EXHIBIT A

murraysmith

CITY OF FOREST GROVE

Water System Master Plan

February 2022
Revised May 2022

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City of Forest Grove

February 2022

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Table of Contents

Tables

Figures

Appendices

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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	miligrams 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 Stated Geological Survey
V	
VFDs	variable frequency drives
W	
WMCP	Water Management and Conservation Plan
WSMP	Water System Master Plan
WTP	water treatment plant

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Executive Summary

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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.

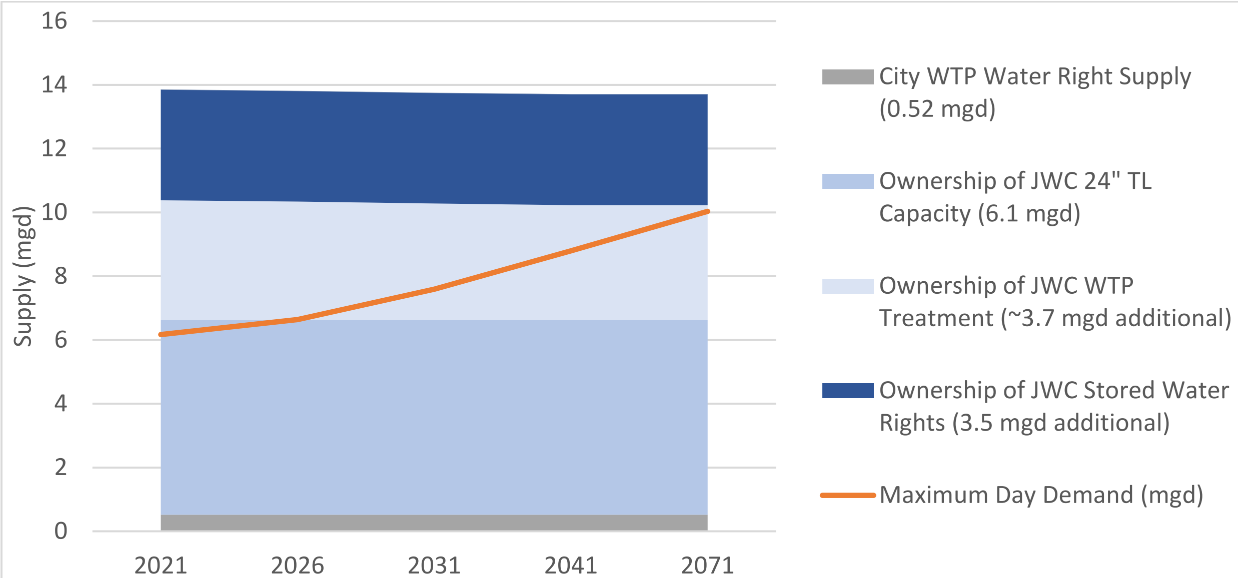
Fire Flow

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. In 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, or 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).

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Section **1**

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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 previous 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. Elevations referenced in this report are all based on the Forest Grove Vertical Datum. 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:

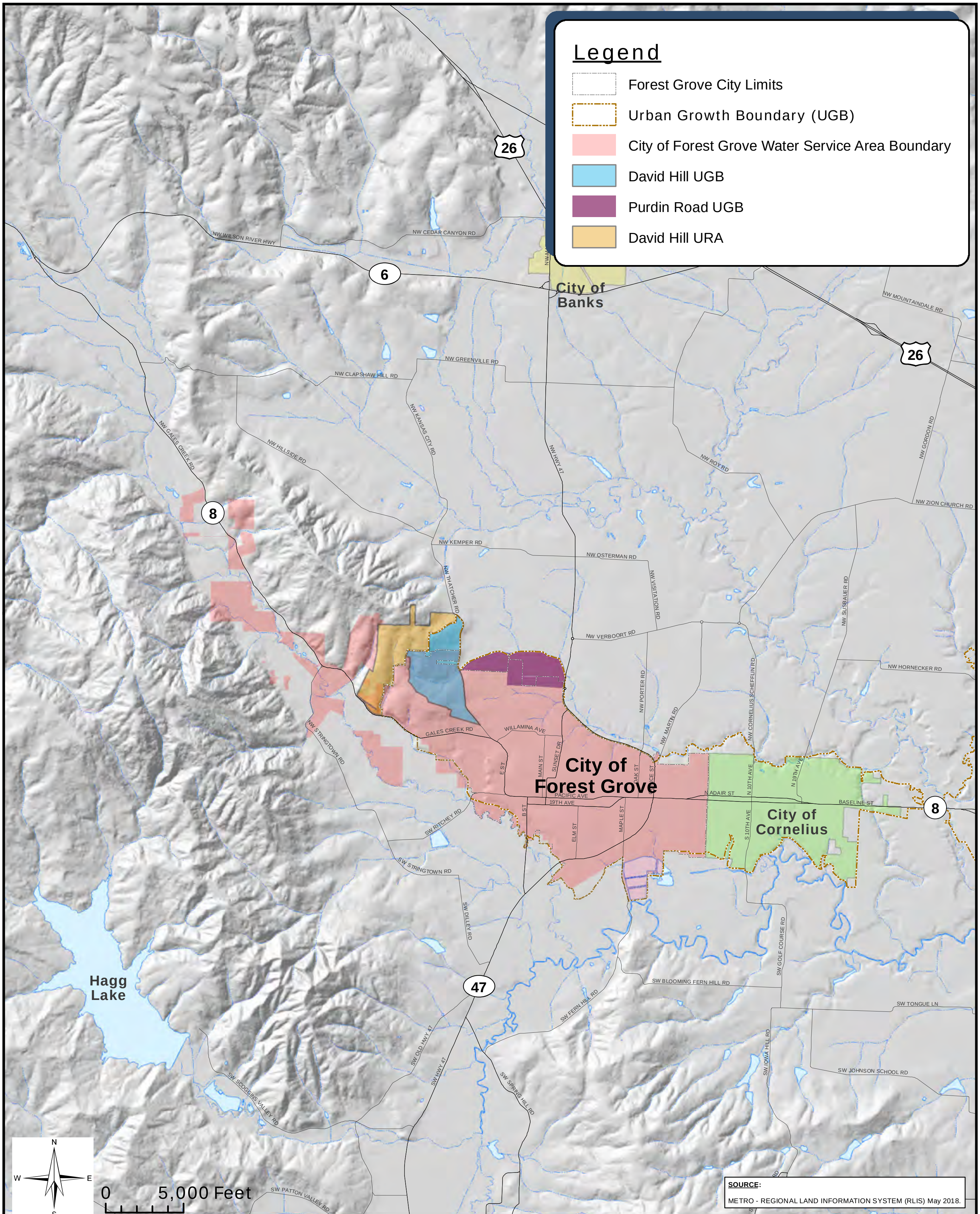
1. Firm capacity is the station capacity with the largest pump out of service. Firm capacity of the Raw Water PS and the Watercrest PS is 0 gpm as there is only one pump at each facility.

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



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City of Forest Grove
Water System
Master Plan

Figure 1-1
Water Service Area Map

FOREST GROVE OREGON
A place where families and businesses thrive

January 2022 18-2197

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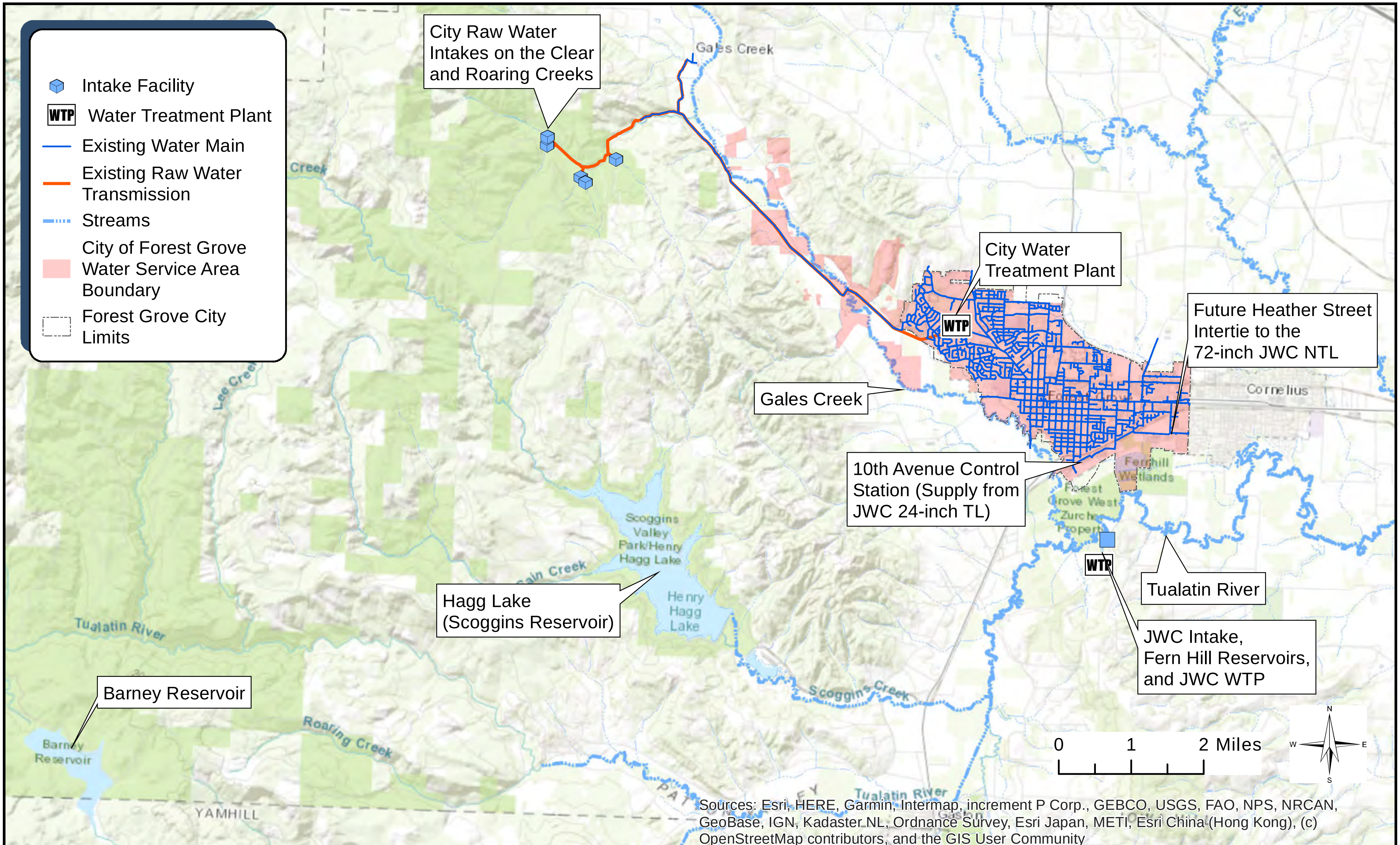

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FOREST GROVE OREGON
A place where families and businesses thrive.

City of Forest Grove
Water System Master Plan

Figure 1-2
Source of Supply

January 2022

18-2197

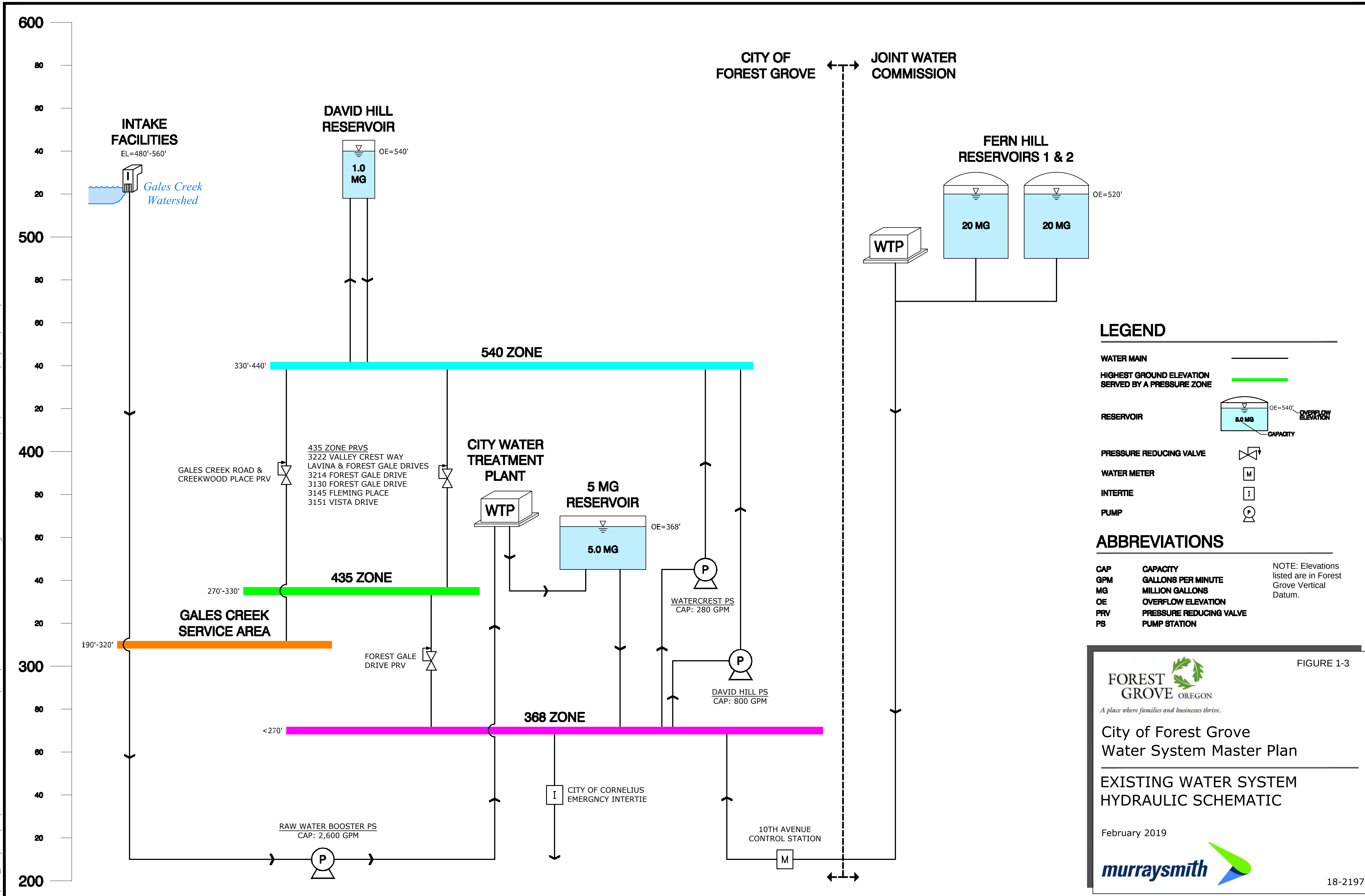

FIGURE 1-3

FOREST GROVE OREGON

A place where families and businesses thrive.

City of Forest Grove
Water System Master Plan

EXISTING WATER SYSTEM
HYDRAULIC SCHEMATIC

February 2019

murraysmith

18-2197

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Section **2**

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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:

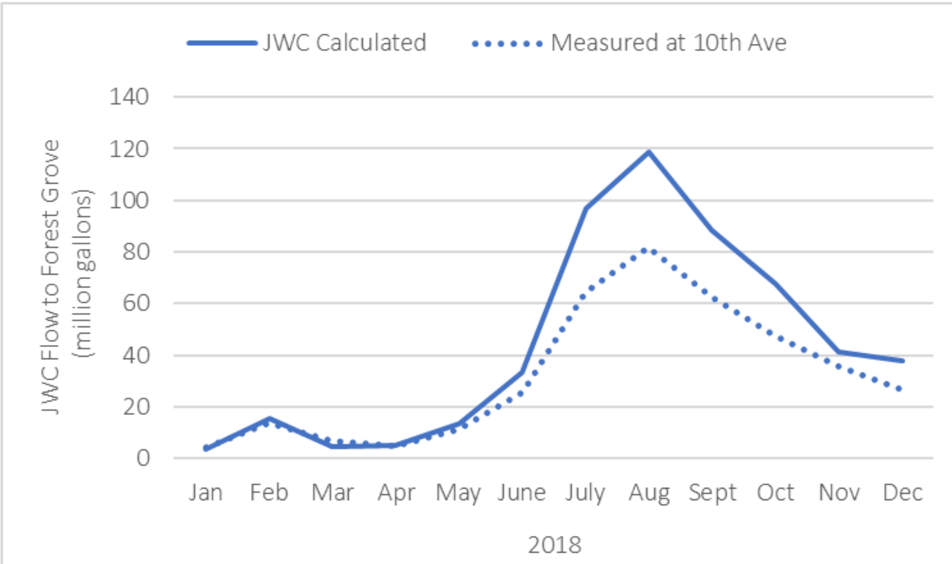
1. Production data calculated as the sum of Forest Grove WTP production and JWC supply through 10th Ave. As discussed in Section 2.4.1, the 10th Ave meter reads low, therefore corrections were used to develop JWC supply assumptions.
2. Unmetered water use includes permitted hydrant use, flushing, and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

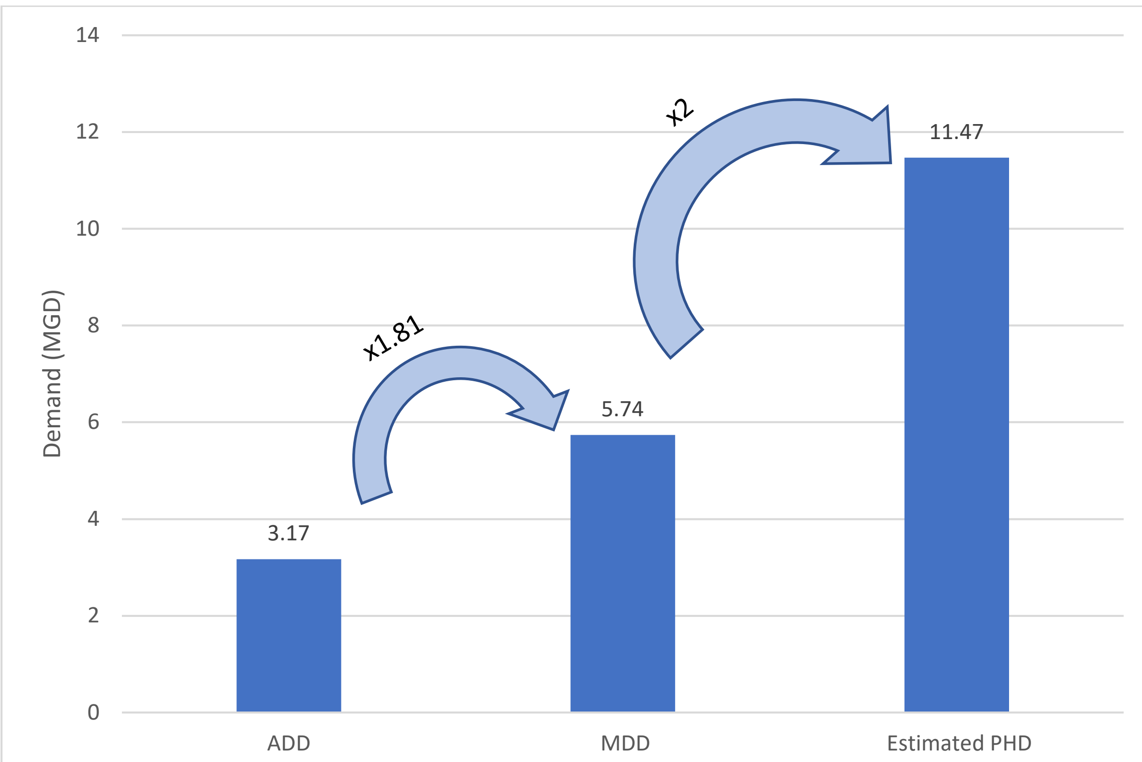
Table 2-2 | Historical ADD, MDD, and PHD

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

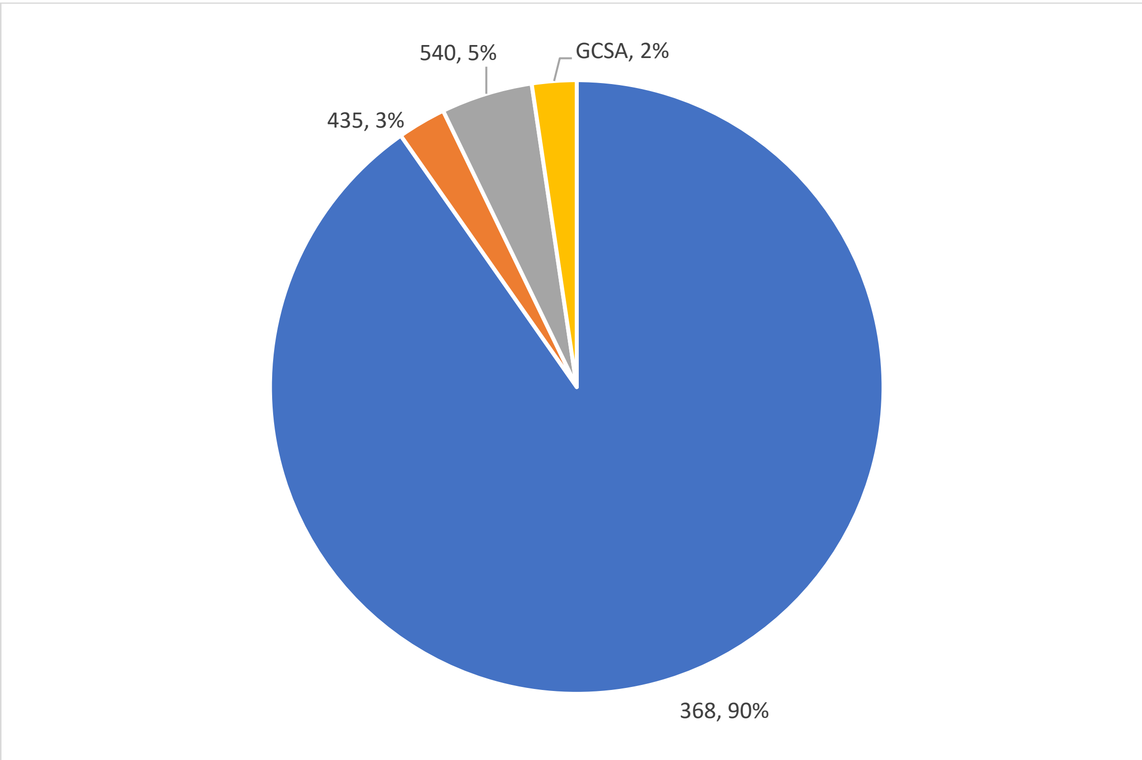
Water billing records provided by the City were used to document current average daily water consumption by pressure zone, customer type, and to correlate non-residential water demand to land use for future demand projections.

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

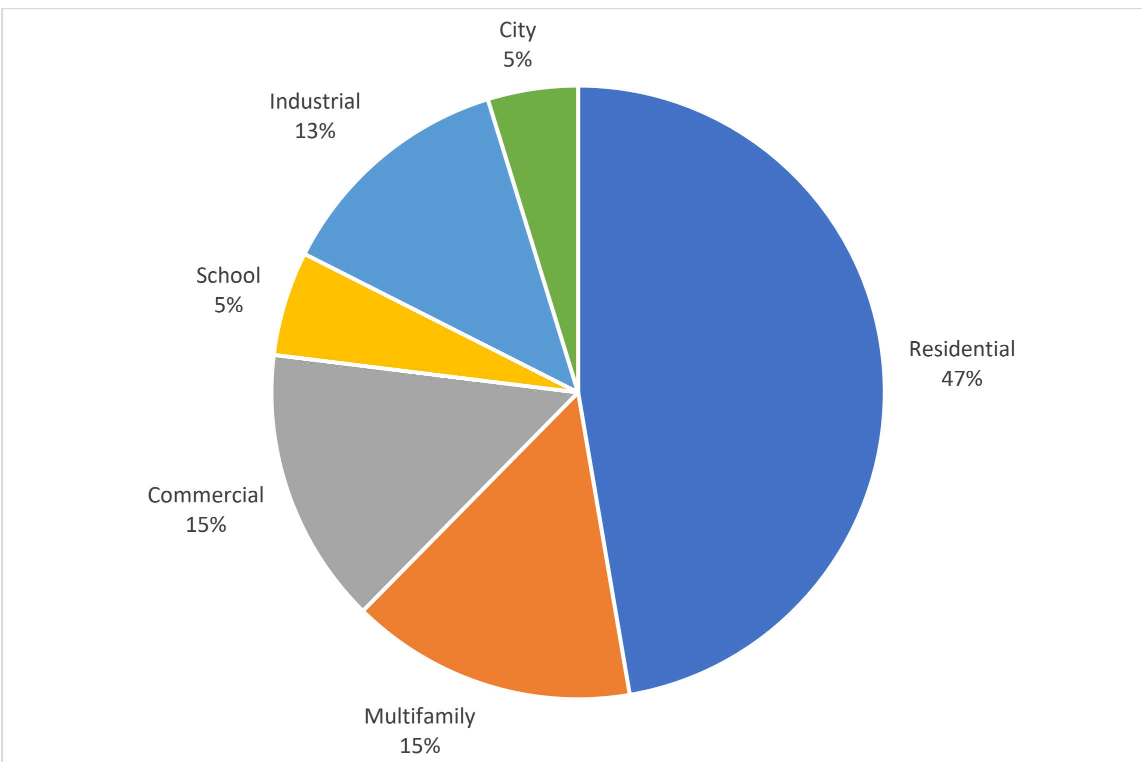
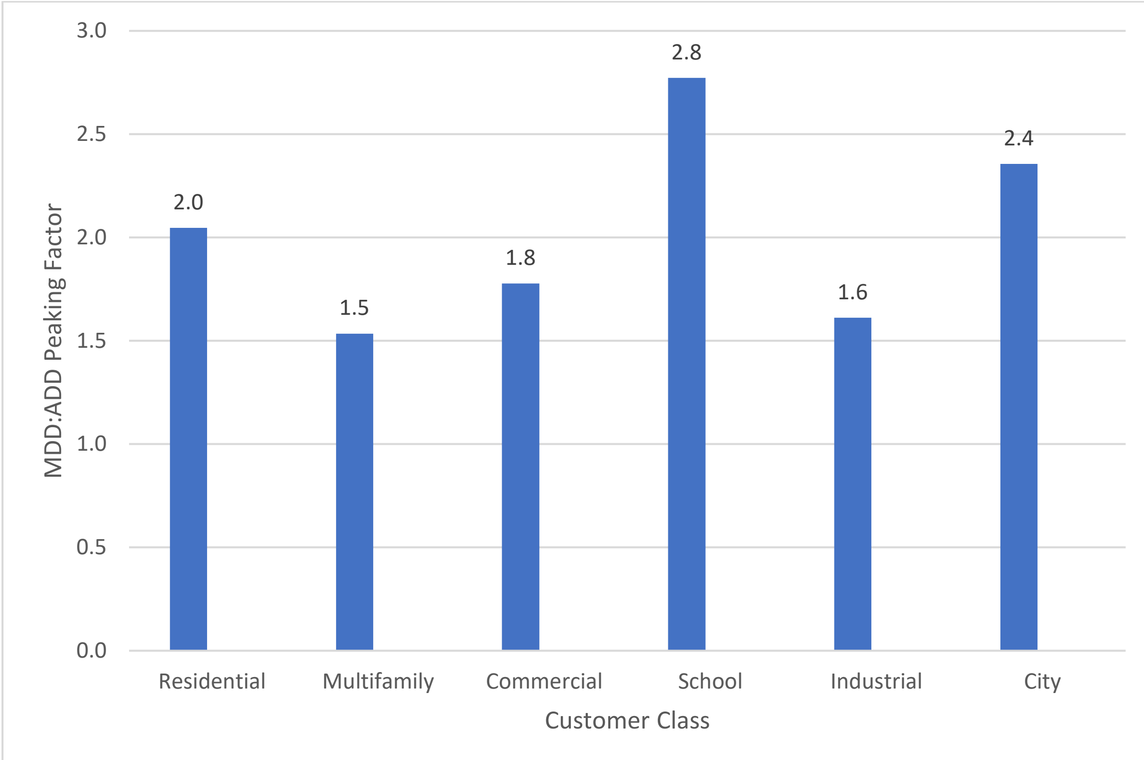


Figure 2-5 | MDD:ADD Peaking Factors by Customer Type, Average 2018-2020



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.

