T-3	Heather Ave Transmission, upsize existing 8-10" from Heather Ave Intertie, north to 19th Ave, to TV Hwy crossing, 20"	\$2,880,000				\$2,880,000	Transmission
	T-4	Heather Ave Transmission, upsize existing 8" from east of TV Hwy, TV Hwy crossing, to Filbert and 18th Ave, 20"		\$3,600,000			\$3,600,000	Transmission
	T-5	Transmission from Watercrest Pump Station to Hillside Way along Forest Gale Dr	\$1,910,000				\$1,910,000	Transmission
		Distribution Mains Subtotal	\$7,840,000	\$5,040,000	\$8,210,000	\$-	\$21,090,000	
Seismic Improvements	Phase I Improvements							
	E1-1	Portable pumping equipment for use at Stringtown Bridge	\$875,000				\$875,000	Resilience
	E1-2	Raw water pump backup power supply	\$200,000				\$200,000	Resilience
	E1-3	Geotechnical study to identify RWTM vulnerabilities between Stringtown Road Bridge and WTP (Section 1)	\$100,000				\$100,000	Resilience
	E1-4	Seismic upgrade of the RWTM (Section 1)	\$3,940,000				\$3,940,000	Resilience
	E1-5	Assess and upgrade anchorage of emergency generator electrical cabinets	\$25,000				\$25,000	Resilience
	E1-6-1	Replace Tier 1 backbone cast iron pipe with seismically resilient pipe from City WTP to B St (20")	\$5,040,000				\$5,040,000	Resilience
	E1-6-2	Replace Tier 1 backbone cast iron pipe with seismically resilient pipe along B St to Forest Grove HS (upsized to 8" minimum)	\$820,000				\$820,000	Resilience
	E1-6-3	Replace Tier 1 backbone cast iron pipe with seismically resilient pipe looping north around Pacific University (10-12")	\$1,340,000				\$1,340,000	Resilience
	E1-6-4	Replace Tier 1 backbone cast iron pipe with seismically resilient pipe along Poplar St and Pacific Ave to loop to industrial center (8" minimum)	\$2,050,000				\$2,050,000	Resilience
	E1-6-5	Replace Tier 1 backbone cast iron pipe with seismically resilient pipe along Mountainview Ln and Yew St to industrial center (8-10" minimum)	\$430,000				\$430,000	Resilience