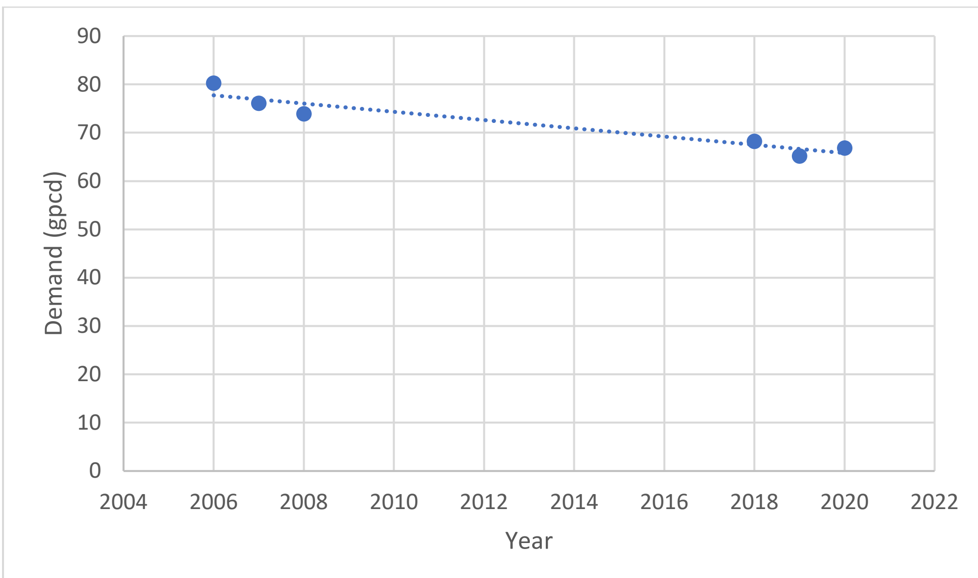
Table 2-5 | Historical Residential Demand per Capita

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

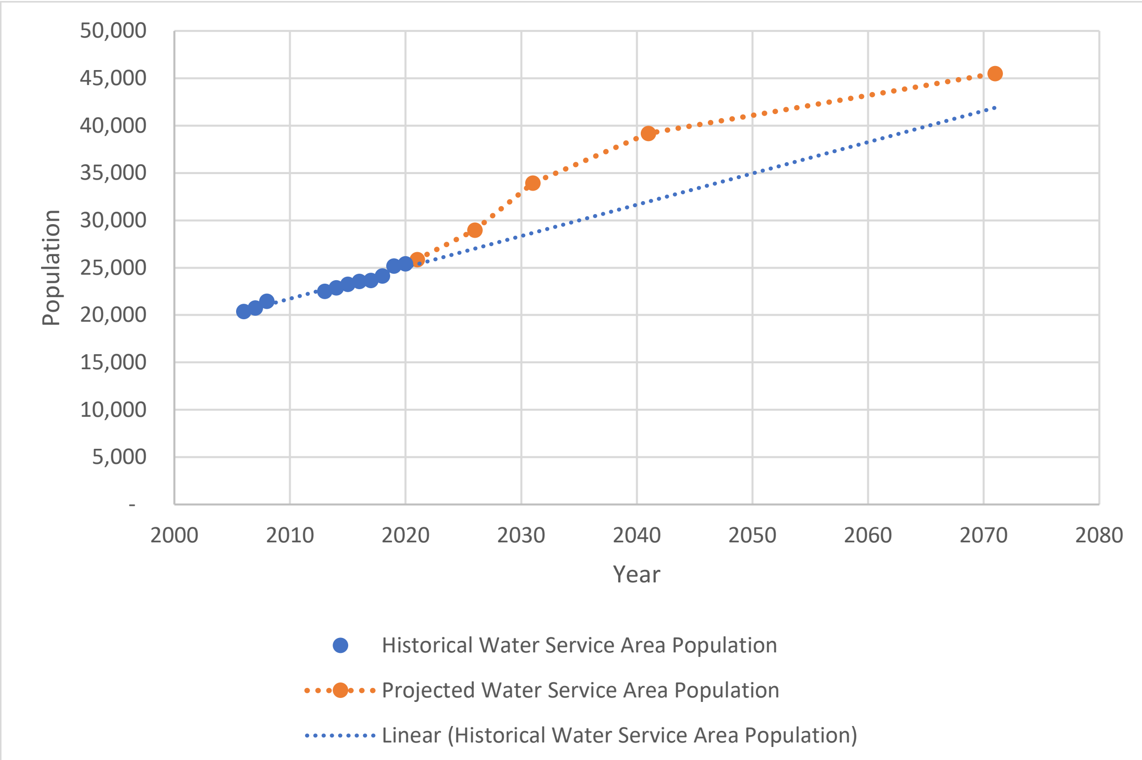
Center (PSU PRC). The PSU PRC provides annual population estimates for all Oregon cities. The population forecast for the City's water service area was part of a special 2019 study commissioned by the Portland metro area Regional Water Providers Consortium (RWPC) of which the City is a member. The population 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 brough 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.

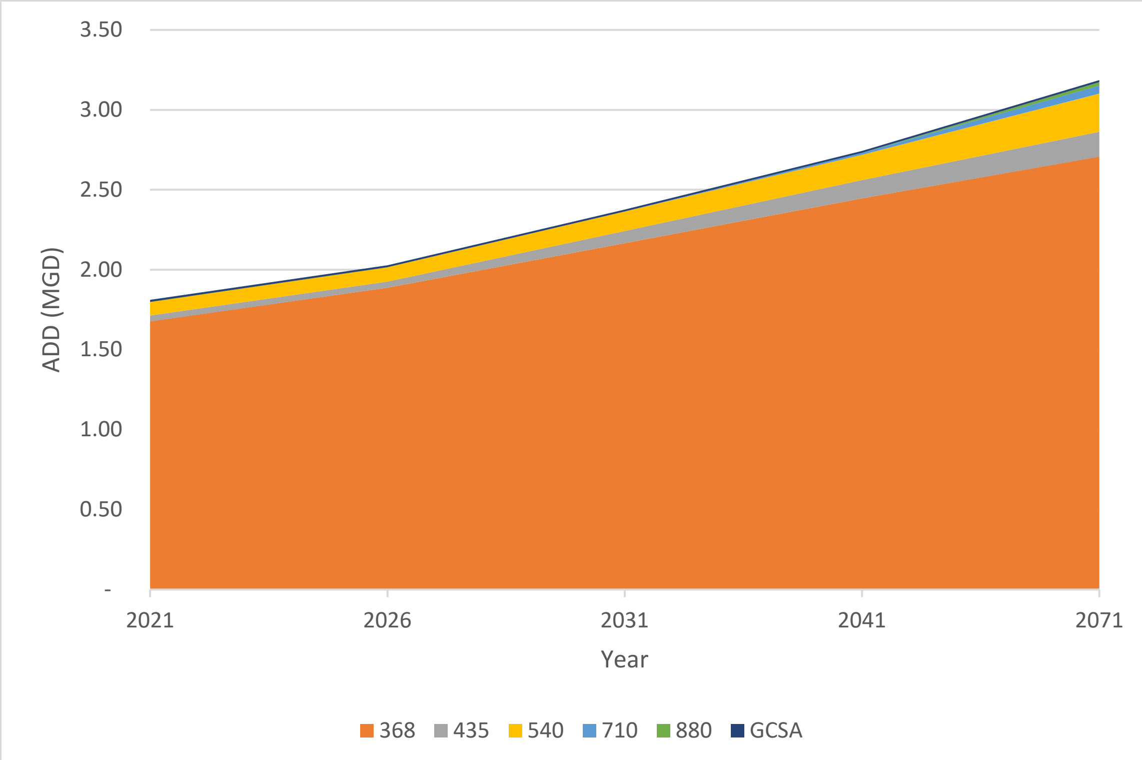
Table 2-11 | Residential and Multifamily - Projected Population and Water Demand by Zone

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
	Mixed Use/Commercial	19.7	Commercial	10	0.034
David Hill	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
ADD (MGD)	5	0.03	0.06	
	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.

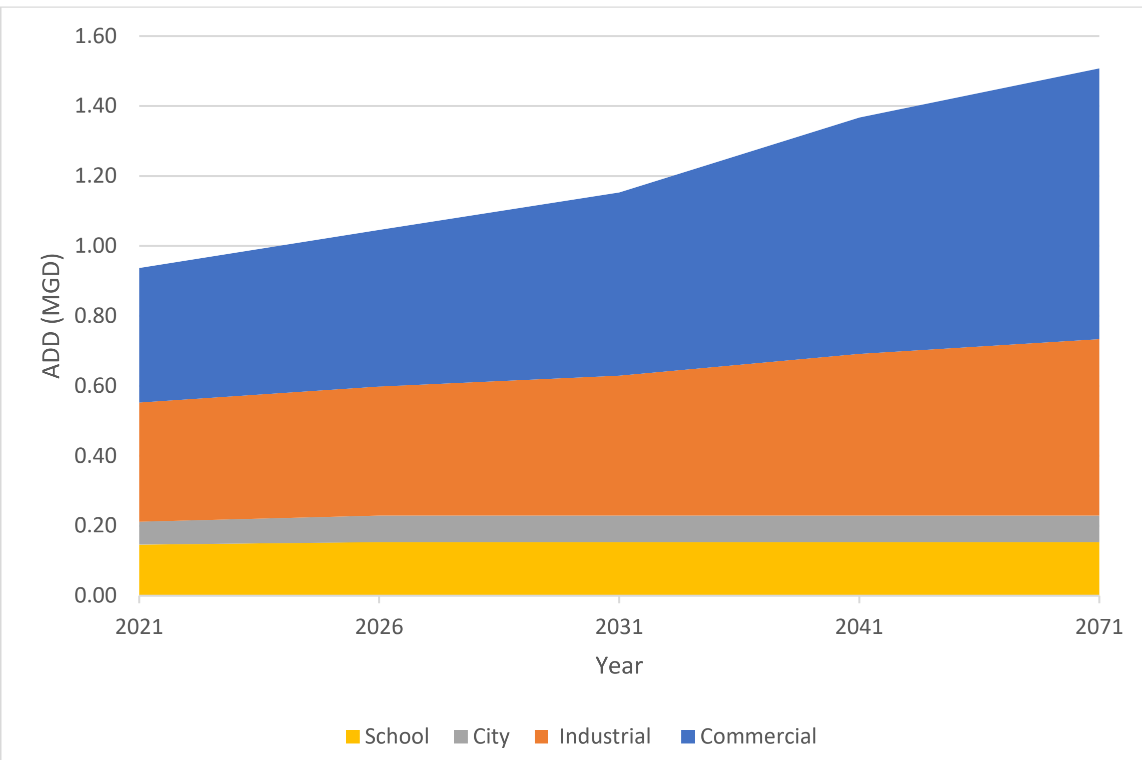
Table 2-15 | Non-Residential Demand Projection, 368 Zone

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 2-10Note:

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

present system wide ADD, MDD, and PHD for the 50-year projection period.

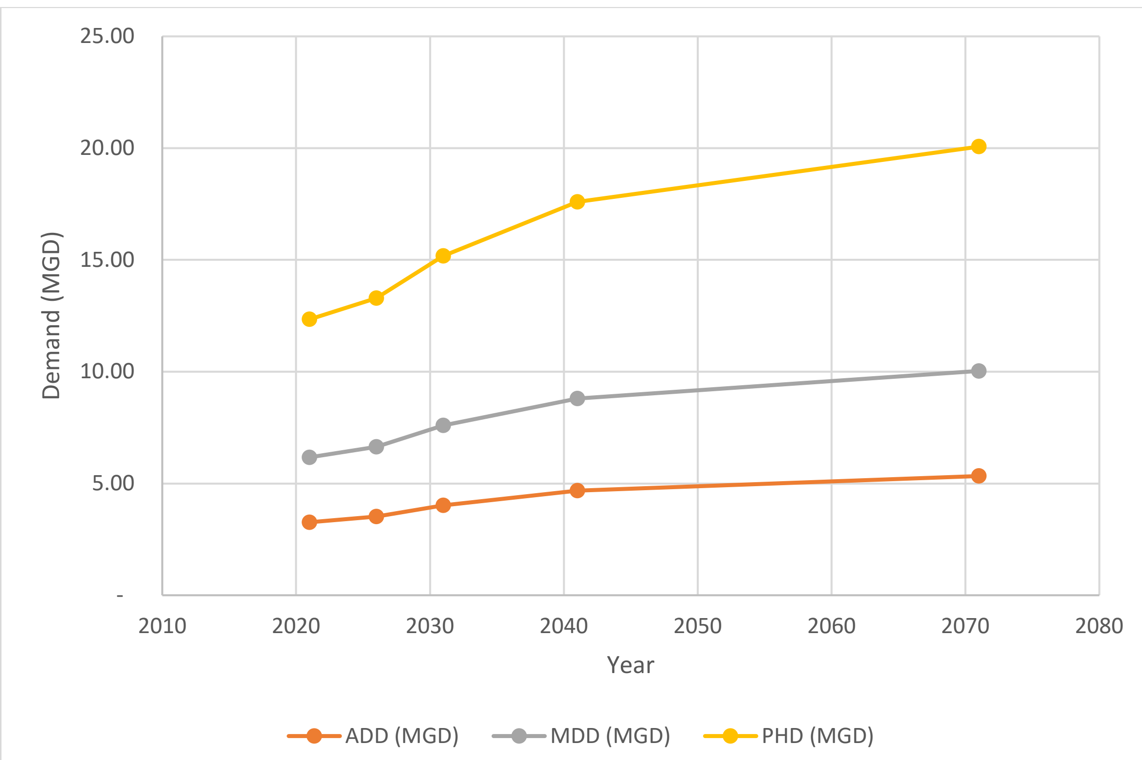
Table 2-16 | Projected Water Demand Summary

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:

2. 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.**

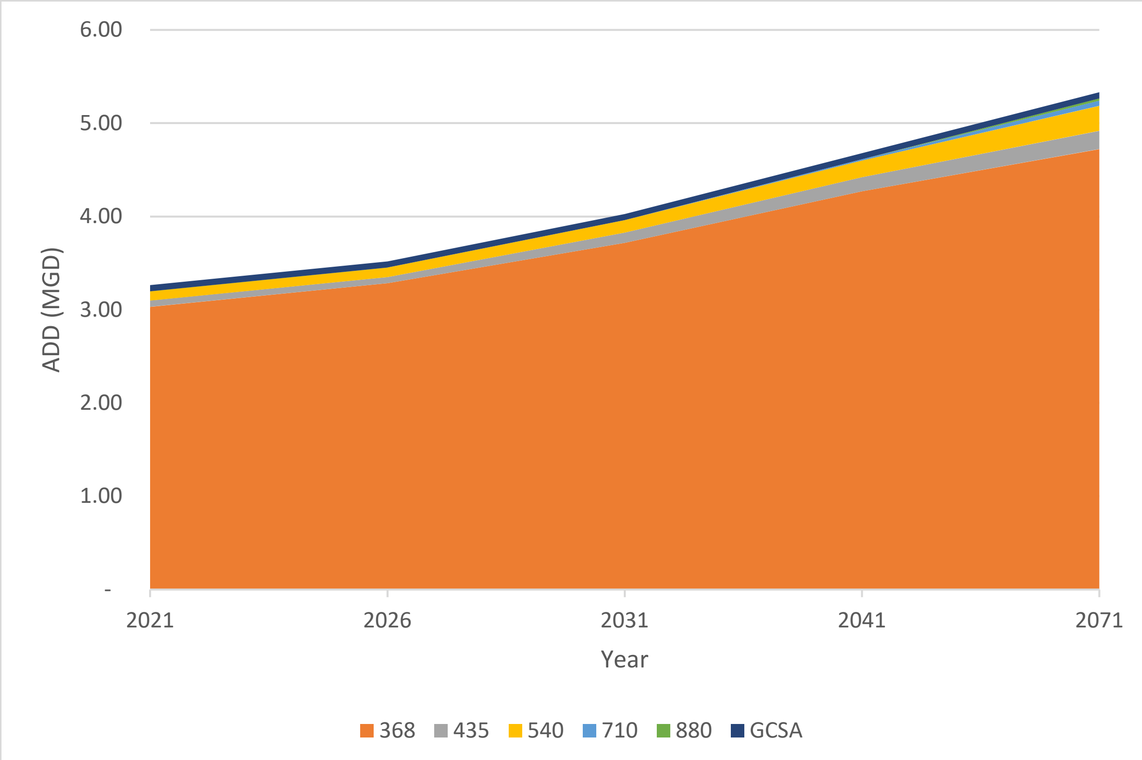
Table 2-17 | Water Demand by Pressure Zone

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



2.7 Water Conservation and the JWC WMCP

The JWC recently completed the 2021 Water Management and Conservation Plan (WMCP, see **Appendix L**). The purpose of the WMCP is similar to a WSMP in that it is used to plan for future needs. A WMCP, however, is more aimed at addressing source supply and includes a significant focus on water conservation and sustainable use of water resources. The City is committed to improving water use efficiency and has implemented the following procedures, among others, to address this:

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

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Section **3**

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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
Service Pressure	Normal Range, during ADD[1]	40-100 psi	City of Forest Grove 2010 Water Master Plan
	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
Distribution Mains	Velocity during PHD[3] or fire flow	Not to exceed 10 fps	AWWA M32
	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
Storage	Operational Storage	25% of MDD[2]	2010 Water Master Plan
	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
Pump Stations	Supplying Storage - Required Capacity	MDD[2] at firm capacity	Washington Water System Design Manual
	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**

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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.

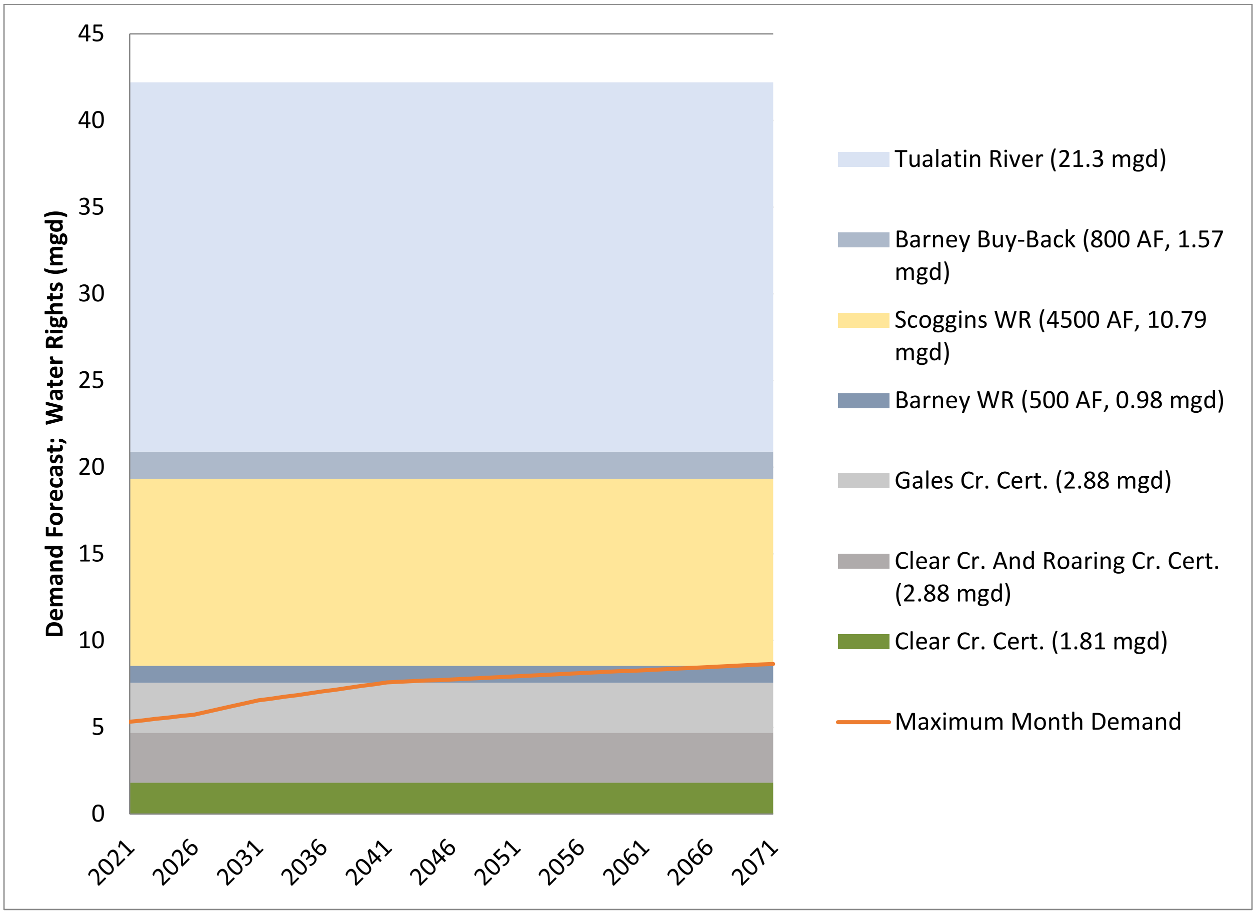
Both Barney and Hagg Lake (Scoggins Reservoir) have filled to over 85 percent by May 1 every year of data except 2001. In 2001, an extreme drought reduced fill at the beginning of the summer to approximately 50 percent. This 50 percent fill is four to five standard deviations away from the mean fill 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** Error! Reference source not found.

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

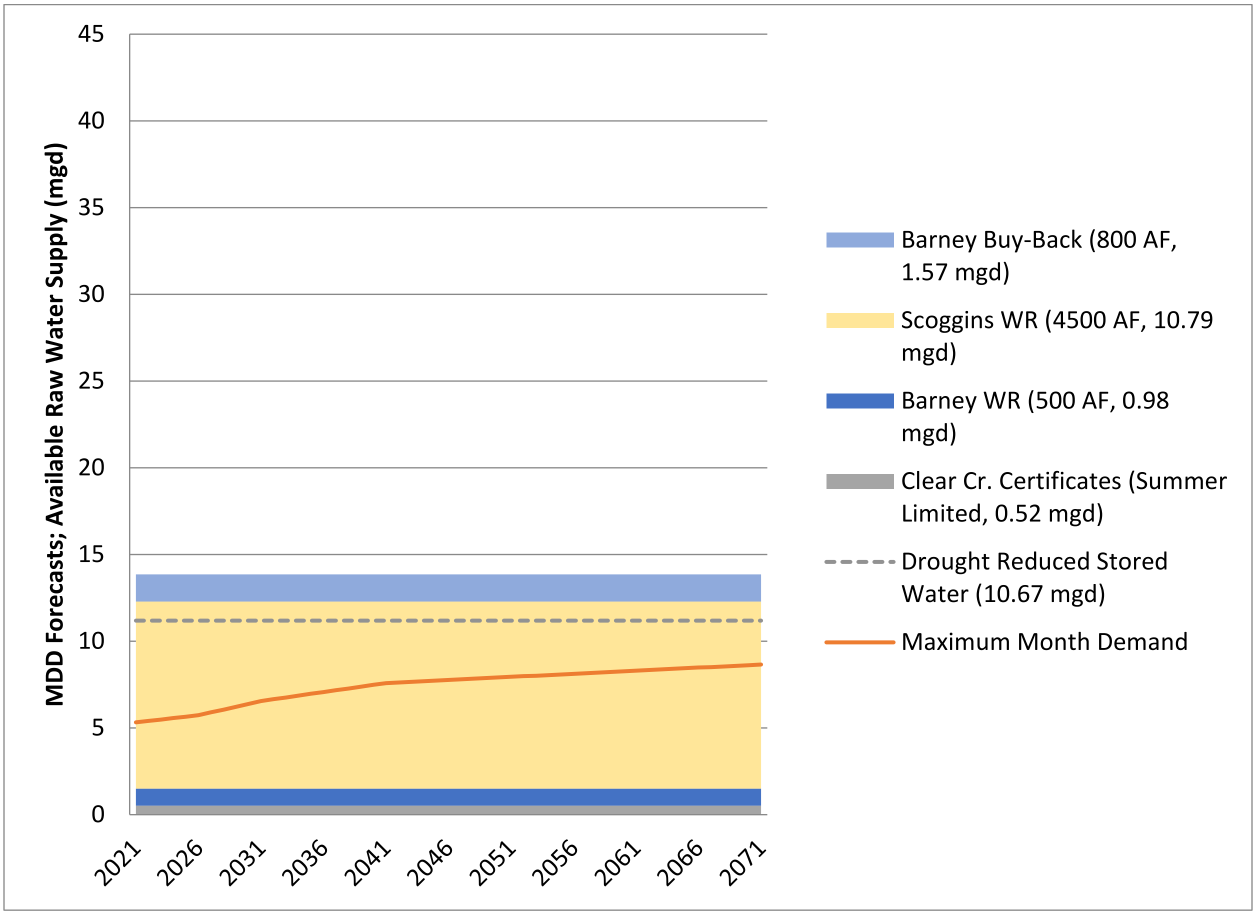


Note:

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

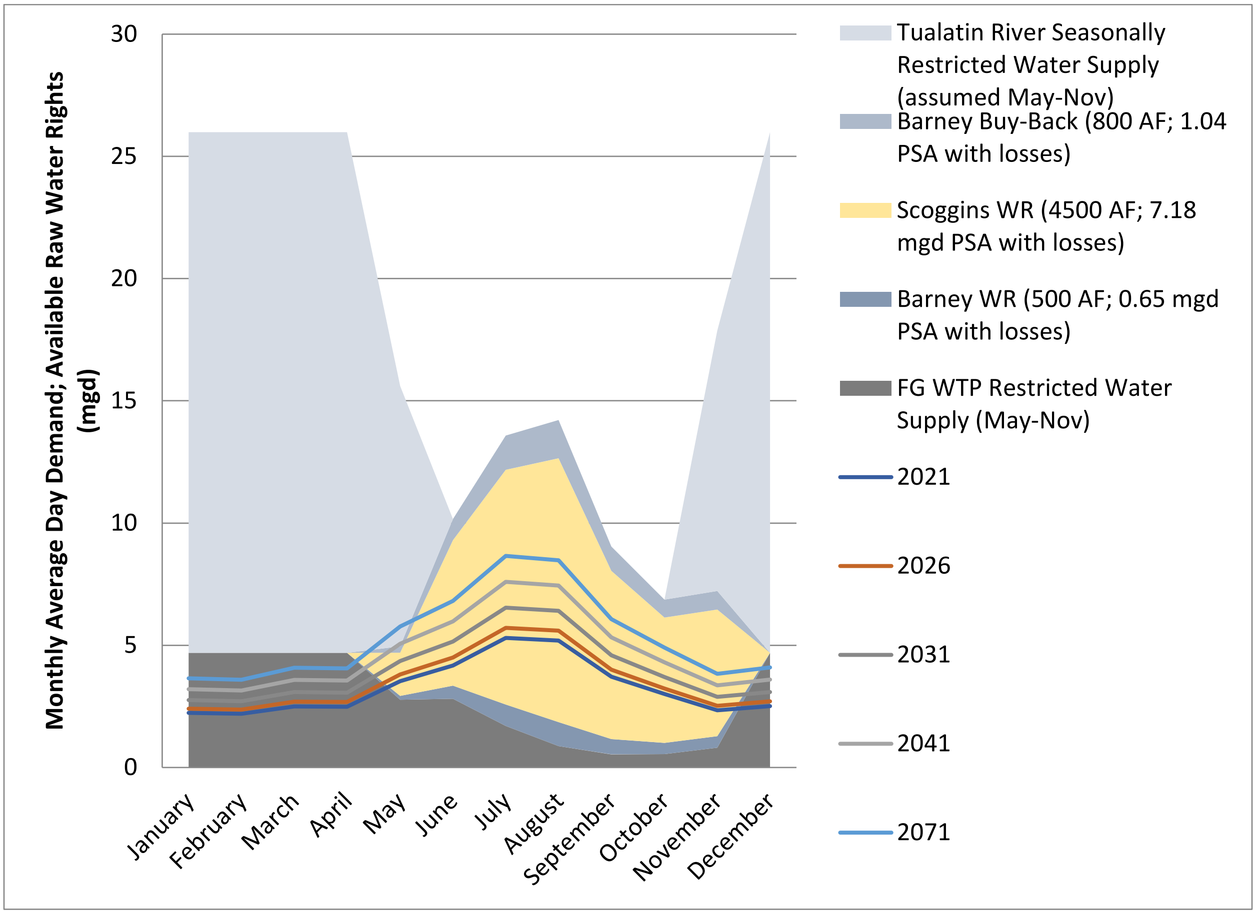


Note:

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

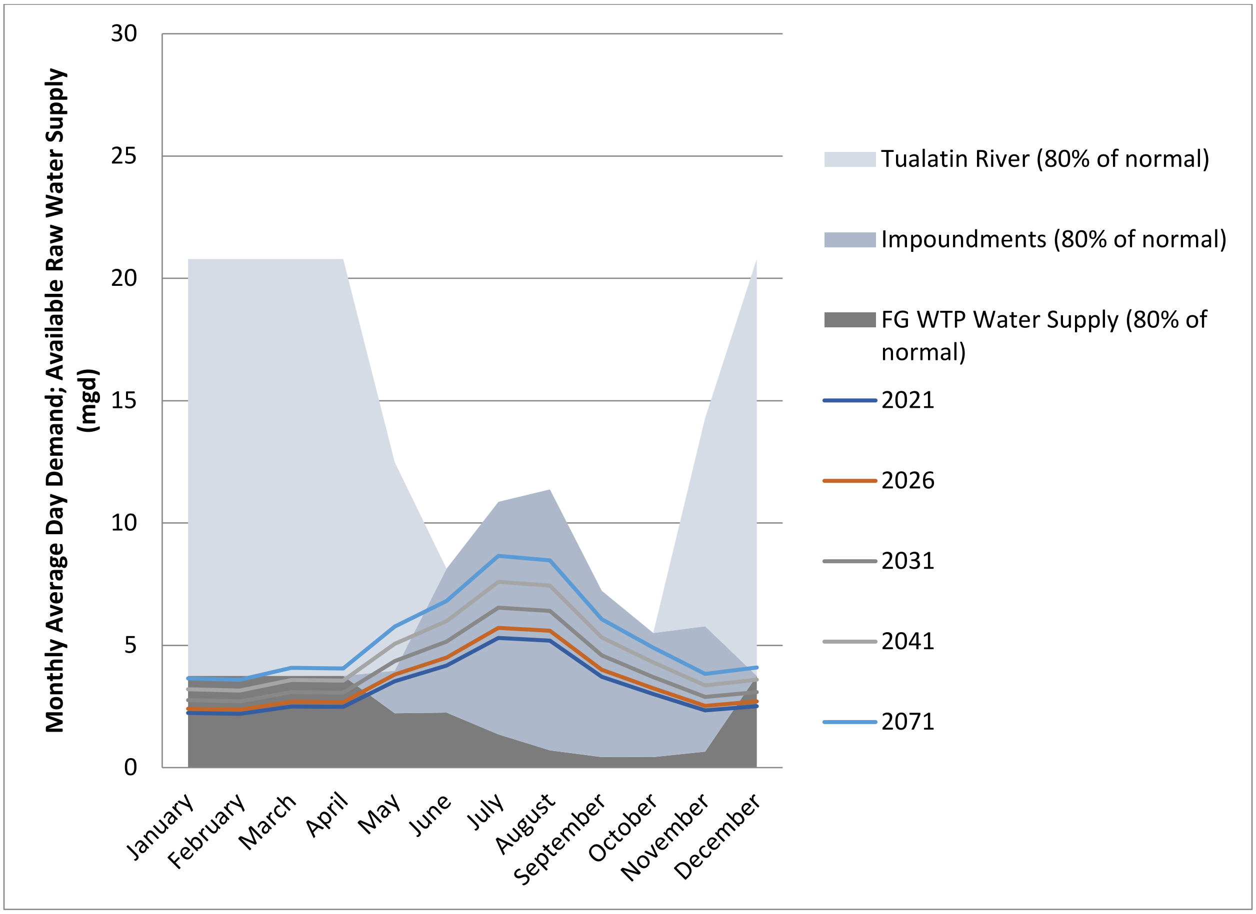


Note:

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.

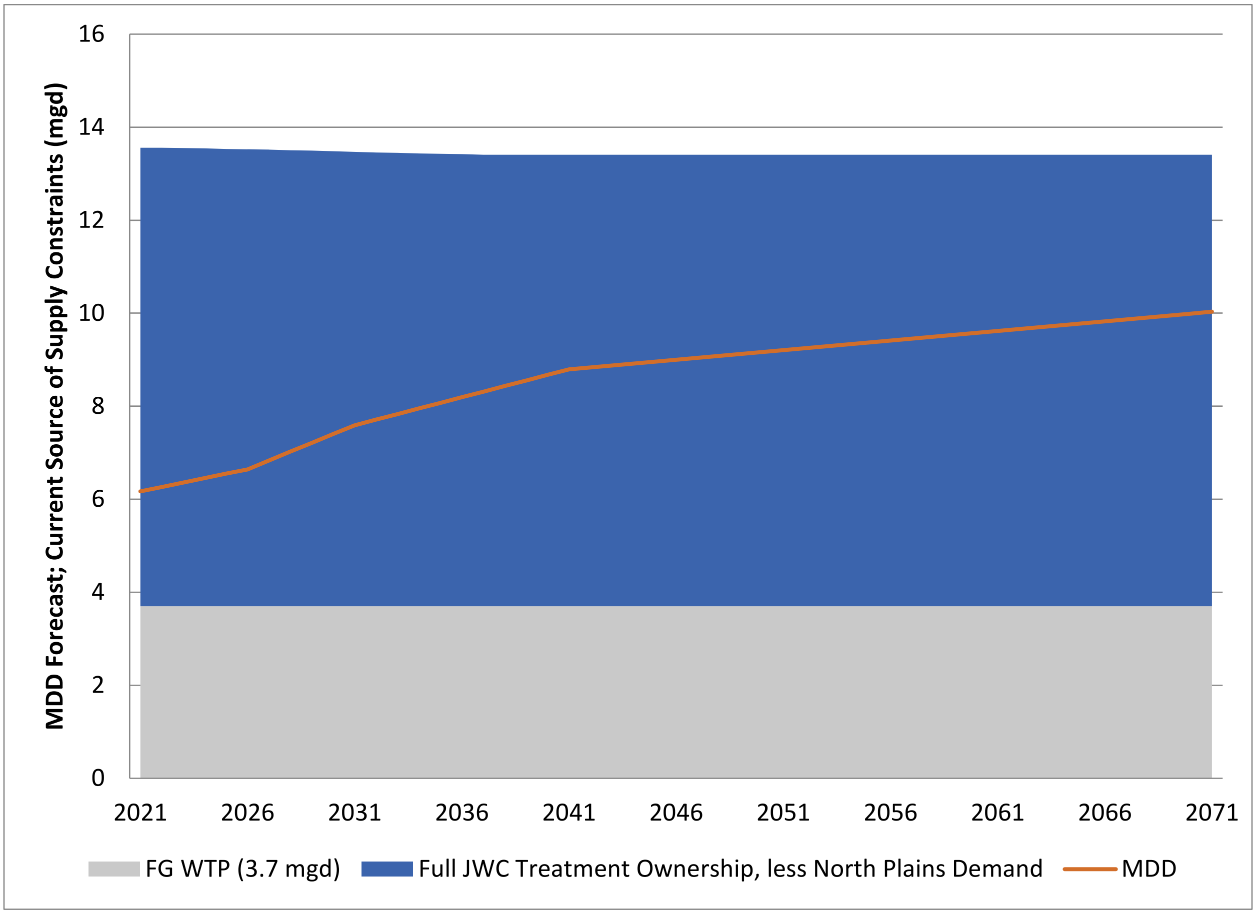
Table 4-4 | North Plains Wholesale Supply – Contracted Capacity

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

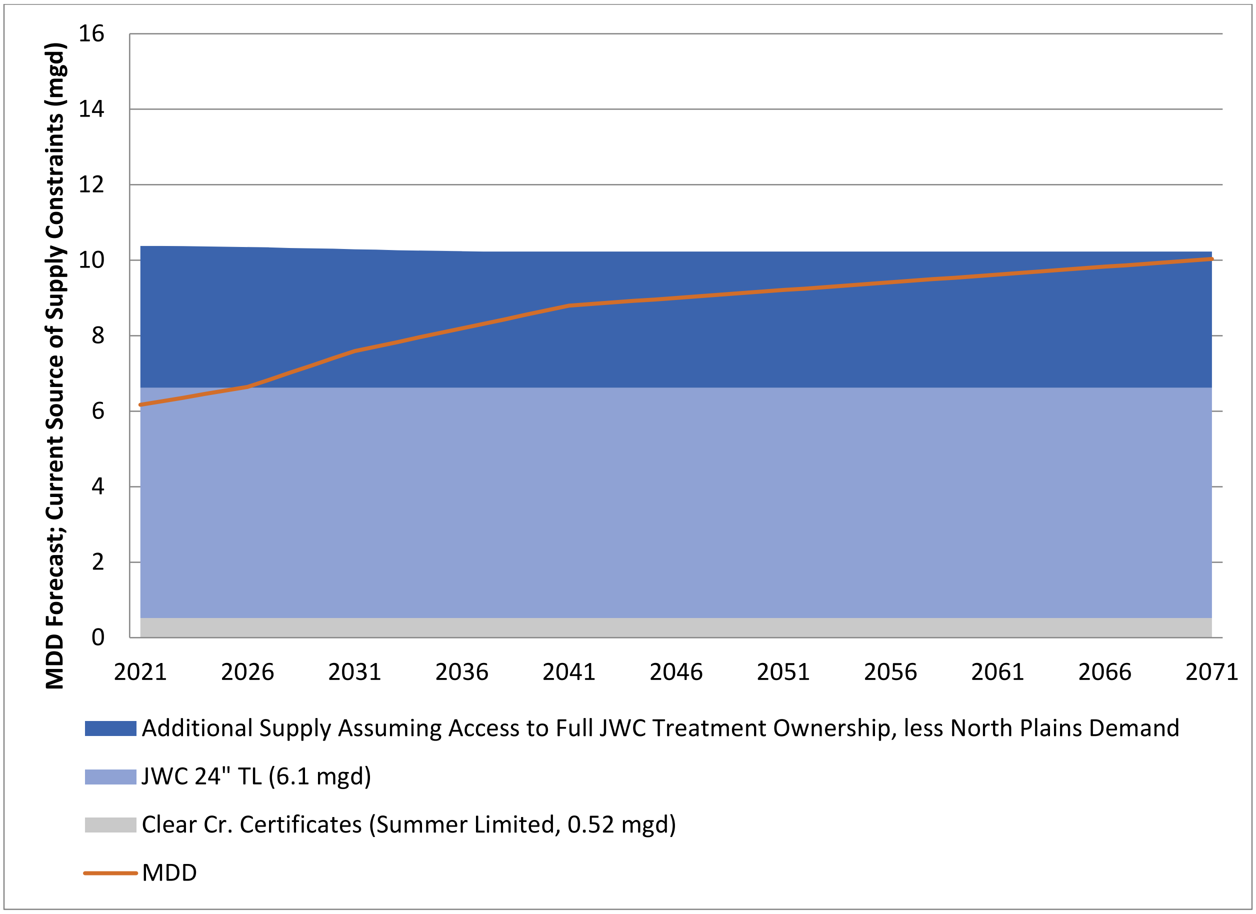


Figure 4-6 – The City does not have sufficient available summer rights or transmission capacity to utilize the full treatment capacity of either the City WTP or the JWC WTP. City supply is limited to the 1917 water right, and JWC supply is most limited by the 24-inch JWC TL capacity. With current agreements, 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. There may also be an option to increase the allowable velocity in the 24-inch JWC TL, providing for increased flow to the City without reducing the Hillsboro supply. This option should also be discussed with the City of Hillsboro. 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. A new pipeline, whether complete replacement or parallel, is included in the SRP projects.

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' 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

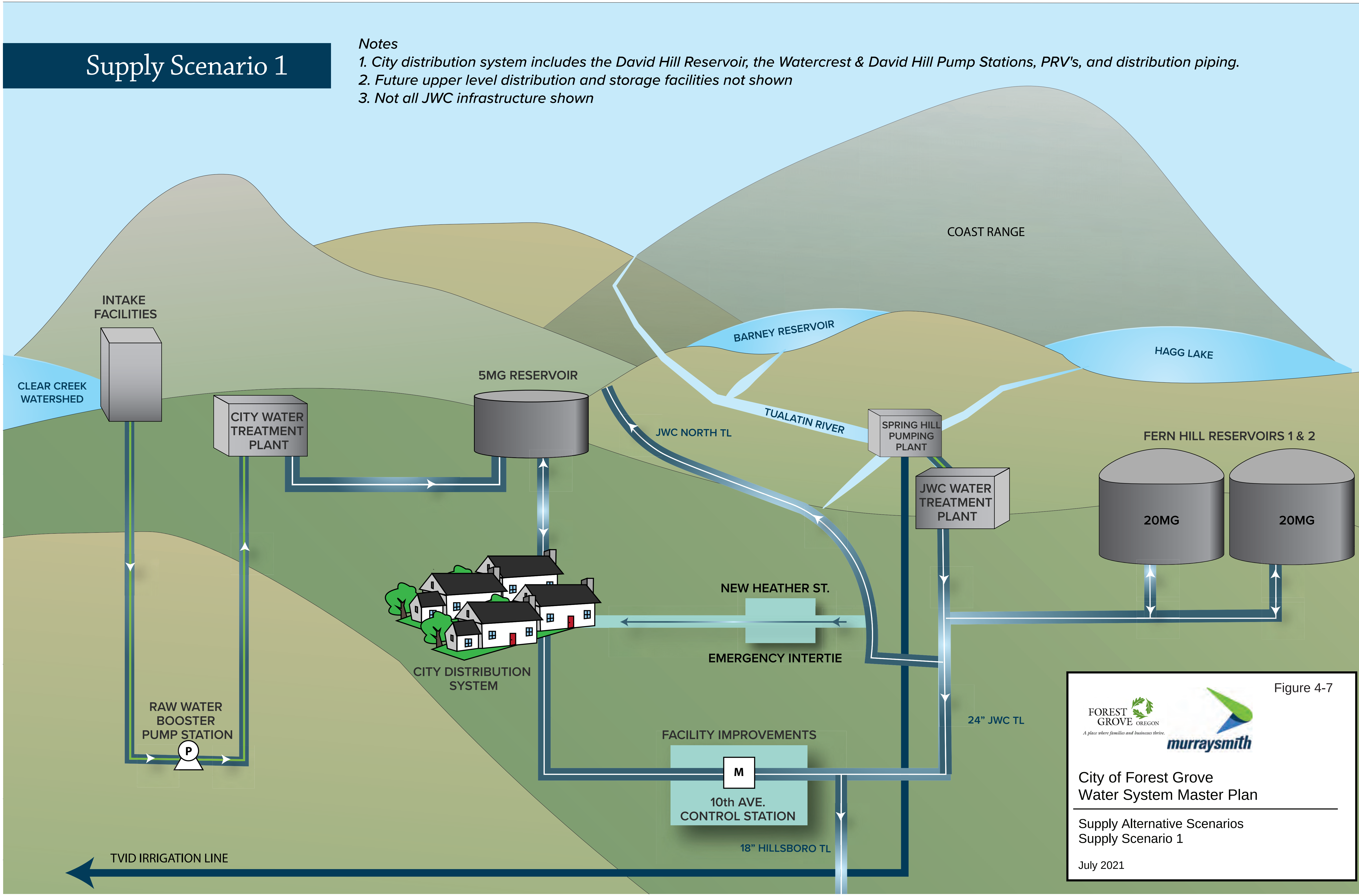
The City should complete a Water Supply Study to make an informed decision on the best long-term supply strategy and fill the remaining information gaps. The following actions are recommended as part of the Water Supply Study.

- 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 or increase in allowable velocity 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 eval 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
COAST RANGE
INTAKE FACILITIES
CLEAR CREEK WATERSHED
CITY WATER TREATMENT PLANT
5MG RESERVOIR
JWC NORTH TL
BARNEY RESERVOIR
TUALATIN RIVER
HAGG LAKE
SPRING HILL PUMPING PLANT
JWC WATER TREATMENT PLANT
FERN HILL RESERVOIRS 1 & 2
20MG
20MG
NEW HEATHER ST.
EMERGENCY INTERTIE
CITY DISTRIBUTION SYSTEM
RAW WATER BOOSTER PUMP STATION
P
FACILITY IMPROVEMENTS
M
10th AVE. CONTROL STATION
24" JWC TL
18" HILLSBORO TL
TVID IRRIGATION LINE
Figure 4-7
FOREST GROVE OREGON
A place where families and businesses thrive.
murraysmith
City of Forest Grove
Water System Master Plan
Supply Alternative Scenarios
Supply Scenario 1
July 2021