Improvement Category	Project No.	Project Title	CIP Cost Summary ¹					Purpose
			5-year 2022 to 2027	5 to 10-year 2028 to 2032	10 to 20-year 2033 to 2042	20-year +	20-year TOTAL	
	E1-7	Structural analysis of Public Works Office Building to assess life safety performance and mechanical equipment/electrical panel anchorage	\$100,000				\$100,000	Resilience
	E1-8	Install isolation valves along backbone	\$1,000,000				\$1,000,000	Resilience
	Phase II Improvements							
	E2-1	Replace 4,600 lf of 8-10" cast iron pipe in Tier 2 backbone with seismically resilient pipe			\$1,500,000		\$1,500,000	Resilience
	E2-2	Geotechnical study to identify RWTM vulnerabilities between Clear Creek Watershed and Stringtown Road Bridge (Section 2)			\$100,000		\$100,000	Resilience
	E2-3	Seismic upgrade of the RWTM (Section 2)				\$17,040,000	\$-	Resilience
	E2-4	Detailed structural study of Stringtown Road Bridge and alternatives analysis for RWTM crossing of Gales Creek			\$150,000		\$150,000	Resilience
	E2-5	Replace 1.3 miles of existing 24-inch JWC TL with seismic resistant pipe, including 10th Ave Control Station building penetrations	\$5,940,000				\$5,940,000	Resilience
	E2-6	Detailed seismic structural analysis on 10th Avenue Control Station and required improvements			\$50,000		\$50,000	Resilience
	E2-7	Backup power added to David Hill Pump Stations			\$125,000		\$125,000	Resilience
	E2-8	Seismic analysis of David Hill Reservoir			\$75,000		\$75,000	Resilience
	E2-9	Replace 15.5 miles of cast iron pipe in distribution system				\$23,570,000	\$-	Resilience
	E2-10	Install isolation valves throughout the system			\$2,000,000		\$2,000,000	Resilience
	Additional Improvements							
	E3-1	Develop long term pipeline improvement program	\$25,000				\$25,000	Resilience
	E3-2	Stockpile repair resources for 10 workdays of repairs	\$50,000				\$50,000	Resilience
	E3-3	Establish material procurement protocols and on-call contracts with suppliers	\$5,000				\$5,000	Resilience
	E3-4	Develop repair protocols for rapid reimbursement from the Federal Emergency Management Agency (FEMA).	\$5,000				\$5,000	Resilience
	E3-5	Develop emergency management assistance compact (EMAC) with OR for mutual aid from other states.	\$2,500				\$2,500	Resilience
	E3-6	Emergency response training and protocols.	\$40,000				\$40,000	Resilience
	E3-7	Programs to evaluate and test emergency response equipment.	\$10,000				\$10,000	Resilience
	E3-8	Develop and maintain utility maps with locations of pipeline repairs.	\$50,000	\$50,000	\$100,000		\$200,000	Resilience
		Seismic Subtotal	\$22,047,500	\$50,000	\$4,100,000	\$40,610,000	\$26,197,500	
Planning	PL-1	Water Management & Conservation Plan update		\$100,000			\$100,000	Requirement
	PL-2	Water Master Plan update			\$300,000		\$300,000	Requirement
	PL-3	Emergency Water Supply Study		\$150,000			\$150,000	Resilience
	PL-4	Develop new engineering standards		\$50,000			\$50,000	Resilience
	PL-5	Complete Rate Study after WSMP adoption	\$50,000				\$50,000	Requirement
		Planning Subtotal	\$50,000	\$300,000	\$300,000	\$-	\$650,000	
		CIP Total	\$45,932,500	\$16,690,000	\$22,100,000	\$85,170,000	\$84,722,500	