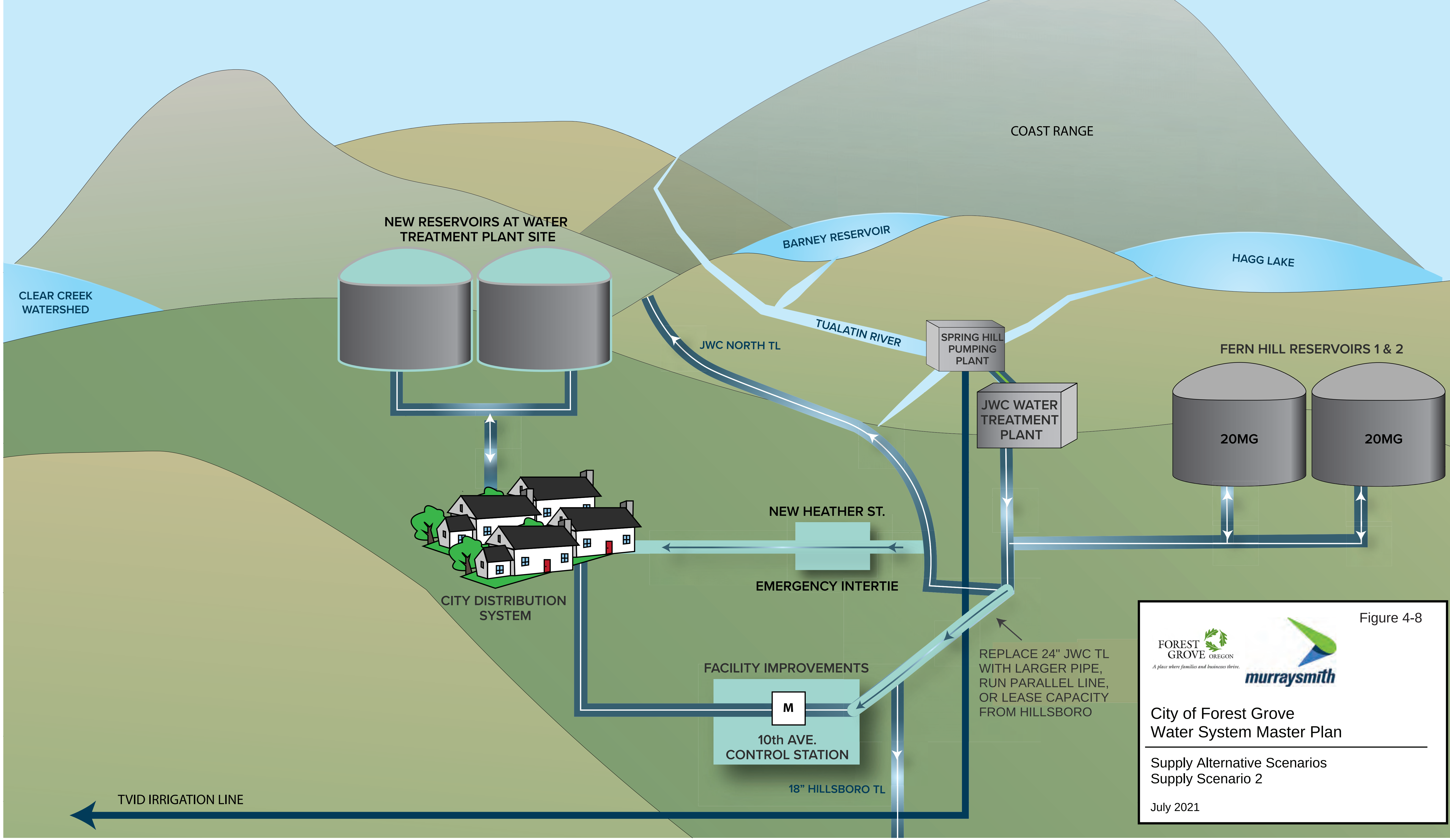
Supply Scenario 2

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



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

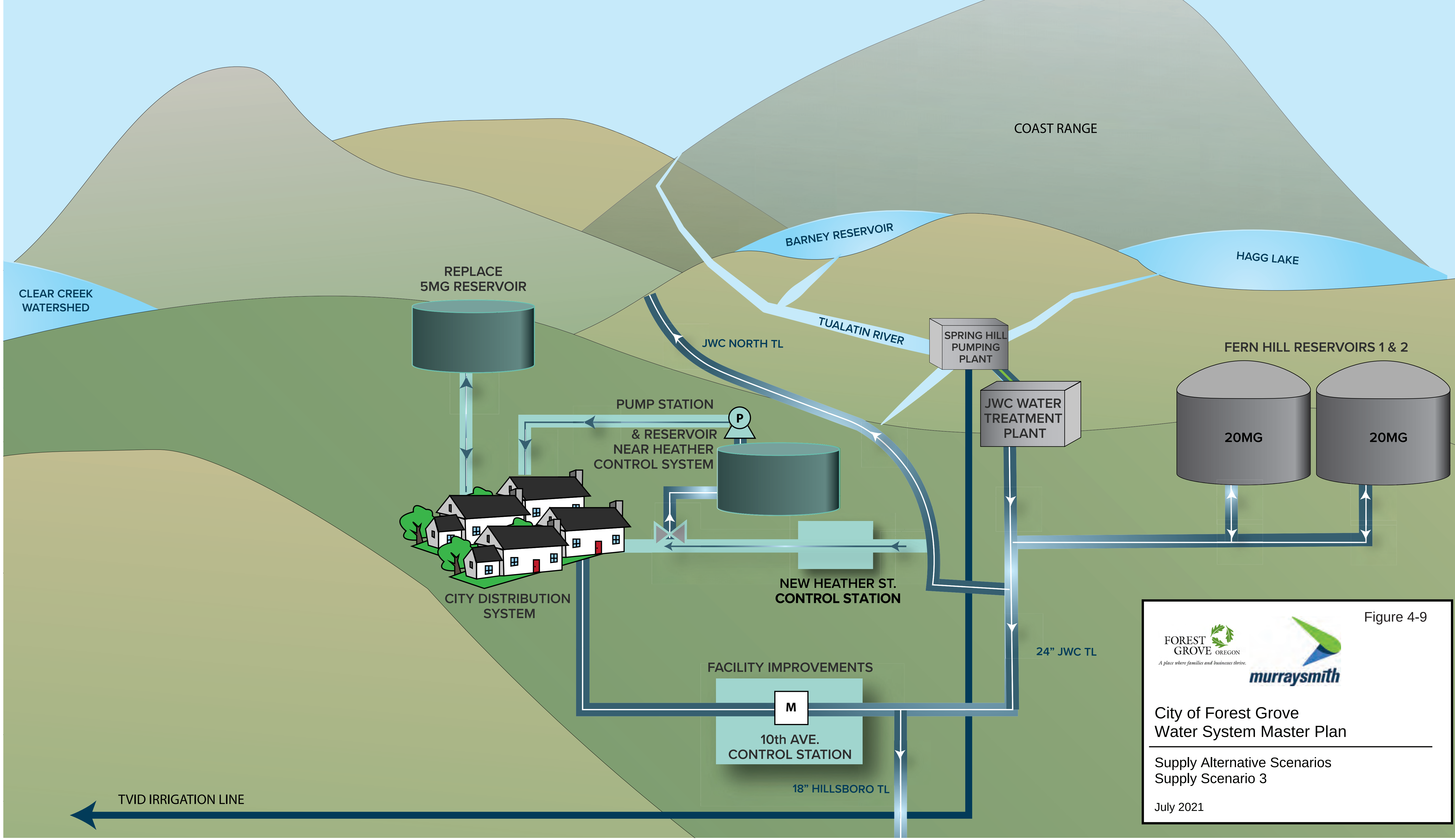


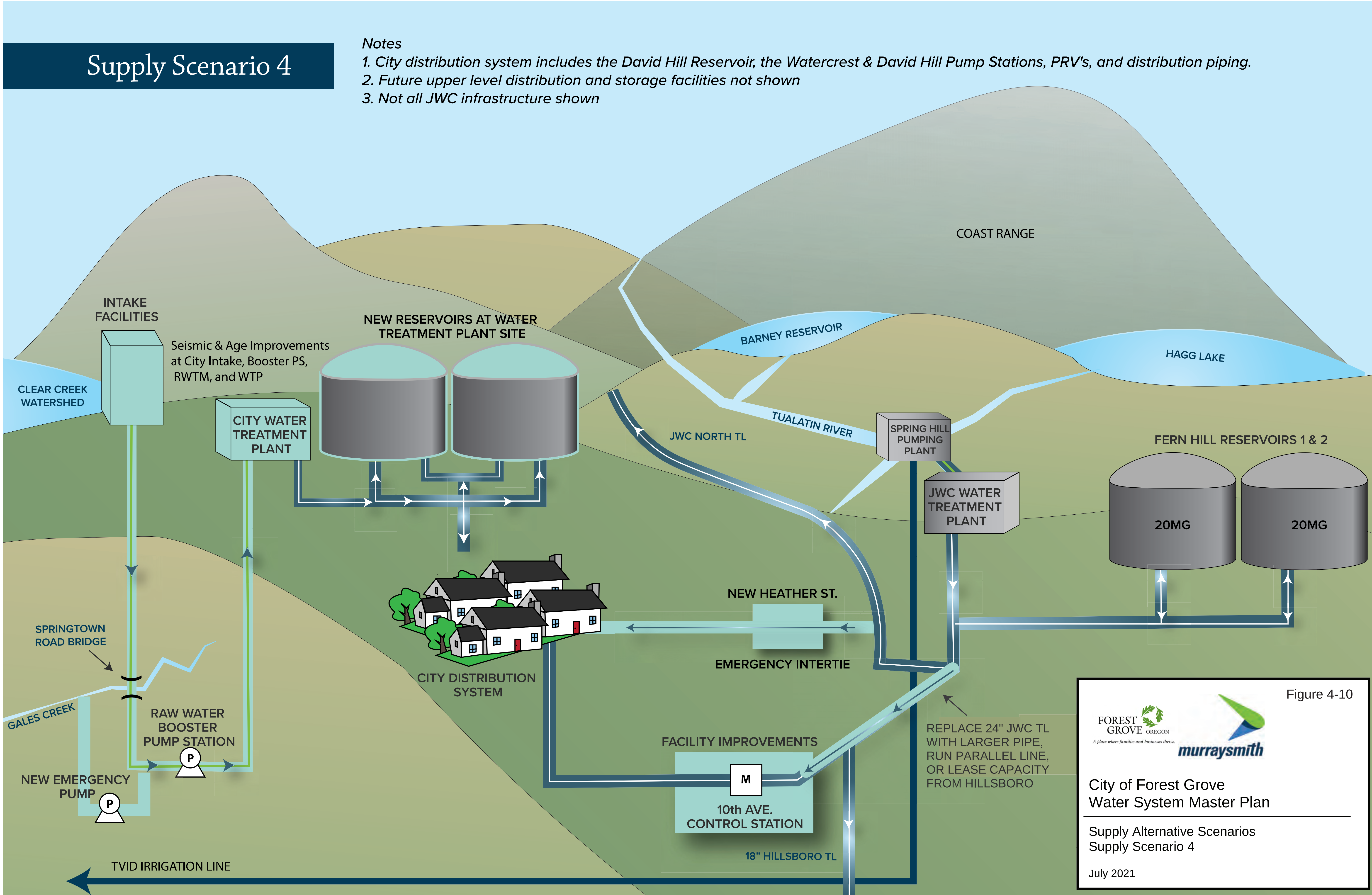
Figure 4-9

FOREST GROVE OREGON
A place where families and businesses thrive.
murraysmith

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
COAST RANGE
INTAKE FACILITIES
Seismic & Age Improvements at City Intake, Booster PS, RWTM, and WTP
NEW RESERVOIRS AT WATER TREATMENT PLANT SITE
BARNEY RESERVOIR
HAGG LAKE
CLEAR CREEK WATERSHED
CITY WATER TREATMENT PLANT
JWC NORTH TL
TUALATIN RIVER
SPRING HILL PUMPING PLANT
FERN HILL RESERVOIRS 1 & 2
JWC WATER TREATMENT PLANT
20MG
20MG
NEW HEATHER ST.
EMERGENCY INTERTIE
SPRINGTOWN ROAD BRIDGE
CITY DISTRIBUTION SYSTEM
GALES CREEK
RAW WATER BOOSTER PUMP STATION
P
NEW EMERGENCY PUMP
P
FACILITY IMPROVEMENTS
M
10th AVE. CONTROL STATION
REPLACE 24" JWC TL WITH LARGER PIPE, RUN PARALLEL LINE, OR LEASE CAPACITY FROM HILLSBORO
18" HILLSBORO TL
TVID IRRIGATION LINE
Figure 4-10
FOREST GROVE OREGON
A place where families and businesses thrive.
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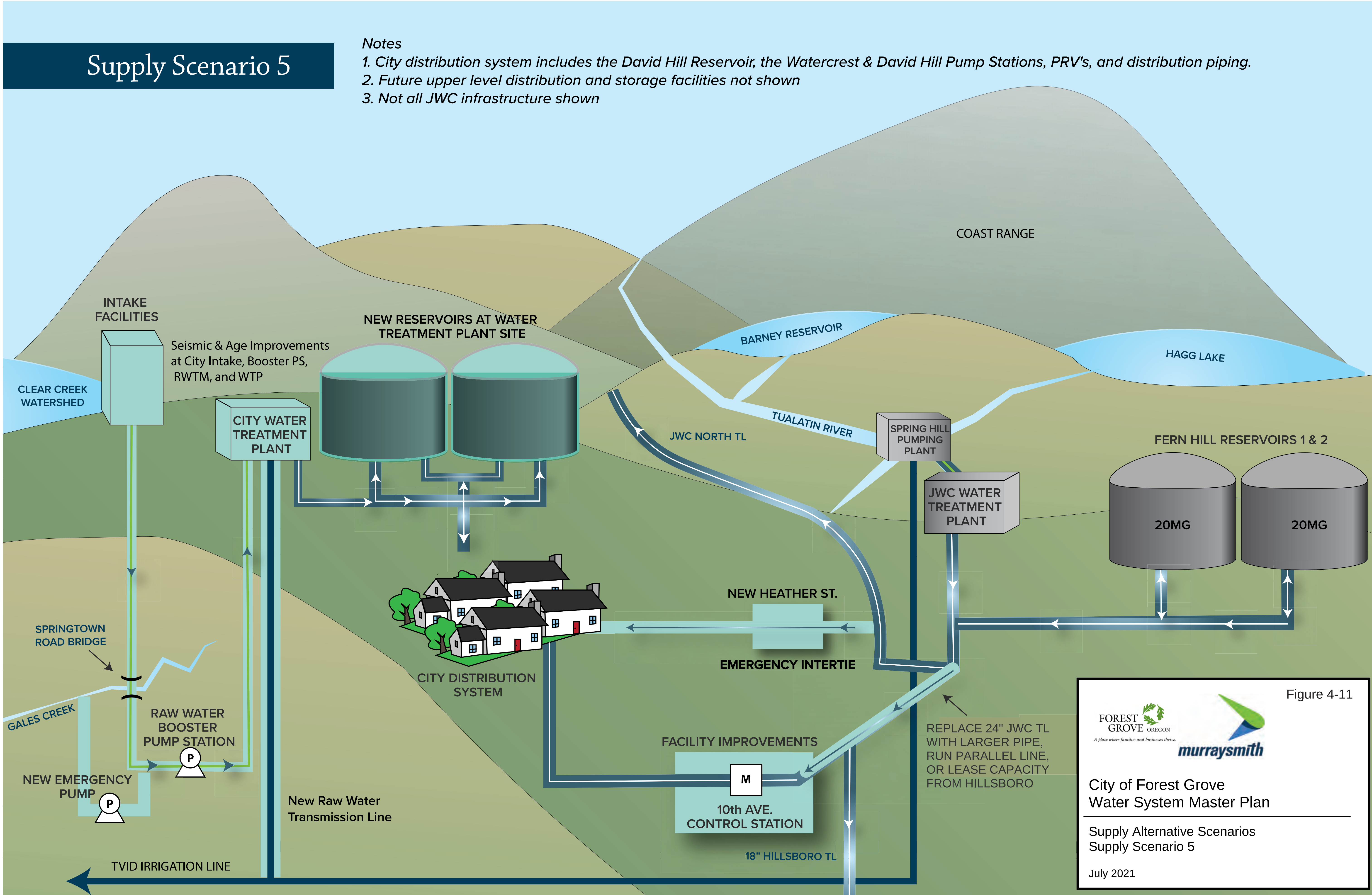
City of Forest Grove
Water System Master Plan
Supply Alternative Scenarios
Supply Scenario 4
July 2021



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
COAST RANGE
INTAKE FACILITIES
Seismic & Age Improvements at City Intake, Booster PS, RWTM, and WTP
NEW RESERVOIRS AT WATER TREATMENT PLANT SITE
CLEAR CREEK WATERSHED
CITY WATER TREATMENT PLANT
BARNEY RESERVOIR
HAGG LAKE
TUALATIN RIVER
JWC NORTH TL
SPRING HILL PUMPING PLANT
JWC WATER TREATMENT PLANT
FERN HILL RESERVOIRS 1 & 2
20MG
20MG
NEW HEATHER ST.
EMERGENCY INTERTIE
SPRINGTOWN ROAD BRIDGE
CITY DISTRIBUTION SYSTEM
GALES CREEK
RAW WATER BOOSTER PUMP STATION
P
NEW EMERGENCY PUMP
P
FACILITY IMPROVEMENTS
M
10th AVE. CONTROL STATION
REPLACE 24" JWC TL WITH LARGER PIPE, RUN PARALLEL LINE, OR LEASE CAPACITY FROM HILLSBORO
New Raw Water Transmission Line
18" HILLSBORO TL
TVID IRRIGATION LINE
Figure 4-11
FOREST GROVE OREGON
murraysmith
City of Forest Grove
Water System Master Plan
Supply Alternative Scenarios
Supply Scenario 5
July 2021

Section **5**

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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.

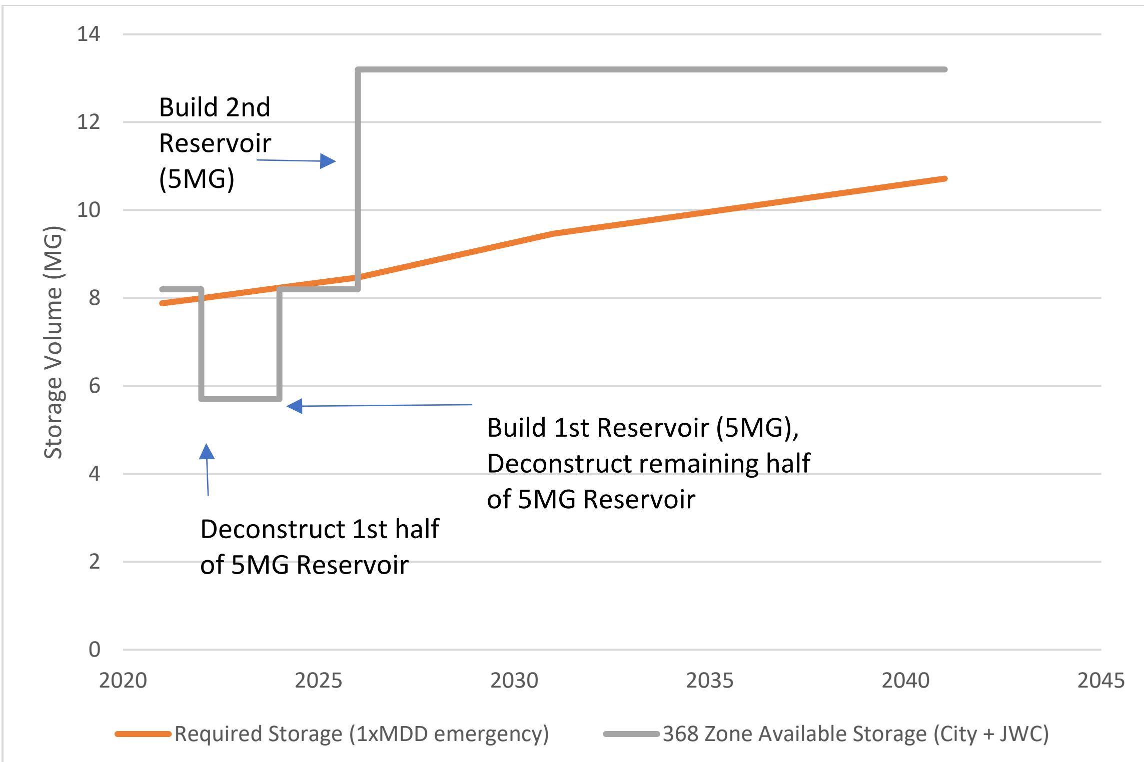
5.3.6.1 Storage Analysis Findings

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 currently provides adequate storage volume but will require an additional 2.52 MG in 20 years, and 3.54 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 (10 MG total). Additionally, the upper zones (435, 540, and GCSA) will max out existing storage in about 10 years, and by 50 years require an additional 0.55 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 including 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 during those periods.

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

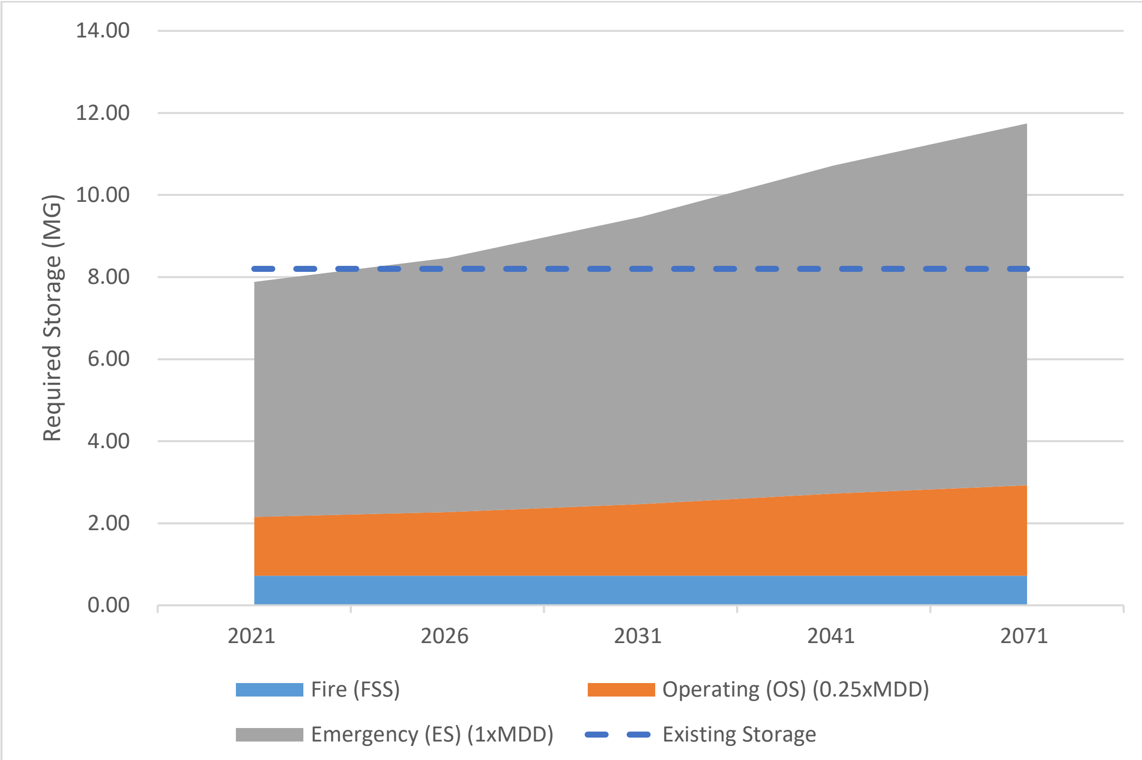


Figure 5-3 | 435, 540, and GCSA Zone Storage Requirements

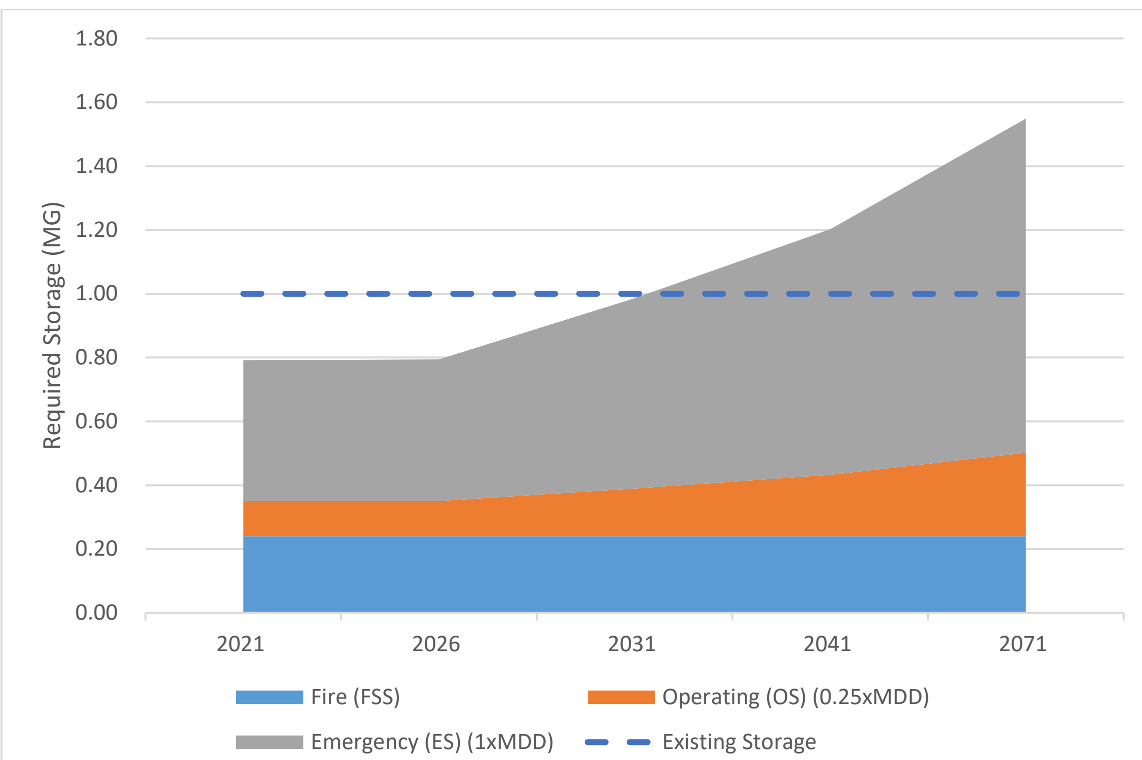
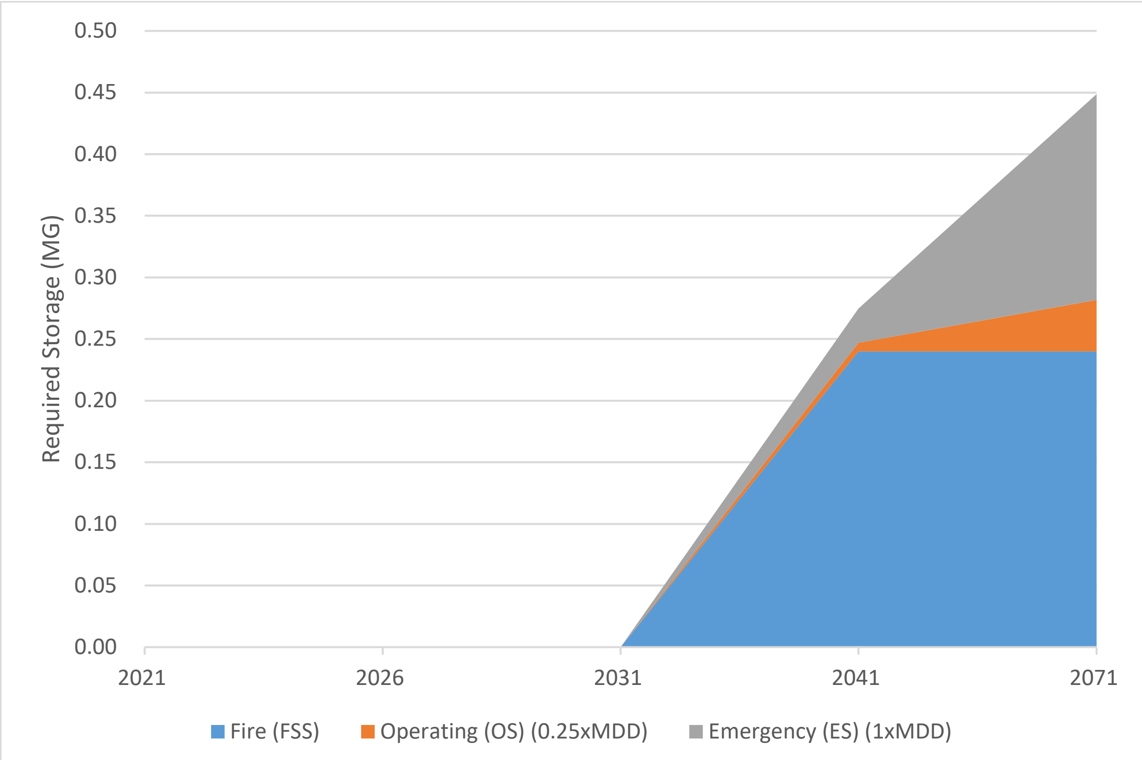


Figure 5-4 | 710 and 880 Zone Storage Requirements



Note:

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

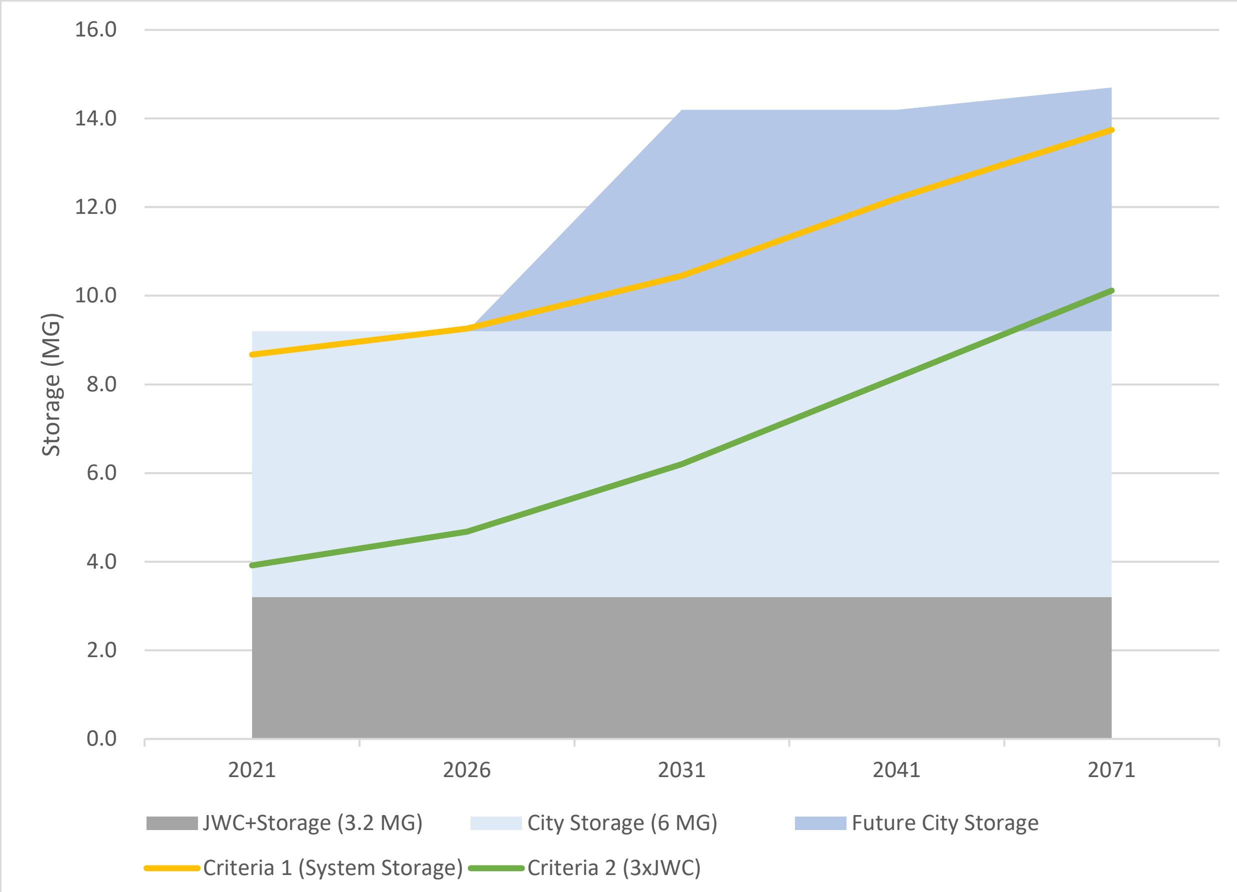
Table 5-7 | Total Storage Deficiencies

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.