Table 7-2 | 0-5 Year Capital Improvement Plan Prioritization

Category	Project No.	Project Title	Total Cost	FY22-23	FY23-24	FY24-25	FY25-26	FY26-27
Supply	S-1	Streamflow gauging station - Gales Creek	\$75,000	\$75,000				
	S-3	Long Term Water Supply Study and City WTP Facility Plan	\$400,000	\$400,000				
	S-4	JWC capital repair and replacement	\$1,100,000			\$1,100,000		
	S-5	Expansion projects - cathodic protection, Spring Hill Pumping Plant mitigation, disinfection facility, land purchase	\$900,000	\$180,000	\$180,000	\$180,000	\$180,000	\$180,000
	S-6	Minor capital projects - meters, equipment, building improvements	\$120,000	\$24,000	\$24,000	\$24,000	\$24,000	\$24,000
Storage Pump Stations	R-1	Replace existing 5 MG Reservoir at City WTP with two 5 MG Reservoirs (10 MG total, 5MG in 0-5 yr)	\$11,300,000	\$2,825,000	\$8,475,000			
	PS-1	Upgrade Watercrest Pump Station	\$1,200,000		\$300,000	\$900,000		
	PS-2	710 constant pressure Pump Station	\$900,000			\$225,000	\$675,000	
Piping	T-1	10th Ave Transmission, upsize existing 12" transmission from 18th and Filbert St to 23rd and B St, 20"	\$3,050,000	\$1,525,000	\$1,525,000			
	T-3	Heather Ave Transmission, upsize existing 8-10" from Heather Ave Intertie, north to 19th Ave, to TV Hwy crossing, 20"	\$2,880,000		\$1,440,000	\$1,440,000		
	T-5	Transmission from Watercrest Pump Station to Hillside Way along Forest Gale Dr	\$1,910,000			\$955,000	\$955,000	
	E1-1	Portable pumping equipment for use at Stringtown Bridge	\$875,000	\$875,000				
	E1-2	Raw water pump backup power supply	\$200,000		\$200,000			
Seismic	E1-3	Geotechnical study to identify RWTM vulnerabilities between Stringtown Road Bridge and WTP (Section 1)	\$100,000		\$100,000			
	E1-4	Seismic upgrade of the RWTM (Section 1)	\$3,940,000				\$1,970,000	\$1,970,000
	E1-5	Assess and upgrade anchorage of emergency generator electrical cabinets	\$25,000			\$25,000		
	E1-6-1	Replace Tier 1 backbone cast iron pipe with seismically resilient pipe from City WTP to B St (20")	\$5,040,000	\$1,008,000	\$1,008,000	\$1,008,000	\$1,008,000	\$1,008,000
	E1-6-2	Replace Tier 1 backbone cast iron pipe with seismically resilient pipe along B St to Forest Grove HS (upsized to 8" minimum)	\$820,000		\$820,000			
	E1-6-3	Replace Tier 1 backbone cast iron pipe with seismically resilient pipe looping north around Pacific University (10-12")	\$1,340,000	\$268,000	\$268,000	\$268,000	\$268,000	\$268,000
	E1-6-4	Replace Tier 1 backbone cast iron pipe with seismically resilient pipe along Poplar St and Pacific Ave to loop to industrial center (8" minimum)	\$2,050,000		\$512,500	\$1,025,000	\$512,500	
	E1-6-5	Replace Tier 1 backbone cast iron pipe with seismically resilient pipe along Mountainview Ln and Yew St to industrial center (8-10" minimum)	\$430,000				\$430,000	
	E1-7	Structural analysis of Public Works Office Building to assess life safety performance and mechanical equipment/electrical panel anchorage	\$100,000	\$20,000	\$20,000	\$20,000	\$20,000	\$20,000
	E1-8	Install isolation valves along backbone	\$1,000,000	\$200,000	\$200,000	\$200,000	\$200,000	\$200,000
	E2-5	Replace 1.3 miles of existing 24-inch JWC TL with seismic resistant pipe, including 10th Ave Control Station building penetrations	\$5,940,000	\$1,485,000	\$4,455,000			
	E3-1	Develop long term pipeline improvement program	\$25,000					\$25,000
	E3-2	Stockpile repair resources for 10 workdays of repairs	\$50,000					\$50,000
	E3-3	Establish material procurement protocols and on-call contracts with suppliers	\$5,000	\$5,000				
	E3-4	Develop repair protocols for rapid reimbursement from the Federal Emergency Management Agency (FEMA).	\$5,000	\$5,000				
	E3-5	Develop emergency management assistance compact (EMAC) with OR for mutual aid from other states.	\$2,500	\$2,500				
	E3-6	Emergency response training and protocols.	\$40,000	\$40,000				
	E3-7	Programs to evaluate and test emergency response equipment.	\$10,000	\$10,000				
	E3-8	Develop and maintain utility maps with locations of pipeline repairs.	\$50,000	\$50,000				
	PL-5	Complete Rate Study after WSMP adoption	\$50,000	\$50,000				
0-5 Year CIP Totals			\$45,932,500	\$9,047,500	\$19,527,500	\$7,370,000	\$6,242,500	\$3,745,000

Attachment B Water Master Plan Update Adoption Findings

Oregon Statewide Planning Goal 11 Public Facilities and Planning Oregon Administrative Rules Chapter 660, Division 11

Goal 11 states: To plan and develop a timely, orderly and efficient arrangement of public facilities and services to serve as a framework for urban and rural development. A timely, orderly, and efficient arrangement refers to a system or plan that coordinates the type, locations and delivery of public facilities and services in a manner that best supports the existing and proposed land uses.

Finding: The Water Master Plan update identifies a timely, orderly and efficient arrangement of water system improvements for supply, storage, and distribution. Improvements are prioritized based on short-term, medium-term and long-term needs. Identified improvements are intended to support existing and proposed land uses consistent with the Forest Grove Comprehensive Plan map.

Cities or counties shall develop and adopt a public facility plan for areas within an urban growth boundary containing a population greater than 2,500 persons.

Finding: According to the Portland State University Center for Population Research and Census, Forest Grove has a July 1, 2021 population of 26,242. The City's population exceeds the minimum population needed for preparing public facility plans including a water system master plan. The Water System Master Plan update fulfills this requirement.