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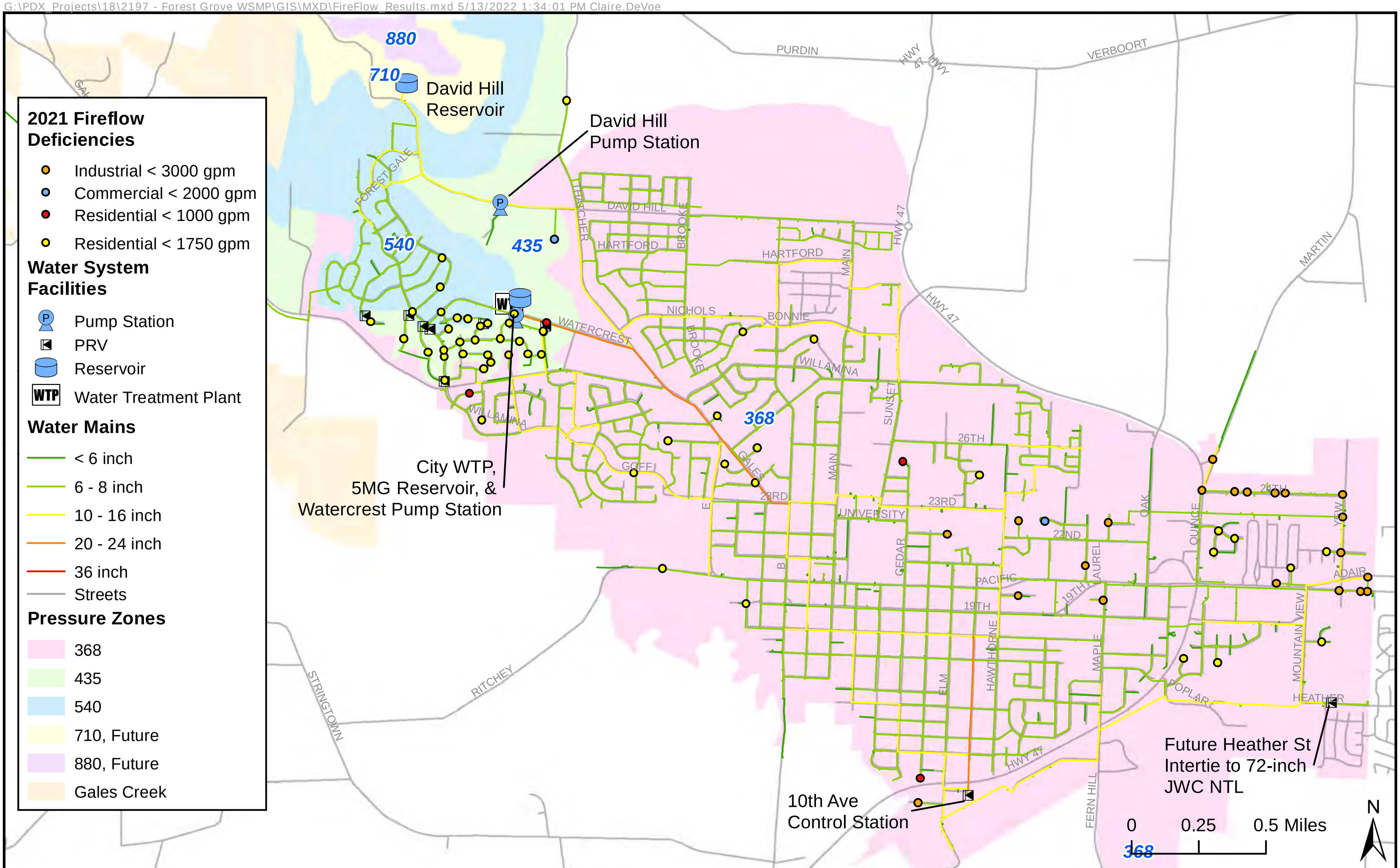

City of Forest Grove
Water System Master Plan

Figure 5.6
Hydraulic Model Calibration
2021 Fire Flow Deficiencies

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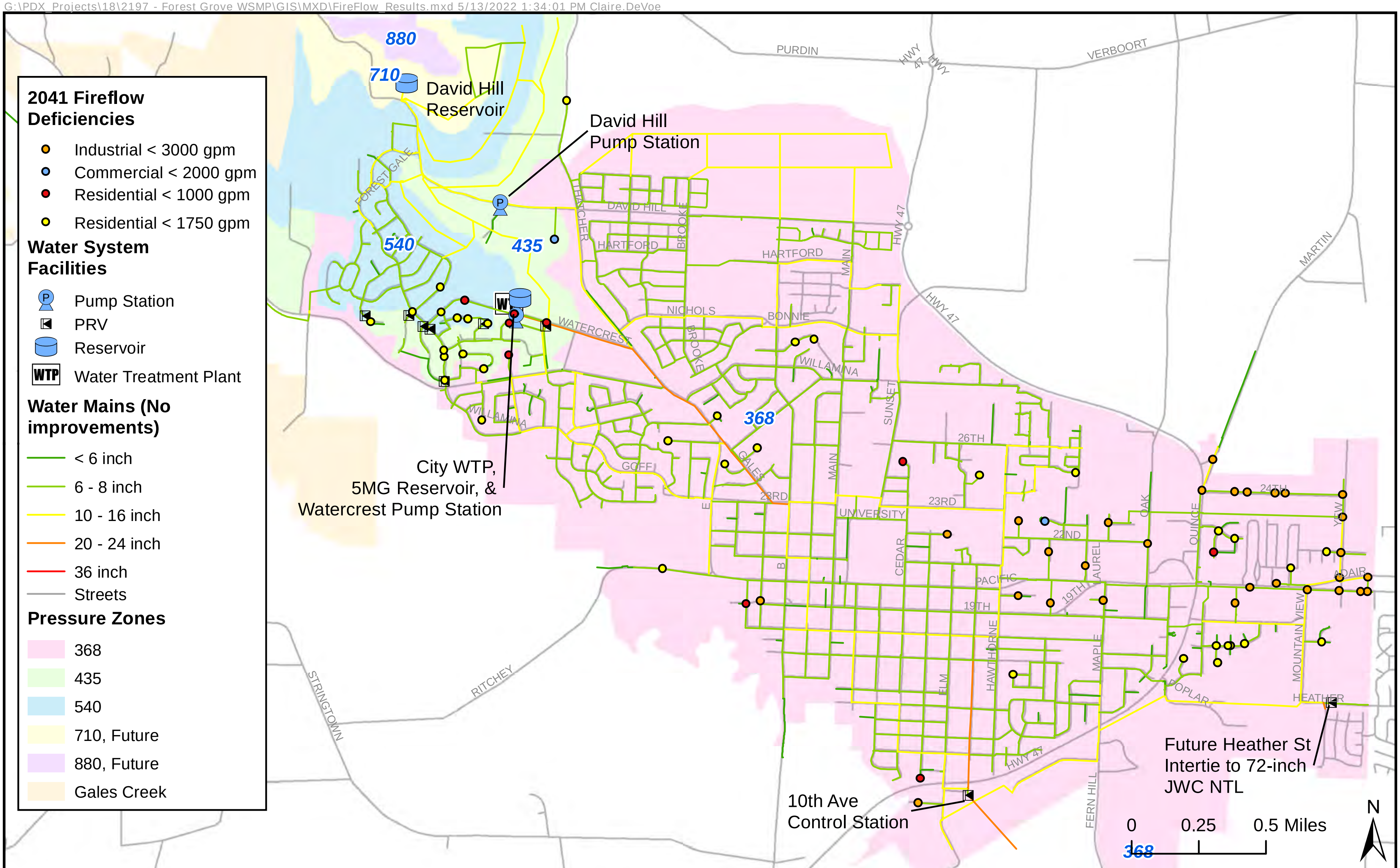

City of Forest Grove
Water System Master Plan

Figure 5.7
Hydraulic Model Calibration
2041 Fire Flow Deficiencies
No Improvements

murraysmith

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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 (TTHM) 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**

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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	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 utlize alternative water sources to suppress fires 2. David Hill Reservoir continued operation 3. 5MG WTP Reservoir continued opration	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** (Table 12 from the SRP). 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

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

Notes:

1. Upper estimate represents median + 1 lognormal deviation.
2. Lower estimate represents median - 1 lognormal deviation.
3. Table comprised of Table 12 from the SRP

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**

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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 or increasing the maximum allowable velocity in the existing 24-inch JWC TL. 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) and 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

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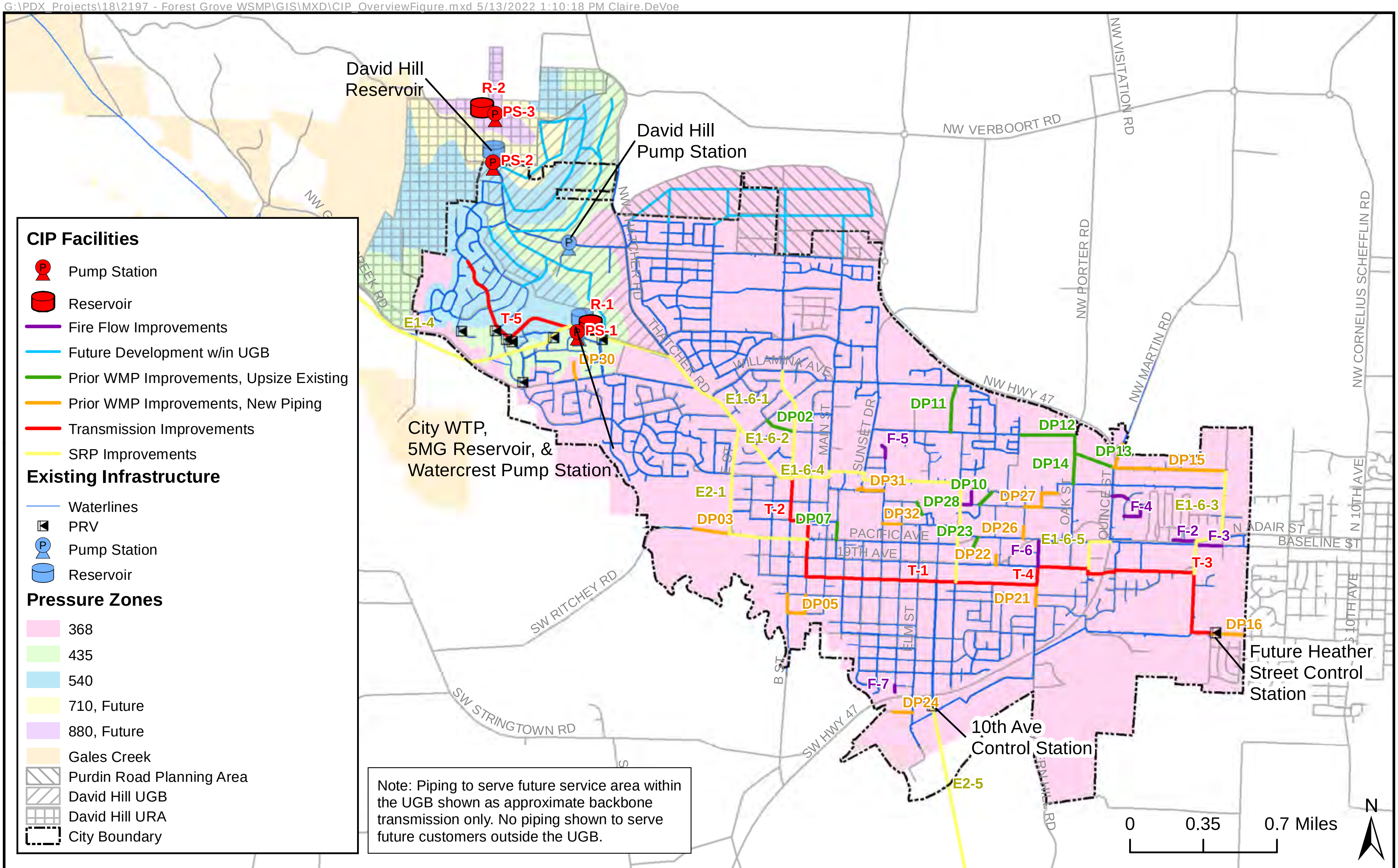

murraysmith

City of Forest Grove
Water System Master Plan

Figure 7-1
CIP Improvements

FOREST GROVE OREGON
A place where families and businesses thrive.

- 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, or 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
	S-2	Barney Reservoir raw water capacity "buy-back" from TVWD				$36,400,000		Growth, Reliability
	S-3	Long Term Water Supply Study and City WTP Facility Plan	$400,000				$400,000	Reliability
	S-9	Increase transmission capacity in the JWC 24-inch TL (See CIP E2-5 for long term costs)						Capacity
	JWC Supply Projects - Forest Grove share							
	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	Growth
		Storage Subtotal	**$11,300,000**	**$11,300,000**	**$1,000,000**	**$-**	**$23,600,000**	
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	*Fire Flow Improvements*							
	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 – 23rd 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
	HDR Improvements - New Pipes							
	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

Improvement Category	Project No.	Project Title	CIP Cost Summary[1] 5-year 2022 to 2027	5 to 10-year 2028 to 2032	10 to 20-year 2033 to 2042	20-year +	20-year TOTAL	Purpose
	HDR Improvements - Upsize Existing Pipes							
	HDR_DP03	Tom McCall Upper Elementary			$390,000		$390,000	HDR Upsize
	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 (upsize 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

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	
	E1-6-5	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
	E1-7	Structural analysis of Public Works Office Building to assess the Immediate Occupancy level 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
	S-9	Increase transmission capacity in the JWC 24-inch TL (See CIP E2-5 for long term costs)						
Storage	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			
Pump Stations	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	
Seismic	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			
	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 (upsize 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				
Planning	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**

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Appendix

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APPENDIX A
PLATE 1: WATER SYSTEM MAP

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SEE INSET FOR GALES CREEK SERVICE AREA AND INTAKE FACILITIES
GALES CREEK SERVICE AREA AND GALES CREEK WATERSHED INTAKE FACILITIES
DAVID HILL PLANNING AREA
PURDIN ROAD PLANNING AREA
CITY OF FOREST GROVE
CITY OF CORNELIUS
David Hill Pump Station
David Hill Reservoir
City WTP
5 MG Reservoir
Watercrest Pump Station
Raw Water Booster Pump Station
10th Avenue Control Station
NW HILLSIDE RD
NW KANSAS CITY RD
NW GALES CREEK RD
NW STRINGTOWN RD
NW THATCHER RD
THATCHER RD
GALES CREEK RD
WILLAMINA AVE
SUNSET DR
MAIN ST
PACIFIC AVE
19TH AVE
E ST
B ST
ELM ST
MAPLE ST
OAK ST
QUINCE ST
NW HWY 47
SW HWY 47
NW MARTIN RD
NW PORTER RD
NW CORNELIUS SCHEFFLIN RD
N ADAIR ST
BASELINE ST
N 33TH AVE
N 30TH AVE
S 30TH AVE
SW FERN HILL RD
SW STRINGTOWN RD
SW RITCHEY RD
SW DILLEY RD
Legend
Existing Reservoir
Existing Pump Station
Water Treatment Plant
PRV
Intertie
Intake Facility
Existing Raw Water Transmission
Existing Water Main
Urban Growth Boundary (UGB)
City Limits
Railroad
Pressure Zones
368
435
540
710, Future
880, Future
GalesCreek
Planning Areas:
David Hill UGB
Purdin Road Planning Area
David Hill URA
PLATE 1
city of forest grove
City of Forest Grove
Water System Master Plan
Existing Water System Map
murraysmith

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APPENDIX B
FOREST GROVE AND DILLEY PRV FLOW TEST, JWC, 2019

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MEMORANDUM

To: Kevin Hanway, General Manager

From: Nesh Mucibabic, Principal Engineer

Date: May 6, 2019

Re: Uncounted flows along 24-inch transmission main between JWC Plant and delivery points at the City of Hillsboro Dilley and Forest Grove pressure reducing valve (PRV) facilities.

1. Introduction

In spring of 2017, the JWC installed a new 24-inch insertion magnetic flow meter on the 24-inch finished water transmission main at the JWC Plant. The 24-inch insertion flow meter provided an opportunity to compare combined flows sent via 24-inch transmission main with the individual flows recorded at City of Hillsboro (COH) Dilley PRV and Forest Grove PRV facilities. Both facilities are located in Forest Grove, 1.5 miles NE from the treatment plant, close to the intersection of Hwy 47 and Elm Street.

Table 1 shows monthly flow volumes recorded at JWC 24-inch insertion flow meter and water volumes recorded at Dilley PRV and Forest Grove (FG) PRV facilities, compares differences, and calculates capture rates that indicated approximately 25% to 30% uncounted water loss.

Table 1 Monthly Water Volumes Recorded at Flow Meters

Month	Monthly Water Volumes (MG) Recorded at				Uncounted Water Volume (MG)	
	JWC 24" Insertion Flow Meter	Dilley PRV Magnetic Flow Meter	Forest Grove PRV Ultrasonic Flow Meter	Sum: Dilley PRV + FG PRV Water Volumes	JWC 24" Water Volume - (Dilley PRV + FG PRV) Water Volumes	Percent Capture
May-18	29.5	15.9	10.98	26.9	2.56	**91%**
Jun-18	45.4	12.2	27.33	39.5	5.92	**87%**
Jul-18	113.4	16.8	65.78	82.6	30.87	**73%**
Aug-18	132.9	14.0	80.87	94.9	38.01	**71%**
Sep-18	103.7	15.3	61.41	76.7	27.02	**74%**
Oct-18	82.0	14.2	47.38	61.6	20.35	**75%**

Uncounted water volumes may be caused by two main reasons:

1. Potential leaks from 24-inch transmission main, and/or,
2. Inaccuracy in flow/volume recorded at the JWC 24-inch insertion flow meter, COH Dilley PRV magnetic flow meter and/or FG PRV ultrasonic flow meter.

A flow testing procedure was developed, reviewed and approved by JWC, COH and Forest Grove representatives. Testing was conducted on March 27, 2019, to verify the accuracy of the water meters and potential leakage from 24-inch transmission main. A total of four tests were performed. The testing team consisted of Mike Anunsen and Alexis Cooley from COH Water Department, Jamie Davis and Adam Thompson from COH Water Operations, Jeff Wright from JWC WTP, and Brian Dixon, Richard Blackmun and Derek Robbins from the City of Forest Grove. All flow data recorded during testing was signed and approved by team members, and it is included in Attachment A of this memo.

2. Testing Procedure and Results

The testing included four tests. The test purpose and results are described in the following text. The site testing data is provided in Attachment A at the end of this memo. The Table 2 and Figures 1 to 4 were developed to numerically and graphically present original testing data and SCADA data recorded at the plant. Descriptions of each test and of the test results follows Table 2.

Table 2 Test Results

Dilley/Forest Grove/JWC 24" Meter Test Results								
Wednesday, March 27, 2019								
Procedure:			Conference Call Phone Number 503-345-7637					
Test #1 = Forest Grove and Dilley both Closed			Mike Anunsen will call the times.					
Test #2 = Forest Grove closed, Dilley Open								
Test #3 = Forest Grove Open, Dilley Closed								
Test #4 = Forest Grove and Dilley Open								
TEST #1	Target Flow	Time of Day	JWC Flow per Meter Display	Dilley Meter Display	Forest Grove Meter Display	Difference	Difference	
Both Valves Closed	gpm	HR:MIN	gpm	gpm	gpm	gpm	%	
	0	10:01:00 AM	0	0	0	0	0	
TEST #2	Target Flow	Time of Day	JWC Flow per Meter Display	Dilley Meter Display	Forest Grove Meter Display	Difference	Difference	
Dilley PRV Open	gpm	HR:MIN	gpm	gpm	gpm	gpm	%	
FG PRV Closed	0	10:02:00 AM	0	0	Closed	0		
	250	10:07:00 AM	252	269	Closed	-17	7%	
	500	10:11:00 AM	492	502	Closed	-10	2%	
	750	10:14:00 AM	818	815	Closed	3	0%	
	1000	10:18:00 AM	987	1000	Closed	-13	1%	
	1500	10:22:00 AM	1514	1500	Closed	14	1%	
	2000	NA	NA	NA	Closed			
TEST #3	Target Flow	Time of Day	JWC Flow per Meter Display	Dilley Meter Display	Forest Grove Meter Display	Difference	Difference	
Dilley PRV Closed	gpm	HR:MIN	gpm	gpm	gpm	gpm	%	
FG PRV Open	0	10:26:00 AM	0	Closed	0	0		
	250	10:31:00 AM	182	Closed	275	-93	41%	
	500	10:40:00 AM	502	Closed	525	-23	4%	
	750			Closed				
	1000	10:46:00 AM	1462	Closed	950	512	42%	
	1500	10:50:00 AM	2225	Closed	1600	625	33%	
	2000	10:54:00 AM	3085	Closed	2100	985	38%	
TEST #4	Target Flow	Time of Day	JWC Flow per Meter Display	Dilley Meter Display	Forest Grove Meter Display	FG+Dilley	Difference	Difference
Dilley PRV Open	gpm	HR:MIN	gpm	gpm	gpm	gpm	gpm	%
FG PRV Open	0	11:13:00 AM	0	0	0			
	250							
	500	11:24:00 AM	1012	550	400	950	62	6%
	750							
	1000	11:29:00 AM	2478	1020	975	1995	483	22%
	1500	11:33:00 AM	3915	1520	1500	3020	895	26%
	2000							

Test #1: Purpose - Check for leakage from JWC 24-inch Transmission Main
COH Dilley and FG PRVs fully closed (no flow) to check whether the 24-inch insertion flow meter at the plant records any flow.

Test #1: Results: No flows were recorded at the 24-inch insertion meter. This indicates that there is no leakage from 24-inch transmission line between the JWC Plant and Dilley and FG PRVs. For references see Attachment A, and Table 2-Test 1 data.

Test #2: Purpose - Compare flows at JWC 24-inch insertion flow meter and Dilley PRV magnetic flow meter to check for accuracy of both meters.
The Forest Grove PRV was closed during this test and Dilley PRV was open. The test was performed for different flow rates of 250, 500, 750, 1000, and 1500 gpm. Proposed test at 2000 gpm was cancelled by COH Operations due to a potential of overflowing Dilley reservoir. To achieve those flows valves in Dilley PRV station were throttled.

Test #2 Results: Flows recorded at different flow rates at COH Dilley PRV were almost identical with flows recorded at the JWC 24-inch insertion flow meter. This indicates that both the JWC 24-inch Insertion meter and the Dilley PRV magnetic meter operate at very high accuracy. See Attachment A, Table 2-Test 2, and Figure 1.

March 27, 2019 - Dilley PRV is open; FG PRV is closed

Figure 1

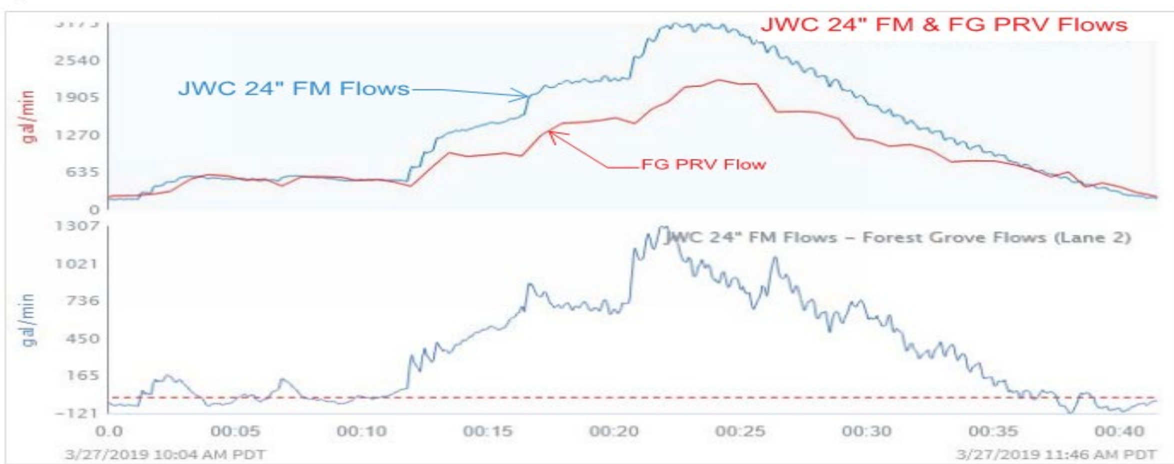
<u>Test #3 Purpose</u>: <u>Check for FG meter accuracy by comparing flows at JWC 24-inch insertion flow meter and FG PRV ultrasonic flow meter</u>

The Dilley PRV was closed during this test. The test was performed for different flow rates of 250, 500, 750, 1000, and 1500 gpm. To achieve those flows valves in FG PRV station were throttled. However, FG crew was not able to throttle their valves to establish constant flow of 750 gpm and the 750 gpm test was cancelled.

<u>Test #3 Results:</u> Flows recorded at Forest Grove PRV ultrasonic flow meter were significantly different from flows measured and recorded at the 24-inch insertion flow meter. The flows recorded at the FG ultrasonic flow meter were significantly lower than flows recorded at 24-inch Insertion meter. Since Test #2 indicated that the JWC 24-inch insertion meter provides accurate flow readings, this difference indicates potentially significant inaccuracy (under-reading) of the Forest Grove flow meter (see Attachment A, Table 2-Test 3, Figure 2).

March 27, 2019 - Dilley PRV is closed, FG PRV is open

Figure 2



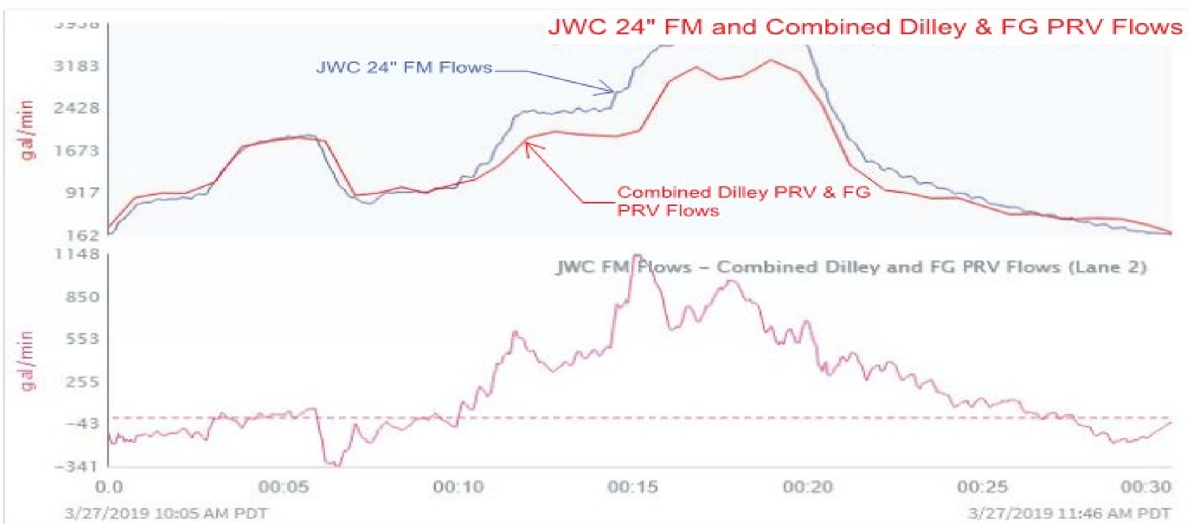
<u>Test #4 - Purpose</u>: Compare flows recorded at the JWC 24-inch insertion meter with combined flows recorded at Dilley PRV and Forest Grove PRV.

Both the Dilley PRV and Forest Grove PRV were open, and valves at those locations were throttled to readings that showed delivery through each of the PRVs of half of the target flows through the JWC 24-inch insertion valve. The test was performed for different flow rates of 1000, 2500, and approximately 4000 gpm through JWC 24-inch insertion flow meter. The readings on the JWC 24-inch insertion meter should have equaled the sum of the flows recorded at the Dilley PRV and the FG PRV for each flow rate.

<u>Test #4 - Results:</u> Flow recorded at JWC 24-inch Insertion flow meter was significantly higher than combined flows at Dilley and FG PRVs, as shown in Attachment A, Table 2-Test #4 and Figure #3. Since Test #2 demonstrated the accuracy of JWC 24-inch meter and Dilley PRV, the Test #4 result indicates that the FG PRV is recording flows that are significantly lower than actual flow.

March 27, 2019 Dilley PRV & FG PRV both open

Figure 3



3. Further Evaluation

Two correlation graphs were developed based on March 27, 2019 flow testing data to establish relationship between Dilley PRV and the 24" Insertion Meter flows (Figure 4) and between Forest Grove PRV and the 24-inch Insertion Meter flows (Figure 5).

From Figure 4 it could be seen that flows of 250, 500, 750, 1000, and 1500 gpm measured and recorded at Dilley PRV flow meter were almost identical with related flows recorded at the same time at the 24-insertion flow meter. However, the Forest Grove flow meter (Figure 5) recorded significantly lower flows than the 24-inch Insertion flow meter. The orange line in Figure 5 shows the approximate line where the flow readings from the JWC 24-inch insertion meter should have been based on the readings on the FG PFV. (for example: 1500 gpm recorded at 24-inch insertion meter relates to approximately 1000 gpm recorded at FG PRV, and 3000 gpm recorded at 24" insertion flow meter relates to approximately 2000 gpm recorded at FG PRV). However, the actual flow readings in the JWC meter, as illustrated by the blue line, are significantly higher than the flow reading on the FG PRV.

Figure 4. Flows recorded at 24" insertion flow meter and Dilley PRV flow meter

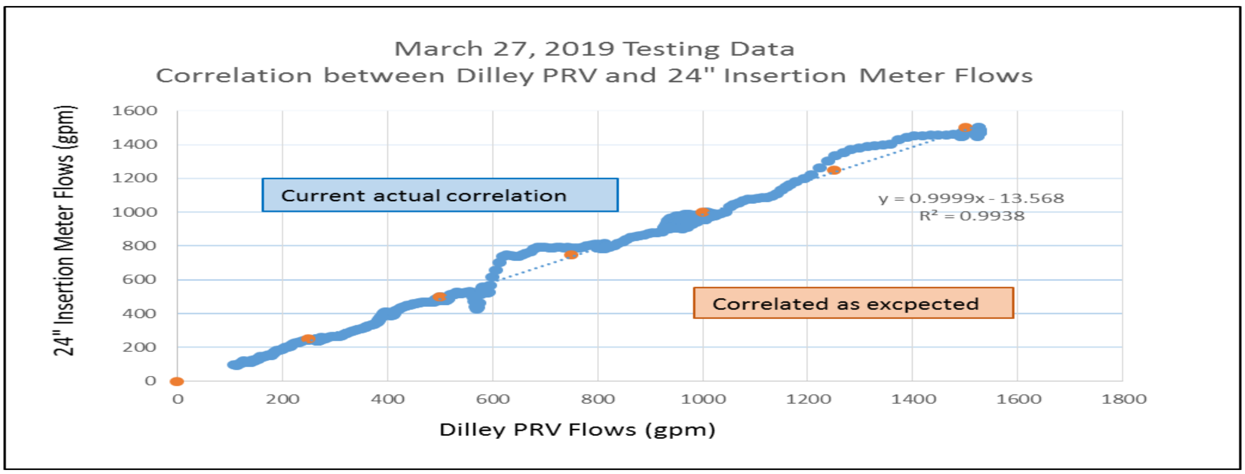
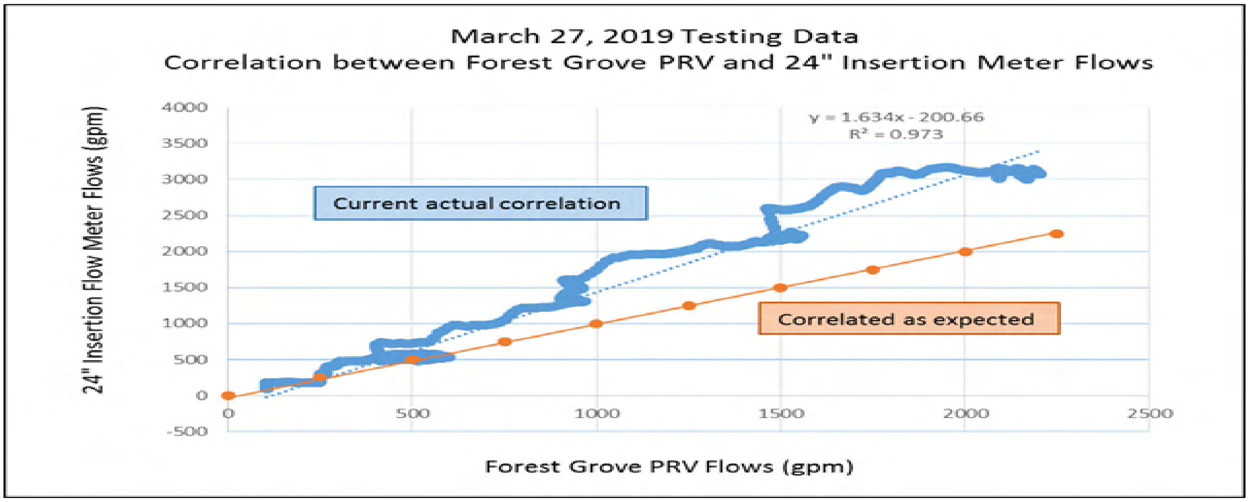


Figure 5. Flows recorded at 24” insertion flow meter and Forest Grove PRV flow meter



4. Recommendations

Based on testing results and further evaluation provided, JWC Staff recommend that the JWC General Manager meet with the Forest Grove management team to:

1. Develop a plan and schedule for Forest Grove meter replacement.
2. Discuss methodology to account for the meter inaccuracy by estimating future billings for water volumes used by Forest Grove, until the Forest Grove PRV flow meter is replaced.
    a. Staff proposes calculating the future estimated water volumes used by Forest Grove based on the difference in the monthly meter reads recorded at the JWC 24” insertion flow meter and at the Dilley meter.
3. Once a plan and schedule is developed for the Forest Grove meter replacement and for estimating water volumes used by Forest Grove, the plan will be presented to the JWC Operations Committee for their information.

Attachment A – Site Testing Data

JWC 24" Meter Worksheet

Wednesday, March 27, 2019

Procedure:

Test #1 = Forest Grove and Dilley both Closed
Test #2 = Forest Grove closed, Dilley Open
Test #3 = Forest Grove Open, Dilley Closed
Test #4 = Forest Grove and Dilley Open

Conference Call Phone Number 503 345-7637
Mike Anunsen will call the times.

TEST #1 Both Valves Closed	Target Flow gmp	Time of Day HR:MIN	JWC Flow per Meter Display gmp	Totalizer gal
	0	10:01	0	1382946

TEST #2 Dilley Open Forest Grove Closed	Target Flow gmp	Time of Day HR:MIN	JWC Flow per Meter Display gmp	Totalizer gal
	0	1002	0	1382946
	250	1007	252	
	500	1011	492	
	750	1014	818	
	1000	1018	987	
	1500	1022	1514	
	2000			

TEST #3 Dilley Closed Forest Grove Open	Target Flow gmp	Time of Day HR:MIN	JWC Flow per Meter Display gmp	Totalizer gal
	0	1026	0	1382962
	250	1031	182	
	500	1040	502	
	750			
	1000	1046	1462	"+500"
	1500	1050	2225	"+700"
	2000	1054	3085	"+1000"

TEST #4 Dilley Open Forest Grove Open	Target Flow gmp	Time of Day HR:MIN	JWC Flow per Meter Display gmp	Totalizer gal
	0	1113		1383018
	250			
	500	1124	1012	
	750			
	1000	1129	2478	
	1500	1133	3915	
	2000			

Name: JEFF WRIGHT Signature: [signature] Date: 3-27-19

Dilley PRV/Meter Worksheet

Wednesday, March 27, 2019

Procedure:

Test #1 = Forest Grove and Dilley both Closed

Test #2 = Forest Grove closed, Dilley Open

Test #3 = Forest Grove Open, Dilley Closed

Test #4 = Forest Grove and Dilley Open

Conference Call Phone Number 503-345-7637

Mike Anunsen will call the times.

TEST #1 Both Valves Closed	Target Flow gmp	Time of Day HR:MIN	Dilley Flow per Meter Display gmp	Totalizer Kgal
	0	10:01 AM	0	1073189 Kgal 8"

TEST #2 Dilley Open Forest Grove Closed	Target Flow gmp	Time of Day HR:MIN	Dilley Flow per Meter Display gmp	Totalizer Kgal
	0	10:02 AM	0	1073189 kgal
	250	10:07 AM	269	
	500	10:11 AM	502	
	750	10:14 AM	815	
	1000	10:18 AM	1000	
	1500	10:22 AM	1500	
	2000			

TEST #3 Dilley Closed Forest Grove Open	Target Flow gmp	Time of Day HR:MIN	Dilley Flow per Meter Display gmp	Totalizer Kgal
	0	10:26	0	27.601 MG.
	250	10:31	275	
	500	10:40	525	
	750			
	1000	10:46	950	
	1500	10:50	1600	
	2000	10:54	2100	

PRV Flow Bounces ~ 100gpm ± ~ ORing needs Replaced

TEST #4 Dilley Open Forest Grove Open	Target Flow gmp	Time of Day HR:MIN	Dilley Flow per Meter Display gmp (Dilly / FG)	Totalizer K gal
	0	11:13		1073206 Dilley
	~~250~~			27.704 F.G.
	500	11:24	550 / 400	
	~~750~~			
	1000	11:29	1020 / 975	
	1500	11:33	1520 / 1500	
	~~2000~~			

Final
1073226 gal Dilly
27.729 mg FG

Name: MIKE ANUNSEN Signature: [signature] Date: 3/27/19

BRIAN DIXON

APPENDIX C
EVALUATION OF GROUNDWATER SOURCE FOR EMERGENCY USE, GSI, 2020

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MEMORANDUM - FINAL

Evaluation of Groundwater Source for Emergency Use for Forest Grove Water Master Plan

To: Rich Blackmun, PE (Forest Grove); Heidi Springer, PE (Murraysmith)

From: Ronan Igloria, PE; Rodrigo Prugue

Date: March 25, 2020

The City of Forest Grove (City) contracted with Murraysmith to prepare a Water Master Plan Update. As part of this effort, GSI Water Solutions, Inc. (GSI) as subconsultant to Murraysmith was tasked with evaluating groundwater wells as a water source for emergency use, in particular to support the City's seismic resiliency efforts. The City identified the need for this evaluation because emergency groundwater wells could be the only potable water supply available after the Cascadia Subduction Zone Earthquake (CSZE) until the City's water system backbone becomes seismically resilient.

This memorandum presents a summary of the evaluation. This memorandum was prepared in parallel to the Water System Master Plan Update (WSP) being prepared by Murraysmith and the Water System Seismic Resiliency Plan (SRP) being prepared by InferTerra. Details of the City's water system infrastructure and operations and resiliency goals are documented in those respective plans.

The scope of this effort to evaluate groundwater wells for emergency use is as follows:

1. Identify coordination opportunities with Washington County emergency response and operations;
2. Define preliminary level-of-service and operational concept for use of emergency wells;
3. Identify and assess the existing well network for potential emergency wells for further evaluation;
4. Develop recommendations for potential next steps.

This memorandum discuss the information related to each of the scope items above, and is intended as input to the City to decide whether to proceed with the contingency task assigned to GSI to conduct further evaluation of any specific well(s) identified in this evaluation.

1.0 Background and Related Planning Efforts

The City utilizes two sources of supply:

(1) City of Forest Grove Water Treatment Plant (FGWTP). The City has intake facilities within the Clear Creek watershed on Clear Creek, a tributary of Gales Creek, Roaring Creek, Thomas Creek, Deep Creek and Smith Creek.

(2) Joint Water Commission Water Treatment Plant (JWC WTP), which receives water from the Tualatin River watershed through the Springhill Intake and Pump Station. The City is a member of the JWC.

The City does not currently utilize groundwater as a source of supply and does not have any groundwater rights.

In 2018, the City started the development of the WMP. The WMP scope of work included a task to evaluate at a planning level, the potential for using groundwater as an emergency water supply. The City had not previously considered groundwater as an emergency source. Thus, no defined criteria or "level-of-service" had been developed for how groundwater wells or other sources could be used to provide emergency potable water supply after the CSZE or other events. The WMP provided an opportunity for the City to assess the feasibility of groundwater for emergency use, and included this work as part of the WMP update.

The primary purpose of this assessment is to determine if groundwater wells could be an option to provide water to the community for emergency use. It was beyond the scope of this effort to evaluate the types of hazards and risks or to define the range of emergencies for which groundwater wells could be used for supply. However, based on discussions with the City staff, the primary interest was to use groundwater wells in situations when residents lack access to water as a result of distribution system damage or when the City's water supplies are non-functioning for extended periods. Thus, for purposes of this assessment it was assumed that the "emergency" scenario is a major seismic event like the Cascadia Subduction Zone (CSZ), because of its anticipated catastrophic impacts.

The SRP also focuses on the CSZ for its analysis and planning. The SRP mapped the geohazards around the City (e.g. susceptibility to liquefaction, spread, settlement, and landslides), and identified the water system "backbone" infrastructure (raw and finished water transmission lines, major water distribution lines). The geohazard maps inform geologic risk areas for groundwater wells. Preliminary SRP information was used in this assessment as follows:

- Areas with higher geohazard risks pose greater risk for damaged or non-functioning groundwater wells after a seismic event. For example liquefaction may cause groundwater supplies to change and or damage the well casing and related pumping equipment. In general, wells located in lower geohazrd risk areas are preferred for emergency use.
- The backbone infrastructure maps inform the location of groundwater wells relative to these backbone components when considering how the well supplies may complement distribution of water after a seismic event. For system security purposes the backbone infrastructure is not presented in this memo, but the information was used in this assessment to determine the location of potential emergency wells to the backbone of the water distribution system.

The *Washington County Emergency Operations Plan Functional Annex – Catastrophic Mass Reception* document (https://www.co.washington.or.us/EmergencyManagement/upload/FA-C_CatastrophicMassReception_Approved9_24_2010.pdf) lists the following sites as emergency centers for the City:

- Pacific University Athletic Center
- Tom McCall Upper Elementary School
- Neil Armstrong Middle School

- Forest Grove High School

The mission of each Reception Center is to provide a safe environment for evacuees seeking critical respite services. They are intended to be a centralized location with basic resources. With this in mind, the assessment reviewed the proximity of existing wells relative to the four reception centers in the City.

2.0 Level-of-Service and Operational Concepts

The Oregon Health Authority Public Health Division requires that all public water systems maintain a current emergency operations plan and incorporate the results of security vulnerability assessments into the plan. One required component of the emergency operations plan as stated by the Oregon Administrative Rules (OAR), is a plan for emergency water: public water systems shall develop a plan for emergency water to include the rationing of drinking water, identifying and utilizing alternative drinking water sources and supplies, and alternative distribution of drinking water. (OAR 333-061-0064 (1)(e)(D)(ii)).

The City has not defined explicit levels-of-service for these emergency wells relative to other emergency supply options that may be considered as part of its resiliency planning and water master planning efforts. For purposes of this study, the concept assumes that the City will use wells for emergency water supply purposes only. The document “Planning for an Emergency Drinking Water Supply” (EPA, 2011), noted that a value of 1 gallon per person per day is a reasonable planning number, consistent with the Federal Emergency Management Agency (FEMA), U.S. Environmental Protection Agency (EPA), and the American Red Cross estimates for drinking, food preparation, and hygiene related to health and safety. Emergency water required for firefighting, hygiene, and other needs (e.g., domestic animals) would be considered beyond the objective of the emergency drinking water supply.

Based on this preliminary level of service, a well production capacity of 20 gallons per minute (gpm) would produce approximately 28,800 gallons per day (gpd). With a current City population of approximately 25,000, and projected population of approximately 45,000 in 2069, the City can plan to develop two to four groundwater wells with 10 to 30 gpm production rates. These wells can be developed over the next 10 years depending on the actual well production rates and would be sufficient to meet minimum domestic water supply needs for the City.

Following guidance from the Oregon Resiliency Plan, the City’s SRP identified the goal to have drinking water available at 50 percent operational levels within 1 to 3 days and at 80 percent operational levels within 3 to 7 days at community distribution points. During this period, the City would be working to restore supply capacity at its main supply source, as well as repairing distribution system damage. It should be noted that the ORP identifies these as target goals with the expectation that it will take years or decades in some cases to be able to meet, because of the financial burdens on utilities and customers. The City of Forest Grove does not currently meet these goals, and anticipates needing 30 to 50 years (or more) to meet these ORP goals. This is one reason that the City is looking at groundwater wells as potential option to help meet emergency water supply needs in a more near-term timeline.

In the event of a system-wide emergency, water delivered to the City’s customers must meet drinking water criteria to be considered potable water. If water does not meet the potable water criteria, then it could be delivered as non-potable water to customers. This includes any well water or unapproved sources of water. In an emergency, the City could consider delivering chlorinated groundwater of unknown water quality. The water could be sampled at the delivery tap for each well site, and must be absent of total coliform and E. coli bacteria (e.g. testing for presence/absence with field testing method). This water would be considered non-potable but bacteria free. The water would also be sampled for nitrate and arsenic prior to use to verify that it is below the OHA MCLs. Coliform bacteria, nitrate, and arsenic are the acute contaminants of concern in an emergency.

3.0 Evaluation of Existing Well Network

3.1 Hydrogeologic Setting

The summary of hydrogeologic setting presented below is based on work that GSI completed for the City documented in the tech memo “Aquifer Storage and Recovery Feasibility Study for the City of Forest Grove” dated May 17, 2005. The 2005 study concluded that the City not invest in exploring aquifer storage and recovery (ASR) because the primary target aquifer in the area is limited in extent and have low yield potentials. However, feasibility of ASR is different than the using groundwater for emergency well production at the production rates discussed above.

The predominant geologic units of the area, from youngest to oldest, include, relatively fine-grained unconsolidated sediments, Columbia River Basalt Group (CRBG), older marine sediments, and older volcanic rocks.

Unconsolidated Sediments. These units consist of recent undifferentiated sediments predominantly in the drainages (Qal) and also consist of fluvial and lacustrine deposits. The latter consists of unconsolidated to semi-consolidated sediments that are predominantly fine-grained silts and clays with thin discontinuous lenses of sand and gravel. The thickness of the unconsolidated sediments overlying older rocks, including CRBG, ranges from less than 25 feet near the margins of the hills to more than 200 feet farther east of town. These sediments typically have limited extent and variable permeability, and are discontinuous in nature. This unit is not a very highly reliable and productive aquifer; however, some wells completed in this unit could meet emergency water supply needs.

Columbia River Basalt Group (CRBG). The CRBG consists of a series of basalt lava flows originating from eastern Washington, Oregon, and western Idaho that underlie a large area in the Willamette and Tualatin valleys. The CRBG in the Forest Grove area is represented by two distinct groups of flows comprising the Wanapum (Tcw) and the Grande Ronde (Tcg) formations. Groundwater in the basalt is predominantly derived from interflow zones, which represent the contact between individual basalt flows. These interflow zones are typically rubbly and porous, and thus can transmit water easily. Groundwater is also produced from fractured zones in the more massive interior flows of the CRBG if sufficient structural deformation and fracturing has occurred. The basalt contains some of the most water productive aquifers in the area.

Older Sedimentary Rock. These materials consist of marine sediments that typically do not host productive aquifers in the Tualatin basin. However, numerous domestic wells along David Hill tap these sediments (consisting of clays, claystone, sand, and sandstones) for domestic use (i.e. low production rates). In deeper portions of the Tualatin Basin and in faulted areas along the margin, the marine sediments often contain saline water. The water quality in some basalt wells in the region has been affected by saline water migrating up into the basalt from underlying marine sediments.

Older Volcanic Rocks. These materials consist of basaltic flows and breccias and sub-marine basalt breccias, pillow lavas with interbedded basaltic sandstones, siltstones and conglomerates. Little hydrogeologic data are available for these units.

3.2 Evaluation of Existing Wells

An inventory of water wells for the area around Forest Grove was prepared to obtain information about local wells and subsurface conditions. A total of 37 wells (not abandoned) were identified within approximately 2 mile radius of the City center, using data available from Oregon Water Resources Department (OWRD) well database. There can be a discrepancy between what is in the OWRD database and actual field conditions. In some cases, wells may have been improperly abandoned or not reported to the state. The scope and purpose of this assessment is to conduct a high-level and preliminary analysis. The City may decide to conduct additional field confirmation for select sites. Any other sites not identified in the OWRD database would need to be identified through direct contact with or from landowners. The extent of the search area and the wells identified in the search are shown in Figure 1. The inventory included five wells completed in basalt (CRBG) and the remaining 32 wells completed in unconsolidated sediments. Attachment A includes a list of all the wells identified in the search. The well data includes, location, owner, construction date, depth, water level, and well discharge rate (capacity). Based on OWRD well records available at the time of this assessment, a majority of the wells identified are private wells located throughout the service area[1]. Most of the wells are located on the northern part of the service area or just north of the service area boundary. Three wells are located in the southeast part of the service area.

Reported yields for wells completed in the basalt range from less than 15 gpm to 72 gpm and yields for wells completed in sediments range from less than 1 gpm to more than 320 gpm. Most of the wells completed in sediments yield less than 50 gpm. Specific capacity is an additional parameter used to better understand the relative performance and productivity of wells. This value is a ratio of a well's yield per foot of drawdown and can be used to assess the relative performance of a well and the productivity of the aquifer. Most of the wells identified in or near the City did not have sufficient hydraulic data to calculate a specific capacity. However, for those with sufficient data, specific capacities in the sediment wells ranged from 0.03 gallons per minute per foot of drawdown (gpm/ft) to 10 gpm/ft, while specific capacities for basalt wells ranged from less than 0.07 gpm/ft to 0.27gpm/ft. The two wells with the highest specific capacities are in the sediment units. Well WASH 6429 had yield of 50 gpm with a specific capacity of 10 gpm/ft, and WASH 10597 had a yield of 320 gpm with a specific capacity of 2.5 gpm/ft. It should be noted that these specific capacity values are time-dependent, and because most of these data are based on short interval test data there is uncertainty in the values.

Static groundwater levels from well driller's logs were reviewed to evaluate depth to water in wells completed in sediments and basalt. Static water levels in sediment wells ranged from 0 to 265 feet below ground surface (bgs), while water levels in basalt wells ranged from 0 to 64 feet bgs. Wells completed in basalt along the northeast side of David Hill often are flowing (artesian), which may be the result of structures (faults) along the base of the foothills. In addition, the CRBG aquifer in this area is confined and aquifer is under pressure, which means wells that penetrate this unit have a shallower static water level caused by the pressure in the CRBG.

The evaluation of the wells were based on several criteria including available and complete logs, available pump test data, and location relative to high geohazard risk areas. As mentioned earlier, pump test or production test data was limited for the 37 wells that were considered for this evaluation. In addition, the wells evaluated predominantly were located in areas susceptible to liquefaction in the event of an earthquake or similar geologic event. After considering the quality of

[1] OWRD records may not be up-to-date. Ownership of the wells and their water rights would transfer to the purchasing owner of the property when sold.

well data, location relative to geohazards, and proximity to Catastrophe Reception Centers and backbone infrastructure, GSI recommends further evaluation of the following two wells:

1. WASH 10597[2]
2. WASH 60859

WASH 10597 is completed in an alluvial aquifer and has a high listed well yield of 320 gpm. It is located in the southeast part of the City service areas near the Neil Armstrong Middle School Reception Center. WASH 60859 has a listed capacity of 72 gpm and is completed in competent basalt. It is located in the north-northwest area just north of the City service area and closest to the Forest Grove High School Reception Center.

It should be noted, and as stated in the introduction of this memorandum, that the well screening process in this section was completed without any City defined emergency water supply strategy or level of service. The prioritization or selection of wells for further assessment could change based on the strategy when established by the City.

4.0 Implementation Considerations

As noted above, the concept is that the City would use these wells only if needed after a catastrophic event causing major damage to its primary water supply, transmission, and distribution. Otherwise, the wells would be operated annually to ensure they are functioning. These wells would likely have to be outfitted with auxiliary power supplies and disinfection equipment, evaluated to determine seismic resistance and agreements would be needed with owners.

For existing wells, the City would not need to apply for a new water right. If the City decides to construct a new well, a well construction permit would need to be secured, and the City could discuss options with Oregon Water Resources Department (OWRD) about the water right permitting requirements. OWRD may require a water right permit or limited license for the new well depending on how the City plans to use the well as an emergency source. Costs for a new well depend on the specific location, aquifer type (e.g. alluvium or basalt), design (e.g. well diameter and screen material), and depth of the well. For planning purposes and for wells approximately the same size (diameter and depth) as WASH 10597 and WASH 60859 identified in the previous section, the costs would be on the order of $150,000 to $300,000. Shallow (~100 feet), alluvial wells would be on the lower cost range, and deeper (>250 feet), basalt wells would be on the higher cost range.

Treatment is not required for groundwater sources as long as the wells are not under the influence of surface water, and the City can demonstrate that the groundwater meets drinking water requirements for coliform bacteria, nitrate, and arsenic. These are the acute contaminants of concern in an emergency. OHA recommends collecting water quality samples of the well ideally on an annual basis

5.0 Next Steps

This memo summarized the assessment to identify groundwater well(s) that may potentially serve as emergency source of water after a catastrophic event where the City's main water supplies may not function for extended periods. The scope of work was to recommend up to three wells to evaluate

[2] Note, this well is the same as one of the wells that City staff identified as a well of interest (WASH 70665). WASH 10597 is the original well log, and WASH 70665 was simply an alteration.

further. Based on the evaluation presented above, GSI identified two wells that the City could review further.

If the City decides to conduct the next evaluation step, the scoped contingency tasks included:

- Review of any existing water rights for the well;
- Map setback requirements for drinking water wells and potential contaminant risks based on review DEQ database information;
- Conduct site visit to ground-truth accessibility and potential issues for use of the well as an emergency source;
- Outline steps to secure use of the well (i.e. water rights administration, property owner access agreement); description of associated equipment needs; and
- Evaluate drilling a new well at the target sites against using the existing well (or rehabilitating the existing well if needed). Evaluation will include planning level costs for a new well at the target sites

If the City decides to look further into using groundwater wells for emergency use, the City should also consider the following as part of finalizing the WMP:

- Define specific levels of service for potential emergency wells to develop facility layout and equipment needs and sizing. For example, even if a well can produce more than 200 gpm, the City may decide to develop these emergency supply sites to distribute on the order of 50 gpm to simplify operation and maintenance issues.
- Contact well owner to determine if they are willing to consider having the City evaluate their well as a potential emergency backup supply for the community. Pursue access agreement to the well to test the well's performance, collect and analyze a water quality samples to evaluate the need for treatment to make the water is potable; evaluate the well and pump condition, which includes pump testing the well for an extended period of time (multiple days), and pulling the pump system and completing a video log of the well, followed by reinstalling the existing pump system.

It should be noted the two wells were identified without the City having defined their emergency water supply strategy and associated level of service. Ideally, the City will develop their strategy for emergency potable water supply and associated levels of service prior to further evaluation of groundwater wells and other potential sources for emergency water supply.