A public facility plan is a support document to a comprehensive plan. The public facility plan describes the water, sewer, and transportation facilities which are to support the land uses designated in the appropriate acknowledged comprehensive plan.

Finding: The Water Master System Plan update will be incorporated into the Forest Grove Comprehensive Plan. The Planning Commission will make a recommendation to City Council to adopt an ordinance amending the text of the Forest Grove Comprehensive Plan to add the Water Master Plan as a technical appendix.

Goal 11 states that plans providing for public facilities and services should be coordinated with plans for designation of urban boundaries, urbanizable land, and for the transition or rural land to urban uses.

Finding: Preparation of the Water Master Plan update was coordinated with Forest Grove Comprehensive Plan including the Forest Grove Comprehensive Plan map and Westside Refinement Plan. Identified facility needs consider potential population and employment growth based on the land use designations identified on the Forest Grove Comprehensive Plan map.

Public facilities and services in urbanizable areas should be provided at levels necessary and suitable for existing uses. The provision for future public facilities and services in urbanizable areas should be based upon: (1) the time required to provide the service; (2) reliability of service; (3) financial cost; and (4) levels of service needed and desired.

Finding: The Water Master Plan update identifies specific improvement projects needed to serve existing and future development within the urban growth boundary. The Water Master Plan update also identifies anticipated timeframes and estimated project costs. In addition, the Water Master Plan update identifies system performance standards for system pressure, fire flow, and storage capacity.

Public facilities and services should be appropriate to support sufficient amounts of land to maintain an adequate housing market in areas undergoing development or redevelopment.

Finding: The Water Master Plan addresses system needs in the developing area within the urban growth boundary. This includes the area north of David Hill Road between Thatcher Road and Highway 47 added to the urban growth boundary in 2014.

The level of key facilities that can be provided should be considered as a principal factor in planning for various densities and types of urban and rural land uses.

Finding: The facilities identified in the Water System Master Plan update are planned to support the land uses and development densities identified on the Forest Grove Comprehensive Plan map.

Capital improvement programming and budgeting should be utilized to achieve desired types and levels of public facilities and services in urban, urbanizable, and rural areas.

Finding: The Water Master Plan update includes a list of capital improvement projects to achieve the desired type and level of service for the water system in the urban and urbanizable areas of the City's planning area. The Capital improvements are described in detail in Chapter 7 of the Water System Master Plan update.

The public facility plan shall contain the following items:

- (1) An inventory and general assessment of the condition of all the significant public facility systems which support the land uses designated in the acknowledged comprehensive Plan;
- (2) A list of the significant public facility projects which are to support the land uses designated in the acknowledged comprehensive plan
- (3) Rough cost estimates for each public facility project;
- (4) A map or written description of each public facility project's general location or service area;
- (5) A policy statement or growth management agreement identifying the provider of each public facility system.
- (6) An estimate of when each facility project will be needed; and
- (7) A discussion of the provider's existing funding mechanisms and the ability of these and possible new mechanisms to fund the development of each public facility project or system.

Finding:

- (1) The existing water system is described in detail in Section 1 of the Water Master Plan update. This includes an inventory and analysis of water supply, storage, and distribution system. Plan Appendix E provides a water system condition assessment.
- (2) Section 7 of the Plan identifies the public facility projects for the water system needed to support the land uses designated in the acknowledged comprehensive plan.
- (3) Section 7 of the Plan identifies the estimated costs for each capital improvement project needed during the 20-year planning period.
- (4) Section 7 of the Plan describes each project listed in the recommended capital improvement plan. Figure 1-1 in Section 1 and Appendix A is the water system map for the City's service area. The City's water service area includes approximately 26,000 residents and 6,800 residential, commercial, industrial, and municipal service connections. The service area includes all areas within the existing city limits and historic customers located outside the urban growth boundary along Gales Creek, Stringtown Road, Oppenlander Land and Martin Road. Figure 7-1 identifies the locations of recommended water system capital improvements.
- (5) The City's 2018 Urban Planning Area Agreement with Washington County identifies the provider of public services within the City's planning area (Resolution 2018-75). The City's planning area includes the area within the Forest Grove city limits and unincorporated area within the urban growth boundary adjacent to the city limits. The Plan identifies the owner of the water supply servicing City needs including the Joint Water Commission.
- (6) Section 7, Table 7-1 identifies the estimated timeframe for each capital improvement (5-year, 5 to 10-year, 10 to 20-year and 20-year+).