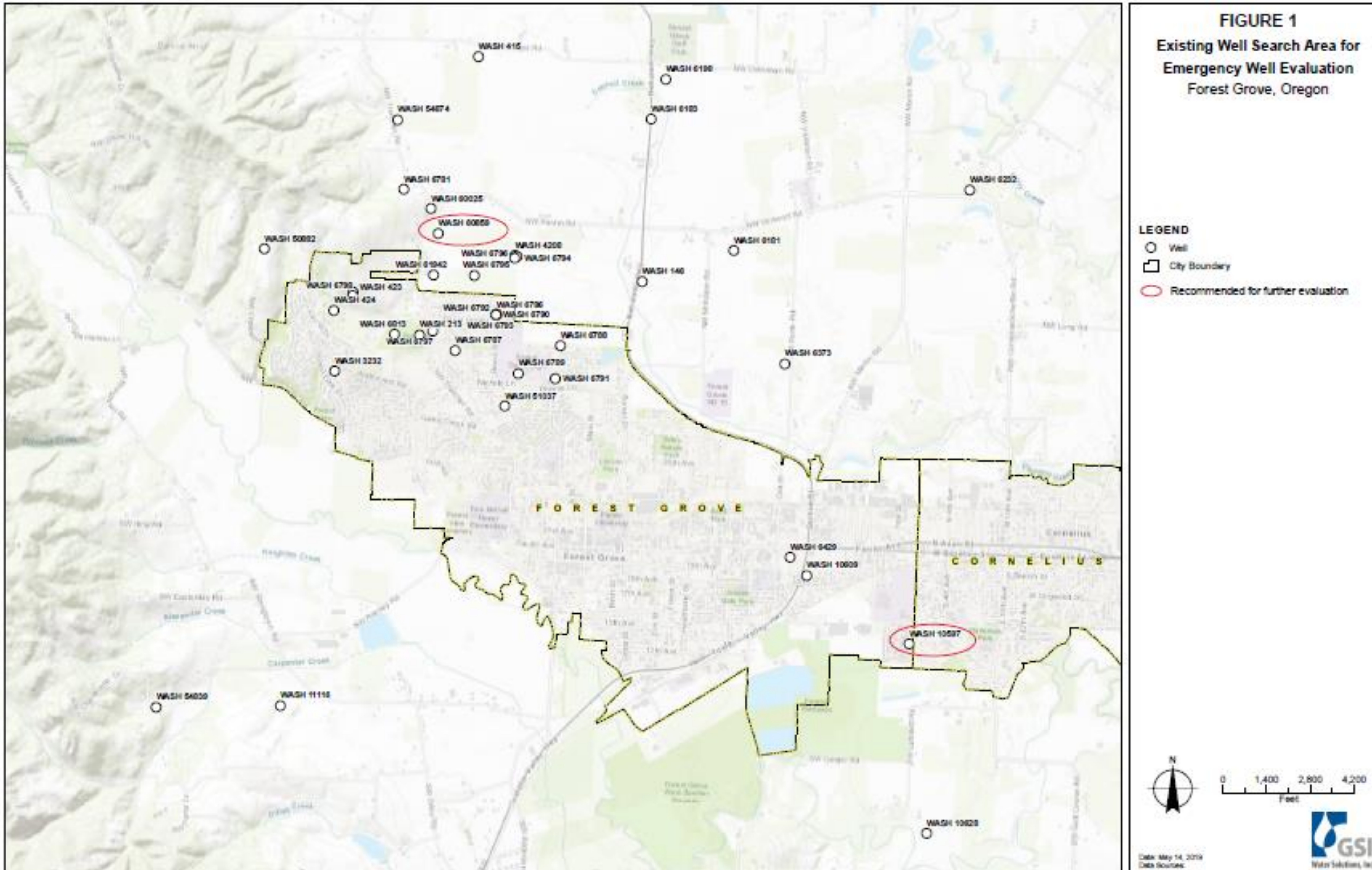

FIGURE 1
Existing Well Search Area for Emergency Well Evaluation
Forest Grove, Oregon

Attachment A – Existing Wells Evaluated

Attachment A-1. Water Production Data for Wells Evaluated in Study

OWRD Primary Well ID Number		Altitude (ft. mean sea level)	Hole Depth (feet below ground surface)	Water Level (feet below ground surface)	Date of Water Level	Discharge (gallons per minute)	Drawdown (feet below ground surface)	Specific Capacity (Discharge/ Drawdown)
WASH	146	175.00	960.00	13	00035384	35	N/A	
WASH	213	240.00	223.00	64	7/21/1990	60	223	0.27
WASH	415	N/A	525.00	Artesian	3/11/1973	40	N/A	
WASH	423	N/A	215.00	75	10/7/1989	18	N/A	
WASH	424	N/A	295.00	50	9/23/1977	35	N/A	
WASH	3232	N/A	300.00	50	7/15/1993	15	N/A	
WASH	4208*	N/A	N/A	N/A	N/A	N/A	N/A	
WASH	6181	185.00	80.00	20	3/10/1998	8	N/A	
WASH	6183	181.00	535.00	265	6/4/1986	1	2	0.50
WASH	6198	185.00	260.00	76	00033476	100	200	0.50
WASH	6232	165.00	220.00	15	00001947	20	N/A	
WASH	6373	200.00	125.00	20	08241950	15	N/A	
WASH	6429	175.00	177.00	25	8/1929	50	5	10.00
WASH	6781	275.00	301.00	Artesian	7/1950	36	166	0.22
WASH	6786	N/A	270.00	30	7/11/1987	50	N/A	
WASH	6787	N/A	400.00	10	6/11/1987	40	N/A	
WASH	6788	N/A	105.00	21	9/13/1979	10	N/A	
WASH	6789	N/A	302.00	28	10/31/1975	10	N/A	
WASH	6790	N/A	205.00	29	3/14/1966	5	N/A	
WASH	6791	N/A	361.00	8	6/20/1975	8	N/A	
WASH	6792	N/A	304.00	4	5/29/1963	20	N/A	
WASH	6793	N/A	267.00	25	7/5/1963	4	N/A	
WASH	6794	N/A	69.00	25	9/30/1950	N/A	N/A	
WASH	6795	200.00	158.00	N/A	N/A	N/A	N/A	
WASH	6796	N/A	120.00	15	11/7/1988	20	N/A	
WASH	6797	N/A	490.00	6	4/30/1956	8	N/A	
WASH	6798	N/A	200.00	Artesian	10/5/1987	5	195	0.03
WASH	6813	N/A	57.00	N/A	N/A	N/A	N/A	
WASH	10597	167.00	260.00	12	6/4/1969	320	128	2.50
WASH	10609	173.00	130.00	30	00018594	30	35	0.86
WASH	10628	160.00	80.00	18	00034151	40	N/A	
WASH	11116	175.00	92.00	8	00018640	N/A	N/A	
WASH	50882	N/A	35.00	N/A	6/4/1996	N/A	N/A	
WASH	51037	N/A	91.00	4	6/28/1996	N/A	N/A	
WASH	54839	N/A	343.00	Artesian	6/24/1999	25	N/A	
WASH	54874	N/A	305.00	31	7/9/1999	15	219	0.07
WASH	60025	N/A	405.00	52	8/19/2003	9	298	0.03
WASH	60859	240.00	286.00	Artesian	11/6/2004	72	N/A	
WASH	61942*	N/A	260.00	70	12/30/2004	N/A	N/A	

** - Well has been abandoned.*

Attachment A-2. Owner and Location Information for Wells Evaluated in Study

OWRD Primary Well ID Number		USGS Site ID	Location by Township-Range-Section	Owner Name (in OWRD database)	Recorded Drill Date	Deepened (Y); Abandoned (A)	Well Known to be in Basalt Aquifer? (Y)	Depth to Competent Basalt (feet below ground surface)
WASH	146	453242123062201	01N/03W-30BDB1	VAN DYKE SEED CO., INC	9/18/1990	N/A		
WASH	213		01N/04W-26SENE	GARY, BILL	7/21/1990	N/A	Y	196
WASH	415			DAVIS, FLORIAN	3/11/1973	N/A	Y	425
WASH	423		01N/04W-26SENE	MARRE, WILLIAM	10/7/1989	N/A		
WASH	424		01N/04W-26	HABERMAN, RICHARD A	9/23/1977	N/A		
WASH	3232		01N/04W-26	MATIACO, STEVE	7/15/1993	N/A		
WASH	4208*		01N/04W-25NWNE	MARSHALL, TOM	10/10/1994	A		
WASH	6181	453253123054101	01N/03W-30AAA1	HAMMOND, RICHARD	3/10/1998	N/A		
WASH	6183	453334123062001	01N/03W-19BDA	MEEUWSEN, HAROLD	6/4/1986	N/A		
WASH	6198	453347123061401	01N/03W-19BAA	Sunset Grove Golf Club	10/29/1968	N/A		
WASH	6232	453314123035601	01N/03W-21CAC	MARSH, BILL	1947	N/A		
WASH	6373	453218123051601	01N/03W-29CBD	MATHISON, M.C.	8/24/1950	N/A		
WASH	6429	453117123051101	01N/03W-32CDC	MASONIC AND EASTERN STAR HOME	8/1929	Y		
WASH	6781	453309123081001	01N/04W-23DDA	GOFF, ARNOLD	7/1950	N/A	Y	168
WASH	6786		01N/04W-25	HOODENPILE, RAY	7/11/1987	N/A		
WASH	6787		01N/04W-25SW	VANAKER, BUD	6/11/1987	N/A		
WASH	6788		01N/04W-25NESE	VANDERZANDEN, KERRY	9/13/1979	N/A		
WASH	6789		01N/04W-25NESW	KNODEL, LARRY	10/31/1975	N/A		
WASH	6790		01N/04W-25	HOODENPYL, RAYMOND L	3/14/1966	N/A		
WASH	6791		01N/04W-25SESE	VAN DYKE, FRANK	6/20/1975	N/A		
WASH	6792		01N/04W-25	FRANKE, HERBERT P	5/29/1963	N/A		
WASH	6793		01N/04W-25	JOHNSON, WAYNE	7/5/1963	N/A		
WASH	6794		01N/04W-25NWNE	PURDIN, IRA LEE	9/30/1950	N/A		
WASH	6795		01N/04W-25SENW	RUETER, E A	N/A	N/A		
WASH	6796		01N/04W-25NWNE	SPIESSCHAERT, MAE	11/7/1988	N/A		
WASH	6797		01N/04W-25NWSW	DR R	4/30/1956	Y		
WASH	6798		01N/04W-26SENE	MARTENS, ROBERT	10/5/1987	N/A		
WASH	6813		01N/04W-26NESE	RUSSELL, FRANK	N/A	N/A		
WASH	10597	453051123041501	01S/03W-04BCC	FOREST GROVE SCHOOL DIST NO 1	6/4/1969	N/A		
WASH	10609	453111123050301	01S/03W-05BAA	STEVENS, W.E.	1950	N/A		
WASH	10628	452951123042601	01S/03W-08DAA	LEFORE, LOYAL	9/18/1987	N/A		
WASH	11116	453025123085701	01S/04W-02CCD	RITCHEY, CURTIS R.	1950	N/A		
WASH	50882		01N/04W-26SWNW	TURNBULL, DAVE	6/4/1996	N/A		
WASH	51037		01N/04W-25SWSE		6/28/1996	N/A		
WASH	54839			KURTZ, KERRY	6/24/1999	N/A	Y	10
WASH	54874			DOBER, BOB	7/9/1999	N/A	Y	236
WASH	60025			STUCK, FLOYD	8/19/2003	N/A		
WASH	60859		01N/04W-25NWNW	HUNTER, DAVID	11/6/2004	N/A	Y	248
WASH	61942*		01N/04W-25NWSW	DAVID HILL DEVELOPMENT; DOW BROTHERS	12/30/2004	A		

** - Well has been abandoned.*

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murraysmith

APPENDIX D
JOINT WATER COMMISSION
BARNEY AGREEMENT

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JOINT WATER COMMISSION
WATER SERVICE AGREEMENT

EXHIBIT A

BARNEY AGREEMENT

Adopted

JOINT OWNERSHIP AGREEMENT
BARNEY PROJECT

DATED OCTOBER 27, 2003

BY AND AMONG

CITY OF HILLSBORO,

CITY OF FOREST GROVE,

CITY OF BEAVERTON,

TUALATIN VALLEY WATER DISTRICT AND

CLEAN WATER SERVICES OF WASHINGTON COUNTY

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF EXHIBITS

EXHIBITS

SECTION 4

VALUE OF RESERVOIR, OWNERSHIP, PURCHASE RIGHTS, LEASING PROVISION AND OPERATION COSTS

4.1 Value of Project

The value of the Project is provided in Exhibit A to this Agreement, which Exhibit may be updated and revised by resolution of the Commission from time to time.

4.2 Ownership Rights

The ownership of the Project is as follows:

Hillsboro	6,200 Ac. Ft. [1]	31.0%
Forest Grove	500 Ac. Ft. [1]	2.5%
Beaverton	4,300 Ac. Ft. [1]	21.5%
TVWD	7,000 Ac. Ft. [1]	35.0%
CWS	2,000 Ac. Ft. [1]	10.0%
Total	20,000 Ac. Ft. [1]	100.0%

[1] Actual amount of water available is dependent on the pond level, fish flow requirements, dead storage and inflow.

The Parties understand that the amount of Stored Raw Water available to the Party is determined as a percentage (based on ownership) of the total Stored Raw Water available to the Parties.

4.3 Buy-Back Rights

It is understood and agreed that certain flexibility is desired as to the ability to use the Stored Raw Water for beneficial municipal and industrial purposes. To that end the Parties further agree that Beaverton and Forest Grove shall have the right to obtain 1,700 acre feet and 800 acre feet, respectively, from the share allocated to TVWD. Upon notice of election to seek these waters, or any part thereof, the Party seeking them shall give TVWD and the remaining members of the Commission written notice. The notice provisions and price paid by the Party seeking purchase from TVWD shall be as set forth in Exhibit C, which exhibit may be updated and revised by resolution of the Commission. Any change in Exhibit C by resolution of the Commission shall require a unanimous vote of the Commission.

4.4 Leasing Provisions

The JWC members have entered into an agreement entitled Joint Water Commission Hillsboro, Forest Grove, Beaverton and Tualatin Valley Water District Water Service Agreement dated _________ 2003, which provides for leasing of Stored Raw Water among the JWC members. This includes leasing of Stored Raw Water from the Project. The Parties to this Agreement agree to allow the JWC members to lease capacity among themselves.

The Parties further agree, to the extent that, after JWC members execute these lease rights, there is excess surplus water available from the Project for that year, that CWS shall have the right to utilize and purchase such water for increased flow augmentation. The terms and conditions of the purchase by CWS shall be as set forth in Exhibit D, which exhibit may be updated and revised by resolution of the Commission. Any change in Exhibit D by resolution of the Commission shall require a unanimous vote of the Commission.

4.5 Payment of Operational Costs

Invoices for operational costs shall be submitted by the Managing Agency no less frequently than quarterly and shall be payable within thirty (30) days following receipt of invoice. Any funds not paid within such thirty (30) day period shall be deemed delinquent and shall draw interest at the rate of 9% per annum. If not paid within 180 days from date of invoice the matter shall be referred to the full Commission which may elect to resolve the matter in any equitable way and, in the event no such way can be agreed upon, in accordance with Section 7 of this Agreement.

4.6 Renewal and Replacements and System Upgrades

The Commission shall budget for renewals and replacements and upgrades, equipment replacement reserves and contingencies in accordance with Section 3.7 of this Agreement. The Parties shall make payments as required for renewals and replacements and upgrades and equipment replacement reserves proportional to the Party’s ownership in the Project in relationship to the total ownership in the Project. The Parties shall make payments as required for contingencies based on the purpose for the contingency.

BARNEY JOINT OWNERSHIP AGREEMENT

EXHIBIT C

BUY-BACK RIGHTS
TERMS AND CONDITIONS

The amount of the buy-back right water requested shall be transferred to the requesting party with Buy Back-Rights not later than four (4) years following the date of the written notice of election. The parties with Buy-Back Rights further agree that every good faith attempt shall be made among the parties to expedite the repurchase and to alleviate any hardship which the repurchase may impose on TVWD. The amount and time of the payment for the repurchase shall be agreed between the requesting party with Buy-Back Rights and the TVWD.

BARNEY JOINT OWNERSHIP AGREEMENT

EXHIBIT D

SURPLUS WATER SALES RATE

APPENDIX E
TASK 3 CONDITION ASSESSMENT, MURRAYSMITH, 2019

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Memorandum

Date: February 13, 2019

Project: Forest Grove Water System Master Plan (18-2197)

To: Mr. Rich Blackmun, P.E.
City of Forest Grove Engineering

From: Heidi Springer, P.E.
Murraysmith

Re: Water Facility Condition Documentation

Introduction

The purpose of this memo is to document City of Forest Grove (City) Public Works and Engineering staff observations on the age and condition of City water facilities. This memo will be used to inform development of a proposed capital improvement program (CIP) for the City's Water System Master Plan (WSMP). One of the key goals of a WSMP is to assess available capacity in the existing water system and identify needed improvement projects for the CIP. The condition information documented in this memo will be used to identify non-capacity driven improvements and to prioritize the recommended CIP.

Water System Overview

Forest Grove has provided water to its citizens for over 100 years. Some of the original water system structures, built in 1912, are still in operation. Currently water is supplied from two sources, the Joint Water Commission (JWC) Water Treatment Plant (WTP) and the City's WTP. The JWC WTP is a regional partnership which treats water from the Tualatin River, Barney Reservoir, and Hagg Lake. Water is delivered to the City from the JWC's Fern Hill storage reservoirs through a 24-inch diameter transmission main and the City's 10th Avenue Control Station. From the 10th Avenue Control Station, JWC supply flows through 368 Zone distribution mains to the 5 million-gallon (5.0 MG) Reservoir.

The City's WTP treats water from the Gales Creek watershed which is piped to the WTP site through a 16-inch diameter raw water transmission main (RWTM). Treated water is stored in the 5.0 MG Reservoir at the WTP site. The 5.0 MG Reservoir supplies the 368 Zone which serves most City water customers.

Higher-elevation customers (540 Zone) in the northwest of the City are served from the David Hill Reservoir and the Watercrest and David Hill Pump Stations. Both pump stations draw suction supply from 368 Zone distribution mains and pump through 540 Zone distribution mains to fill the David Hill Reservoir. The 435 Zone is served from the 540 Zone through multiple pressure reducing valves (PRVs) throughout the distribution system.

JWC Supply Facilities (City owned)

10th Avenue Control Station

Description

The 10th Avenue Control Station is comprised of:

- 18-inch and 8-inch diameter parallel Cla-Val control valves with hydraulic pilot system for pressure control and solenoid-driven flow control
- ultrasonic flow metering equipment
- fluoride injection equipment including a metering pump, with flow paced controls, and in-line analyzer

The control station is housed in a cinder block building on the south side of Forest Grove at the dead end of 10th Avenue west of Elm Street. This section of industrial-zoned land along 10th Avenue forms a wedge between Highway 47 and the Portland & Western Railroad (PNWR) tracks. The station building fills most of the City-owned property it sits on. The property is fenced on three sides up to the building face with chain link fence topped with barbed wire. Vehicle access and parking is along 10th Avenue.

Currently the station control valves are operated based on flow set-points which are adjusted by operations staff at the City's WTP depending on water production at the City's WTP and customer demand. Pressure control through the 10th Avenue Control Station is set at 82 pounds per square inch (psi). In case of a power failure, the station will default to pressure control. Both the City and the JWC monitor flow at the 10th Avenue Control Station through connections to the meter from their respective Supervisory Control and Data Acquisition (SCADA) systems.

Condition and Operation Observations

Per City staff, flow control is disengaged via a switch on the control panel.. This has not been an issue for City staff who report flow control has been an effective way to manage JWC supply.

There is no back-up power on-site at the station.

There is no sanitary sewer connection at the existing station. The lab sink at the site currently drains to a stormwater drainage way behind the building. Although only very small amounts of treated water may be discharged from the sink the need for a sanitary sewer system connection should be evaluated.

City Water Supply Facilities

Clear Creek Watershed Raw Water Transmission Main (RWTM)

The RWTM is a 16-inch diameter concrete cylinder pipe (CCP) constructed in 1963. This transmission main runs approximately 7.8 miles from the City's Gales Creek watershed intakes to the City's WTP. The RWTM alignment crosses active agricultural fields and passes through ancient landslide areas along Soda Springs Road near the City's intakes. **Figure 1** at the end of this memo illustrates ancient landslide mapping from the Oregon Department of Geology and Mineral Industries (DOGAMI) for the area around the RWTM alignment.

City water system operators report that the RWTM continues to function effectively if the cement mortar coating is not cracked. Exterior coating cracks appear to lead to pipe failure as the helically wound reinforcing wire unravels. This is consistent with water industry research on the most common failure modes for CCP mains. City staff have observed cracking of the exterior cement mortar coating on the RWTM due to assumed ground movement in a known slide area between the Clear Creek crossing and Soda Springs Road. This section of pipe, where most recent main breaks have occurred, is shown inside the red circle on **Figure 1** at the end of this memo. RWTM repairs are complicated by limited access for area homeowners along the narrow Soda Springs Road during a repair.

Prior to 1994, customers in the Gales Creek Service Area were served directly from the RWTM. Leaks in the RWTM have also occurred at abandoned service connections. These service connections used cast iron threaded connectors which were abandoned in place.

Raw Water Booster Pump Station

The City's Raw Water Booster Pump Station boosts flow in the gravity-fed RWTM as needed to supply the City's WTP under peak demand conditions. The station, housed in an underground vault along Gales Creek Road next to Forest Glen Park, was connected to the existing RWTM in 1979 by cutting a tee into the 16-inch diameter CCP main. In the summer of 2018 a leak was discovered in the connection between the pump station and the 16-inch diameter CCP main. The connection was repaired in September 2018. This repair was complicated by a large block of concrete poured over the connection during construction in 1979. The station is otherwise in good working condition.

City Water Treatment Plant (WTP)

Detailed analysis of City treatment processes and equipment is outside of the scope of the WSMP and this memo. City WTP staff state that a comprehensive WTP Facility Plan is needed to address the age and condition of multiple facilities on the WTP site and some operational issues such as the City's current dewatering process for residual solids. Four key items noted by City staff are described in the following paragraphs.

Age and Condition Issues

- ***Existing sedimentation basin*** was the City's first storage reservoir constructed in 1912 and may have exceeded its life expectancy.
- ***Transfer pumps*** which boost flow from the sedimentation basin up the hill to WTP filters have had issues with motor lifespan. Motor failure may be exacerbated by weather exposure as the pumps are outside with no cover. The City intends to explore constructing housing over the existing pumps.
- ***Existing house on-site*** is a former single-family residence on the WTP site that is currently used for storage. A different building or interior configuration would be more useful to City staff for storage at the WTP site.

Waste stream dewatering system

The City's current dewatering and solids disposal process requires purchase of perlite for processing which is later disposed of. Disposal of solids requires one to two trips weekly to the landfill, which requires significant staff time. Dewatering equipment is sited within the WTP shop making the space unusable for other maintenance needs.

5.0 MG Reservoir

The City's 5.0 MG Reservoir is a reinforced concrete, hopper bottom, buried rectangular tank built in 1948. The tank is divided into two equally-sized cells (north and south) to provide operational flexibility if needed for maintenance. The tank is relatively shallow with a large 304-foot by 152-foot footprint.

City staff have observed significant increased drainage flow from the reservoir's foundation perimeter drain indicating a potential leak in the tank. As of October 2018, City staff have narrowed the leak area to the discharge sump of the north reservoir cell. City staff have observed voids in the concrete tank wall left by what appear to be decomposing wooden form stakes left from initial construction. Small leaks at these stake sites may be an on-going issue as any remaining stakes degrade.

Due to the tank's construction type and age, it is anticipated that the reservoir may be vulnerable to failure during a seismic event. More detailed evaluation of seismic performance is anticipated in the City's 2018 water system seismic vulnerability assessment, currently underway.

540 Zone Pump Stations

Watercrest Pump Station

The Watercrest Pump Station, across Watercrest Road from the WTP and 5.0 MG Reservoir site, has a single pump housed in a partially-buried concrete building. The building is sited on a narrow un-fenced City-owned property between Watercrest Road and neighboring residential properties. The existing pump is not equipped with a variable frequency drive (VFD). Water is pumped through the distribution system to the David Hill Reservoir. This station is the primary supply to the David Hill Reservoir.

David Hill Pump Station

The David Hill Pump Station supplies the David Hill Reservoir through 540 Zone distribution mains from 368 Zone distribution. The station has two pumps without VFDs which run lead-lag based on the David Hill Reservoir level. The station equipment and pumps have not been replaced since their installation in 1985 when the pump station was constructed. The station is infrequently operated because Watercrest Pump Station provides primary supply to the David Hill Reservoir since Watercrest was upgraded in 2006. The David Hill Pump Station is housed in a brick building with a membrane roof installed in 2018. City staff noted that the slope behind the structure may be steeper than recommended without a retaining wall and may fail during a seismic event. The station property is un-fenced.

David Hill Reservoir

The David Hill Reservoir is a 96-foot by 76-foot partially buried reinforced concrete tank built in 1985. The tank sets the hydraulic grade for the 540 Zone and provides storage for the 540- and 435 Zones. City staff report that there is currently no cleaning or inspection schedule for the tank. City staff were not aware of any recent interior inspection. The Watercrest and David Hill Pump Stations are not configured to serve customers constant pressure if the reservoir were taken out of service.

The reservoir is located on a small parcel of City-owned property within an active Christmas tree farm. A drainage easement within a natural drainageway on the tree farm property provides the flow path to an outfall at David Hill Road for drainage from the reservoir site, the foundation perimeter drain, and the tank's emergency overflow. City staff note that there have been issues maintaining a clear drainage way with neighboring tree farm activity. City staff suggested that piping all drainage and runoff from the site through the existing easement may be a solution for maintaining a clear flow path. City staff would also consider improving site grading around the reservoir to encourage drainage.

Gales Creek Service Area

The Gales Creek Service Area serves customers northwest of the City, outside the Urban Growth Boundary (UGB). These customers were historically served directly from the RWTM. Anticipating legislative amendments to the federal Safe Drinking Water Act, a 6-inch diameter Class 160 PVC distribution main was installed in 1996 parallel to the RWTM alignment to serve treated water to customers in the Gales Creek Service Area. Water is supplied from the David Hill Reservoir and 540 Zone distribution mains through the Gales Creek PRV.

Portions of the Gales Creek Service Area 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 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 staff report significant water loss from assumed leaks within the Gales Creek Service Area distribution mains. City distribution system operators perform a monthly water audit of the Service Area by comparing metered flows through the Gales Creek PRV station with Gales Creek customers' metered consumption. 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 (gpd). Based on recent flow readings from the Gales Creek PRV station, water loss may be as high as 50 percent of all Gales Creek Service Area flow.

Conclusion

Based on discussions with Forest Grove staff and observations during site visits in September 2018, some key condition and operational issues with City water facilities emerged. They are summarized as follows:

- Landslide vulnerability contributing to leaks in the RWTM
- Need for a comprehensive WTP Facility Plan to include:
    - Structural assessment of existing sedimentation basin and 5.0 MG Reservoir, some of which may be addressed in current seismic vulnerability assessment
    - Waste stream dewatering system evaluation – current method is labor intensive
    - Storage and shop space
- 5.0 MG Reservoir seismic vulnerability
- David Hill Pump Station equipment upgrade and potential building/site seismic vulnerability
- David Hill Reservoir clear drainage way issues from adjacent agricultural activity; need for on-going maintenance and inspection plan
- Gales Creek Service Area significant water loss – unmapped distribution piping makes addressing leaks challenging

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APPENDIX F
HYDRAULIC MODEL SOFTWARE SELECTION, MURRAYSMITH, 2018

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Memorandum

Date: June 4, 2019

Project: 18-2197.1001 - City of Forest Grove – Water System Master Plan

To: Mr. Rich Blackmun, P.E.
City of Forest Grove

From: Brian Ginter, P.E.
Heidi Springer, P.E.
Murraysmith

Re: Hydraulic Model Software and Evaluation

Introduction

The purpose of this memorandum is to document a brief evaluation of the two industry-leading hydraulic model software programs and provide a recommendation to the City of Forest Grove (City) regarding which software the City's water system hydraulic model should be updated and maintained in, as part of the current Water System Master Plan development. In addition, this memorandum will provide information to the City to inform a decision to purchase the software for use by City staff.

Background

There are many options available for network analysis hydraulic modeling software and different modeling platforms are better for some clients based on the background of the users. The pipe flow hydraulic modeling industry has standardized on the hydraulic engine EPANet. This was developed by the United States Environmental Protection Agency (US EPA) to perform water quality analysis and includes a hydraulic engine that allows extended period simulation (EPS) analysis. Throughout the industry, and especially in the Pacific Northwest, there are currently two primary software platforms used by public agencies and engineering consultants – WaterGEMS by Bentley and InfoWater by Innovyze.

The City's current hydraulic model is WaterGEMS by Bentley and was the used for 2000 and 2010 Water Master Plans.