- (7) Section 7.9 describes CIP funding. Funding options identified include governmental grant and loan programs, publicly issued debt, and cash resources and revenue. The City's cash resources and revenue available for water system capital projects include water rate funding, cash reserves and system development charges.

Responsibility for Public Facility Plan Preparation (OAR 660-011-0015)

- (1) Specified within the urban growth management agreement
- (2) Jurisdiction shall coordinate with agencies as necessary
- (3) Those state agencies providing funding for making expenditures on public facility systems shall participate in the development of the public facility plan on accordance with state agency coordination agreements under ORS 197.180 and 197.712(2)(f).

Finding:

- (1): The City's 2018 Urban Planning Area Agreement with Washington County identifies the City as the provider of domestic water within the City's service area. Therefore, the requirement established by OAR 660-011-0015(2) is met.
- (2): The Urban Planning Area Agreement establishes roles and responsibilities for coordination with agencies as necessary. Therefore, the requirement established by OAR 660-011-0015(2) is met.
- (3): The water system is funded with City resources. The Water Master Plan update does not identify any state agency as a funder of needed water system capital improvements. Therefore, OAR 660-011-0015(3) does not apply to the Water System Master Plan update.

Public Facility Inventory (OAR 660-011-0020)

- (1) Mapped location of the facility or service area
- (2) Facility capacity or size; and
- (3) General assessment of condition of facility
- (4) Identification of projects in terms of type of facility, service area and facility capacity
- (5) Project descriptions

Finding:

- (1) Figure 1-1in Section 1 and Appendix A of the Water System Master Plan update identifies the mapped location of the City's water service area. Therefore, the requirement established by OAR 660-011-0020 is met.

- (2) Section 2 of the Water Master Plan update describes the existing water system including facility capacity for water supply, storage and transmission. Therefore, the requirement established by OAR 660-011-0020(2) is met.
- (3) Section 2 of the Water Master Plan update provides a general assessment of facility condition. Therefore, the requirement established by OAR 660-011-0020(3) is met.
- (4) Section 7 of the Water Master Plan update identifies recommended projects including facility type. Facility type includes water supply, water storage, and transmission. Section 2 of the Water Master Plan update identifies existing facility capacity. Therefore, the requirement established by OAR 660-011-0020(4) is met.
- (5) Section 7 of the Water Master Plan update provides descriptions of each recommended capital improvement. Therefore, the requirement established by OAR 660-011-0020(5) is met.

Timing of required public facilities (OAR 660-011-0025)

- (1) General estimate of timing

Finding: Section 7 of the Water Master Plan update provides an estimate of timing for each recommended capital improvement. Timeframes include 5-year, 5 to 10-year, 10 to 20-year and 20-year+. Therefore, the requirement established by OAR 660-011-0025 is met.

Location of Projects (OAR 660-011-030)

Finding: Figure 7-1 identifies the locations of recommended water system capital improvements. Therefore, the requirement established by OAR 660-011-0035 is met.

Determination of Rough Cost Estimates (OAR 660-011-0035)

Finding: Section 7 of the Water Master Plan update includes cost estimates for each recommended capital improvement. Therefore, the requirement established by OAR 660-011-0035 is met.

Facility Plan Review

Public facility plans are reviewed as comprehensive plan post acknowledgment plan amendment (OAR 660-011-0040).

Finding: The City is adopting the Water Master Plan update as a Forest Grove Comprehensive Plan post acknowledgment amendment. Required notice of the proposed comprehensive plan post acknowledgement plan amendment was provided to the Oregon Department of Land Conservation and Development on March 1, 2022.

OAR 660-011-0045(1): The governing body of the city responsible for development of the public facility plan shall adopt the plan as a supporting document to the city's comprehensive plan.

Finding: The Forest Grove City Council is expected to adopt an ordinance on May 23, 2022, amending the text of the Forest Grove Comprehensive Plan to add the Water Master Plan update as a technical appendix.

Forest Grove Comprehensive Plan
Chapter 7: Public Facilities and Community Services

Water Service Goals

1. Water facilities shall be designed and sized to serve the needs of future land uses as designated in the Forest Grove Comprehensive Plan map.

Finding: The Water Master Plan update identifies specific water supply, storage, distribution improvements needed to serve current and future land use as designated on the adopted Forest Grove Comprehensive Plan map. System needs consider future population and employment growth based on the land use designation shown on the Comprehensive Plan map and population and employment trends.

2. The Water Master Plan shall be incorporated as part of the Forest Grove Comprehensive Plan.

Finding: The Water Master Plan update will be referred to the City Council after review by the Planning Commission. The City Council will consider an ordinance amending the text of the Forest Grove Comprehensive Plan to add the Water Master Plan update as a technical appendix. This will fulfill Comprehensive Plan Water Service Goal 2.

Water Service Local Policies

A master plan including prioritized lists of capital improvement needs shall be adopted for provision of water service. The plan shall be based on future land use policies and needs.

Finding: The Water Master Plan update includes a prioritized list of capital improvement needs for the provision of water service. The list is prioritized according to short-term and long-term needs (5-year timeframe, 6-to-10-year timeframe, 11-to-20-year timeframe, and 20+ year timeframe).

The plan is based on the adopted Comprehensive Plan land use map and population projections prepared by the Portland State University Center for Population Research and Census for the Regional Water Providers Consortium.

Water Master Plan Section 7 provides detail about the recommended capital improvement program including project cost estimates and anticipated timeframes. The capital improvement program addresses water supply, storage, distribution and seismic improvements.

1. All future development shall be required to comply with the adopted water master plan, Municipal Code including Development Code and the City of Forest Grove Engineering Specifications.

Finding: The Water Master Plan update identifies water supply, storage, distribution and seismic improvements. Once adopted by the City the Plan update provides the policy basis for conditions of development approval to ensure adequate service is provided for development. Such conditions ensure development applications comply with the adopted Water Master Plan update.

2. The sizing of municipal water facilities shall follow land use plan designations and concentrate development in the city center.

Finding: The Water Master Plan update considered the land uses designated on the adopted Forest Grove Comprehensive Plan map. Water facilities identified in the Water Master Plan update support the land use designations and anticipated future growth over the 20-year planning period.

3. The master plan element for water shall include design for the adequate provision of these facilities for those areas designated in the land use plan for industrial use. These design requirements shall serve as the City standards for services to industrial areas.

Finding: The Water Master Plan update considers the needs of future industrial development and anticipated industrial development as documented in the City's 2019 Economic Opportunities Analysis (EOA). The EOA shows a modest need of 40 to 50 acres of land necessary for anticipated industrial land absorption during the upcoming 20-year planning period. The Master Plan update indicates the municipal water system is sufficient and will accommodate this need.

4. The Master Plan for water shall be designed for service to at least the Year 2030 and be adopted as part of the Comprehensive Plan.

Finding: The planning period for the Water Master Plan is 20 years, through the year 2041, consistent with Oregon Administrative Rule requirements for Water System Master Plans (OAR 333-061 and OAR 660-011). Water demand projections included in the Plan also include a 50-year projected water demand for long -range water supply planning.

9. Develop, adopt and achieve, local water conservation and demand management goals.

Finding: The Water Master Plan update includes information pertaining to historical water demand (Table 2-1), water consumption by customer type (Table 2-4), historical water demand per capita (Table 2-5), non-residential average daily demand per acre (Table 2-6), and a list of top water users in 2020 from billing records (Table 2-7). The Plan also includes projected water demand (Table 2-16) and water demand by pressure zone (Table 2-17).

Section 2.6 of the Water Master Plan update indicates existing water loss in the system is estimated to be 14%. The plan calls for a reduction to 10% within 5 years, and then maintained at 10% through buildout in the urban growth boundary.

The capital improvement program in the Water Master Plan update identifies as a project updating the Water Management and Conservation Plan (Table 7-1), Project PL-1). The Water Master Plan update recommends updating the Water Management and Conservation Plan every ten years.