Software Comparison

The table below presents a brief comparison of the two software platforms relative to the base EPANet software available as shareware from US EPA.

Table 1
Modeling Software Comparison

	EPANet	WaterGEMS	InfoWater
Hydraulic Engine	EPANet	*EPANet	*EPANet
Software Vendor	US EPA	Bentley	Innovyze
Platform	Stand-Alone	ArcGIS	ArcGIS
GIS Import/Export	No	Yes	Yes
ODBC Connectivity	No	Yes	Yes
Ability to Subset Model	No	Yes	Yes
Overall Functionality	Low	High	High
Report Quality Graphics	No	Yes	Yes
Complexity of Use	Low	High	High
Cost (3000 pipes)	Free	$17,597	$7,355
Maintenance	Free	$4,224/year	$1,475/year
Technical Support	Minimal	Excellent	Excellent

Note: *Modified from US EPA shareware version

As indicated in the table, both WaterGEMS and InfoWater provide comparable functionality and support. Costs for software purchase and maintenance of WaterGEMS is significantly higher than a comparable license for InfoWater.

Bentley WaterGEMS also offers a pre-paid monthly licensing package where the user makes a $5,000 deposit to start and is charged $822 per month against that balance for each calendar month when the software is used regardless of the number of uses in that month.

It is Murraysmith's experience that the pool of hydraulic modelers with InfoWater proficiency in the Portland Metro area is larger than the pool of those proficient in WaterGEMS. Converting the City's model to InfoWater will open rather than narrow the City's options for future consultants to perform water modeling work. At Murraysmith, a portion of the cost for the annual maintenance of either software platform is incorporated into the respective project costs when the software is necessary for the successful completion of a project.

Murraysmith Experience with Software

Murraysmith maintains active licenses for both software platforms. Since approximately 2005, we have seen a significant number of our clients select the Innovyze InfoWater software platform. As a result, approximately 95 percent of the current active hydraulic models we maintain are in InfoWater. In order to allow for multiple models to be operated simultaneously across multiple project teams, Murraysmith maintains five InfoWater licenses and only one WaterGEMS license.

Due to the high volume of InfoWater models currently maintained by our firm, our hydraulic modeling staff, while proficient with both software platforms, are able to work more efficiently with the InfoWater platform and reduce the level of effort required because it is the more commonly used software amongst modelers.

Considerations for City Purchase of Hydraulic Modeling Software

Murraysmith understands that the City is considering the purchase of hydraulic modeling software for on-going internal use by City staff. Based on our understanding of City staffing levels and experience with hydraulic modeling, it is our recommendation that the City not purchase the software for internal use. The key reasons for this recommendation are:

- Murraysmith is not aware of a similar sized utility in Oregon that currently maintains their own hydraulic model.

- Based on our experience with training and maintaining hydraulic modeling expertise and our coordination with the few larger utilities (City of Gresham, Portland Water Bureau, Springfield Utility Board and Eugene Water & Electric Board) that do maintain water system hydraulic models internally, a utility should not consider in-house model maintenance unless the following conditions can be met:

    - Hire licensed engineering staff with at least 2 years of hydraulic modeling experience

    - Dedicate at least 30 percent time for one full-time employee (FTE) to maintain model, including routine updates, and continuing hydraulic model education and training

Recommendations

Based on the brief evaluation presented above, Murraysmith recommends the following:

- Convert the existing water system hydraulic model to Innovyze InfoWater as part of the Water System Master Plan project. The process of model update and calibration presents an opportunity to efficiently complete the conversion as part of comprehensive model update and calibration efforts.

- Continue to utilize consultant resources for model updates and hydraulic analyses. The City is not likely to re-coup the cost of software purchase, maintenance agreement, and staff resources given the anticipated volume of hydraulic modeling the City water system requires. While the two software platforms are very similar, it is Murraysmith's experience that InfoWater is more commonly used in the Portland Metro area resulting in a larger pool of hydraulic modelers with higher proficiency levels than those seen with WaterGEMS. Converting the City's model from WaterGEMS to InfoWater would also expand the City's capability to work with future consultants for modeling work and reduce the required level of effort for the modelers. This reduction in the level of effort could potentially result in project associated cost savings for the City depending on the nature and complexity of the modeling work being performed.

APPENDIX G
HYDRAULIC MODEL CALIBRATION MEMO, MURRAYSMITH, 2020

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Technical Memorandum

Date: February 11, 2020

Project: Forest Grove Water System Plan (18-2197)

To: Richard Blackmun, PE
City of Forest Grove

From: Heidi Springer, PE
Claire DeVoe, EIT
Murraysmith

Re: Hydraulic Model Calibration

Background

Murraysmith is currently supporting the City of Forest Grove (City) with the update of their Water System Master Plan (WSMP) and hydraulic model. The City's prior hydraulic model used Bentley WaterGems software and was calibrated in 2010 by HDR. This model was converted to Innovyze InfoWater software by Murraysmith and updated with new piping based on GIS mapping provided by the City. Calibration of the Forest Grove model will be completed for a steady state simulation.

Calibration is one of the most important tasks in developing a hydraulic water system model. The goal of the calibration is to represent real-world conditions in the model including demands, pressures, fire flows, and system operations. By collecting flow and pressure data at key points across the system, the model can be validated and used with higher confidence for future planning purposes.

Steady state calibration involves static pressure testing and hydrant flow testing. First a static pressure is measured at a hydrant. Then, a nearby hydrant is opened to stress the distribution system's ability to deliver flows while maintaining pressure. The resulting pressure drop is manually recorded and used with system boundary conditions, such as reservoir water levels at the time of the test, to verify system operations and pipe friction factors in the model. These hydrant flow tests can often identify inaccuracies in PRV settings, faulty valves, elevation errors, poor demand distribution, or connection issues in the model.

Once the model is calibrated, each pressure zone is given a confidence level using the criteria shown in Table 1. Static error is measured as a percent pressure difference between model results and field results ([model value – field value]/[field value]). A negative sign (-) indicates that the model pressure is lower than the field test, and a positive sign indicates that the model is over estimating pressure compared to test data. Calibration results for the fire flow tests are expressed as a difference in the pressure drop recorded in the field and the pressure drop reported from the model simulation ([model static – model residual] - [field static – field residual]). Because the reported result is based on comparing pressure drop as opposed to actual pressure, any error in the static calibration is not carried over to the fire flow calibration. Confidence levels help inform future modeling efforts with the level of accuracy to be expected.

Table 1
Calibration Confidence Levels

Confidence Level	Static Test Percent Error	Residual Fire Flow Pressure Difference
High	<5%	< 10 psi
Medium	5 to 10%	10 to 20 psi
Low	>10%	> 20 psi

1. Percent error and pressure difference represent absolute value difference between field and model results.

Model Conversion and Update

The City's prior WaterGems water system hydraulic model was converted into Innovyze InfoWater software. The prior model's junctions, junction elevations, pipe geometry, pipe lengths, and roughness coefficients were preserved from the WaterGems version. New piping and junctions were added per the updated GIS data provided by the City. Pipe roughness coefficients for new pipes were set at C = 135 which is consistent with the existing model and within the typical range of values for new ductile iron pipe.

Model Elevations and Vertical Datums

Junction elevations were set using contour data available from the regional government Metro's Regional Land Information System (RLIS). The RLIS contours use the 1988 North American Vertical Datum (NAVD 88). After initial model set-up and calibration were complete, it was learned that the City uses a local vertical datum, the Forest Grove Vertical Datum (FGVD) to define water facility elevations. The FGVD is 4 feet lower in elevation than the NAVD 88 datum used to assign junction and pressure reducing valve (PRV) elevations in the model.

The effect of this datum difference, between reservoirs and junctions in the modeled distribution system is that pressures appear slightly lower than field measured conditions. This difference is within the margin of error (+/- 5 pounds per square inch (psi)) of the model and is thus unlikely to significantly impact hydraulic analysis. Junction elevations in the model were adjusted to match the FGVD.

System pressures simulated in the model were checked with field pressures measured during fire hydrant flow testing. There was no significant difference in calibration confidence after the elevation updates.

Pump Curves

Pump curves were not available for distribution system booster pump stations Watercrest or David Hill. Pump curves were approximated using a generalized model pump curve created from a single control point provided by the City. Pump on/off controls were set based on City staff comments. Generally, the single pump at Watercrest Pump Station operates to fill the David Hill Reservoir based on the tank water level. The David Hill Pump Station rarely operates. The two pumps in this station operate lead-lag.

Pressure Reducing Valves (PRVs)

PRV settings were updated from field-verified data provided by the City.

JWC Supply

The 10th Ave Control Station provides supply from the Joint Water Commission (JWC) through a flow control valve/pressure reducing valve (FCV/PRV) that is manually operated when supplemental supply to the City is required. The station can operate under either flow or pressure control. Per City comments, the valve currently operates under flow control and responds to a fire by switching to pressure control. The modeled flow control valve was set at 1,000 gallons per minute (gpm) when active, consistent with data provided during calibration flow testing.

The City installed a pressure logger at the intersection of 19th Avenue and Oak Street, and recorded system pressure for the month of September 2019 at 30-minute resolution. This data was used to verify approximate system pressures. If the City is planning to use the model in the future for very detailed analysis, it would be valuable to look at pressure logging data near the JWC connection in addition to system boundary conditions at the time the data is logged, to understand how the hydraulic grade in the 368 zone is influenced by the 10th Avenue Control Station control valve. This calibration refinement is beyond the scope of this project and is not expected to significantly influence the capital improvement program (CIP) recommendations of this WSMP. It is recommended that the City does not pursue this further at this time.

System Demands

Modeled system demands were also updated. Geocoded consumption data from the City's utility billing system was used to distribute average day demands (ADD) and maximum day demands (MDD) to the closest model node in the correct pressure zone. Nodes close to valves, reservoirs, or pump stations were not included in this set of demand model nodes. Consumption data was only available on a per-account basis by month. Therefore, the max month distribution (August) was used to approximate the MDD distribution.

The distributed demand sets were then scaled so the total system-wide demand matched the 5-year average from 2013-2017 for ADD and MDD, calculated from supply data and summarized in million gallons per day (mgd) Table 2.

Table 2
Existing System Demands

Demand Set	System Demand (mgd)
ADD	3.0
MDD	5.7

Field Testing

On November 13th and 14th, 2018, representatives from the City and Murraysmith performed approximately 20 field tests, distributed across the system and under various supply conditions. On February 13th, 2019, two additional tests were performed to verify calibration of the far eastern reaches of the 368 Zone due to leaking test equipment during the November tests.

Two sets of tests were performed in the 368 Zone to quantify the effects of the City's two water supplies; JWC supply from the 10th Ave Control Station in the south and supply from the City's 5MG Reservoir at the Water Treatment Plant (WTP) site to the north. First, a set of 5 tests were performed with JWC supply. Then the JWC supply was switched off and the same 5 tests were performed with only supply from the City's 5MG Reservoir.

During field testing, a leak in one of the pressure measurement devices was discovered. Several tests were rerun with various City, Murraysmith, and Fire Department instruments to improve accurate results. As described previously, additional tests were performed in February to improve calibration confidence.

Calibration Results

In general, the model calibrated with a medium level of confidence. In all zones, the model typically overpredicts static pressures. On average, the model underestimates the pressure drop caused by a fire flow. Table 1 was used to rate the confidence level of each zone, in addition to data variance, supply path sensitivity, and reliability of model convergence. Table 3 summarizes the calibration results by zone and Figures 1 and 2 map the modeled static pressure and fire flow results. Table 4 includes a complete list of results for each calibration flow test.

Table 3
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

1. No flow tests recorded in the Gales Creek Service Area.
2. Small subzone supplying <20 homes. No flow tests conducted here.

Table 4
Calibration Results

Test No.	Pressure Zone	Static Pressure Percent Error	Residual Fire Flow Pressure Differential
1	540	-0.7%	-6.8
2	540	2.9%	-5.1
5	540	-1.4%	-3.1
3	435	6.5%	-6.4
4	435	3.4%	-3.8
7	435	6.4%	-2.6
9JWC	368	3.4%	-2.3
10JWC	368	5.8%	-4.0
12JWC	368	5.5%	-7.8
13JWC	368	2.7%	-2.9
14JWC	368	1.9%	-9.0
17JWC	368	8.1%	9.7
18JWC	368	4.8%	2.8
6	368	7.1%	-1.6
8	368	5.9%	-4.5
9	368	4.8%	-6.3
10	368	9.6%	-5.0
11	368	5.1%	0.1
12	368	5.0%	-3.7
13	368	4.7%	-0.1
14	368	2.3%	-15.4
15	368	3.1%	1.4
16	368	5.2%	-4.9

1. Test 7 would not converge at listed flow rate. Results shown are for a flow rate of 1100 gpm (127 gpm less than field recorded). Test 7 not included in 435 Zone Average in Table 3.

Calibration Notes

Operating Assumptions

The following additional assumptions were made during calibration:

System Demands - For calibration, the ADD set was scaled to an average (2013-2017) November demand of 1,700 gpm.

Pump Station Operations – Throughout testing, water levels in the David Hill Reservoir remained within an operating range where only the Watercrest Pump Station would turn on. Therefore, the David Hill Pump Station was assumed off for all tests. This is consistent with City comments.

Pressure Reducing Valves – PRVs supplying the 435 Zone and the 368 Zone were field tested in December 2019 by City staff and updated in the model during review. The 2-inch valve at the Lavina PRV station was adjusted up by 1 psi from City values to improve model convergence.

Reservoir Levels – Water levels in both City reservoirs were not available for all tests. Water level in the David Hill Reservoir is measured in feet from the reported base of the tank up to the water surface. Water level in the 5MG Reservoir is measured from the shelf located at an elevation of 358.75 feet to the water surface. The David Hill Reservoir was approximated at 15.75 feet for the tests in the 368 Zone. The 5MG Reservoir was approximated at 7.5 feet for tests in the 435 and 540 Zones.

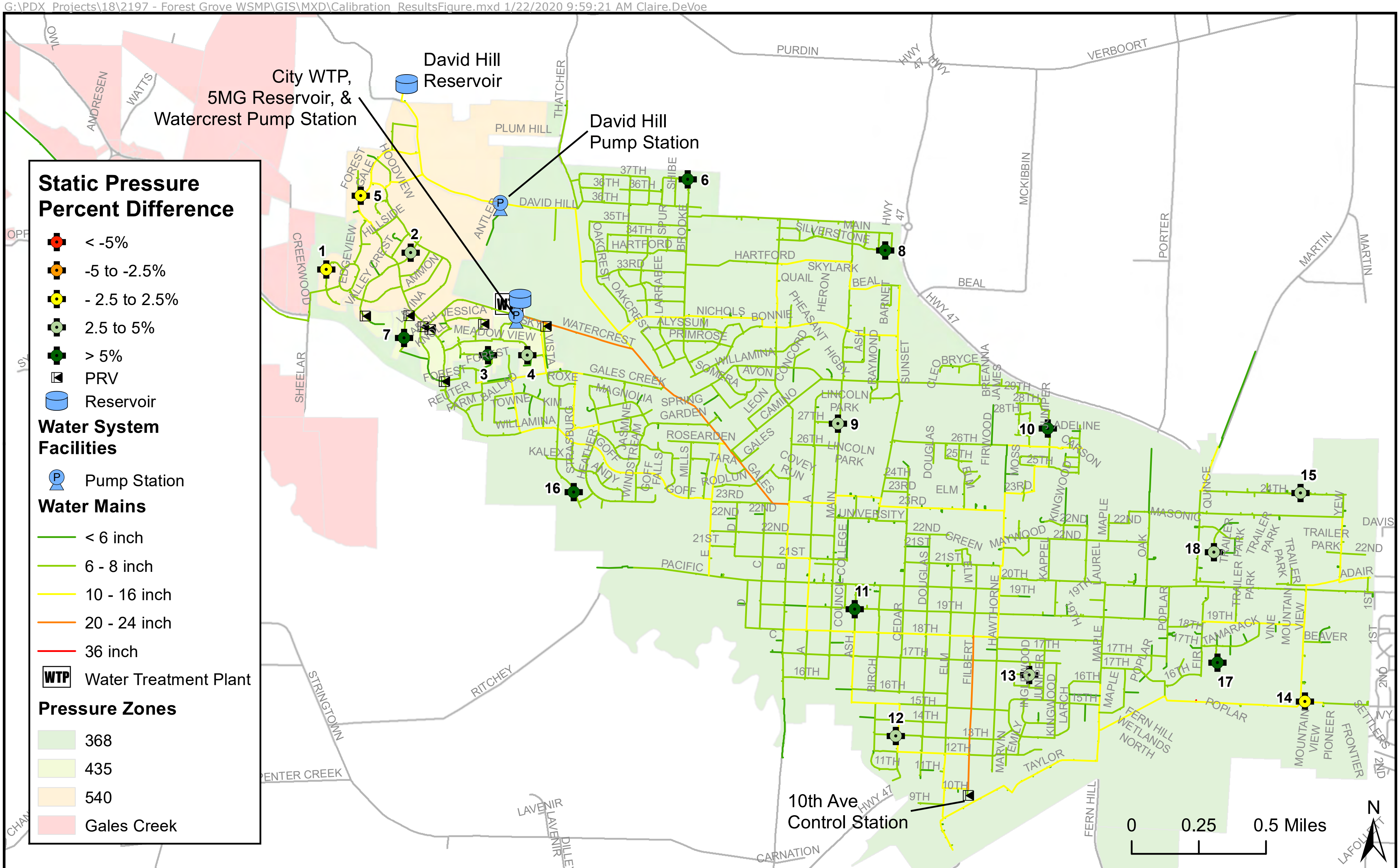
JWC vs WTP Supply to the 368 Zone

Several tests in the 368 Zone were performed under both supply conditions – condition 1: supply from both the JWC and the City's 5MG Reservoir, and condition 2: supply from only the City's 5MG Reservoir. There was not a significant difference in calibration confidence between the two supply conditions. Figures 1 and 2 show the results with supply from only the 5MG Reservoir, except for tests 17 and 18 which show results from JWC supply. In general, the model more accurately predicts fire flow pressure drops without the JWC active.

As stated earlier, if the City would like to use the model for very detailed analysis, then additional calibration may be warranted. This work is beyond the scope of this project and is not recommended at this time.

Pump Station Operations

The pump curves for both the Watercrest and David Hill Pump Stations were not updated in this calibration. While the system performed well with the Watercrest Pump Station operating at a control point and default pump curve, it is recommended that a calibration test be performed for all pumps if specific pump operation is required for additional scenarios.



City of Forest Grove
Water System Master Plan

Figure 1
Hydraulic Model Calibration
Static Pressure

murraysmith

city of forest grove

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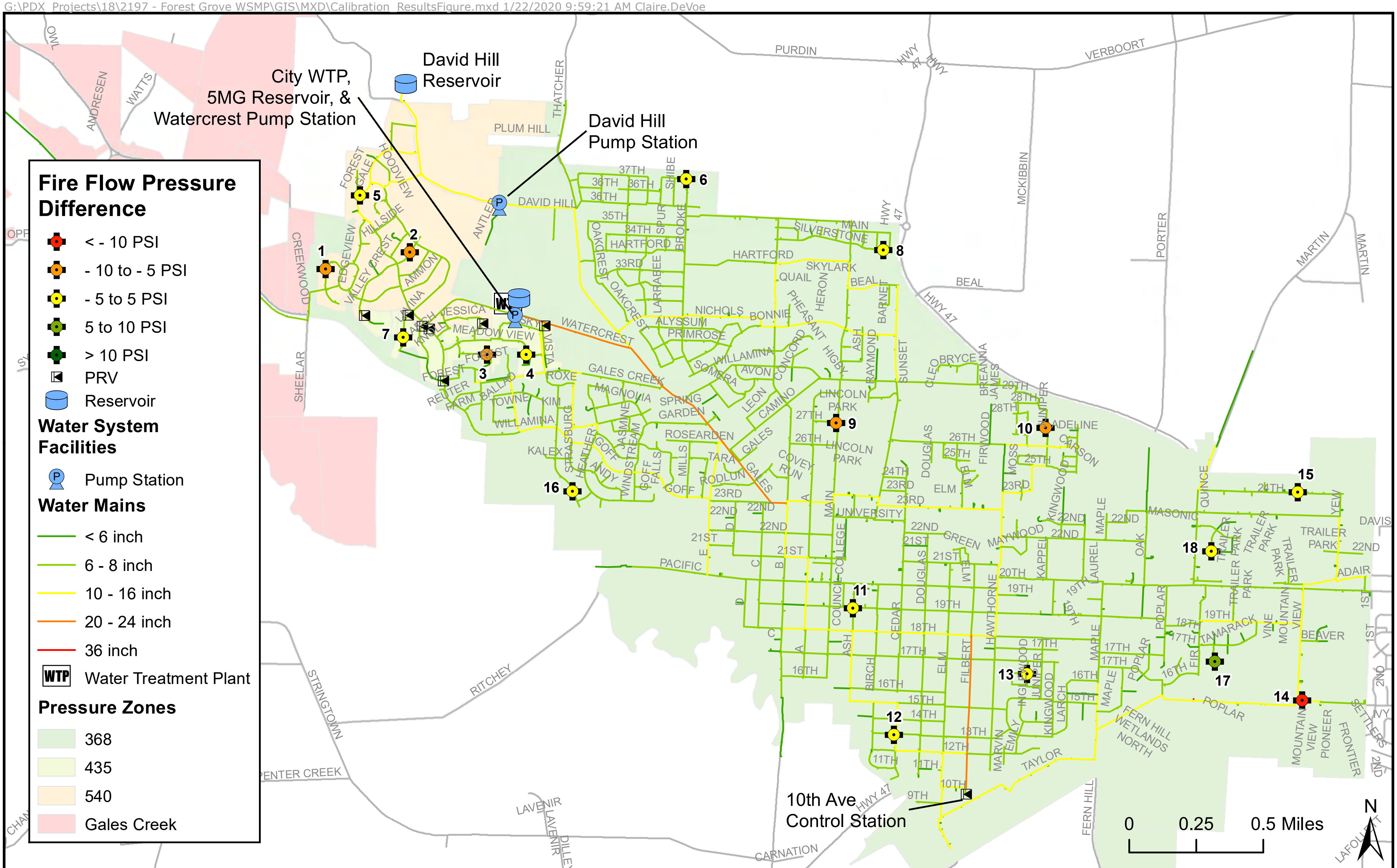

City of Forest Grove
Water System Master Plan

Figure 2
Hydraulic Model Calibration
Fire Flow Results

murraysmith

city of forest grove

February 2020 18-2197

APPENDIX H
WATER SYSTEM SEISMIC
RESILIENCY PLAN, INFRATERRA, 2020

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CITY OF FOREST GROVE

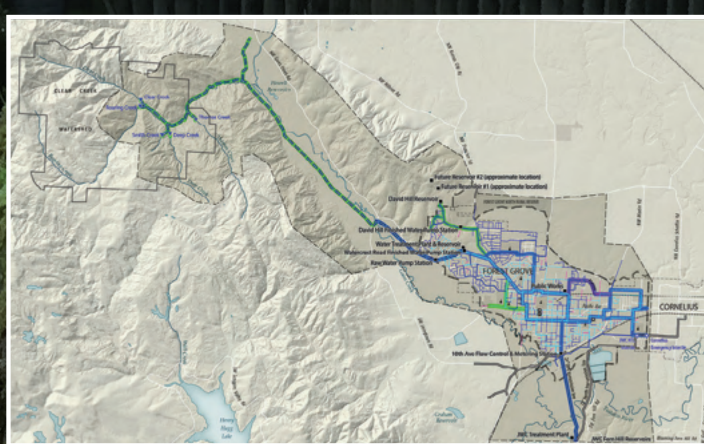
Water System Seismic Resiliency Plan

FINAL

PREPARED BY:

InfraTerra, Inc.

May, 2022



Final Report

City of Forest Grove

Water System Seismic Resiliency Plan

REGISTERED PROFESSIONAL ENGINEER
83512PE
OREGON
NOV 12, 2013
AHMED NISAR
EXPIRES: 12/31/2022

Ahmed Nisar, PE

Principal

InfraTerra, Inc.

May 2022

InfraTerra

Project Team

Company	Role
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SPA Risk, LLC Charles Scawthorn, PhD, SE	Subconsultant
Cascade GIS and Consulting Erica McCormick, GISP, RPA	Subconsultant

City of Forest Grove

Team Member	Title/
Project Team	
Rob Foster, PE	Public Works Director (retired 2019)
Greg Robertson, PE	Public Works Director
Rich Blackmun, PE	Engineering Division & Project Manager
Derek Robbins, PE	Project Engineer
Rick Vanderkin	Operations Superintendent
Brian Dixon	Water Treatment Plant Superintendent (retired 2020)
Dave Nemeyer	Fire Marshal & Public Information Office Division Chief
Leo Cortes	Engineering Technician

TABLE OF CONTENTS

PLATES

TABLES

FIGURES

APPENDICES

Appendix A: Fire Following Earthquake
Appendix B: Regional Geohazard Assessment
Appendix C: Reservoir Stability Analysis
Appendix D: Pipeline Repair Assessment Methodology
Appendix E: Reservoir Seismic Assessment Technical Memo
Appendix F: Facilities Seismic Review

LIST OF ABBREVIATIONS AND ACRONYMS

$(N_1)_{60}$	Corrected Standard Penetration Resistance
3D	Three dimensional
ALA	American Lifelines Alliance
CCP	Concrete Cylinder Pipe
CES	Canterbury earthquake sequence
CI	Cast Iron
CMU	Concrete Masonry Unit
CPT	Cone Penetrometer Test
CRR	Cyclic resistance ratio
CSR	Cyclic stress ratio
CSZ	Cascadia Subduction Zone
DI	Ductile Iron
DOGAMI	Oregon Department of Geology and Mineral Industries
EMAC	Emergency Management Assistance Compact
FEMA	Federal Emergency Management Agency
FFE	Fire Following an Earthquake
FGFR	Forest Grove Fire & Rescue
GIS	Geographic Information System
GPM	Gallons per minute
JWC	Joint Water Commission
MG	Million Gallon
MGD	Million gallons per day
M_W or M	Moment Magnitude
ORP	Oregon Resilience Plan
ORWARN	Oregon Water/Wastewater Agency Response Network
OSSPAC	Oregon Seismic Policy Advisory Commission
PGA	Peak Ground Acceleration
PGD	Permanent Ground Deformation
PGV	Peak Ground Velocity
PNW	Pacific Northwest
PRCI	Pipeline Research Council International
PVC	Polyvinyl Chloride
Qal	Quaternary alluvium (sediments occurring in flood plains)
Qs	Quaternary Silt
RR	Repair Rates
RWTM	Raw Water Transmission Main
S_1	Spectral Acceleration at 1.0 Second
SLIDO	Statewide Landslide Information Database for Oregon

SPT	Standard Penetration Test
SRP	Seismic Resiliency Plan
S_s	Spectral Acceleration
TGD	Transient Ground Deformation
TSoR	Target States of recovery
USGS	United States Geological Survey
WCCCA	Washington County Consolidated Communications Agency
WTP	Water Treatment Plant

EXECUTIVE SUMMARY

Recent studies show that there is a 16 percent to 22 percent probability of a major earthquake on the Cascadia Subduction Zone (CSZ) in the next 50 years. Such an earthquake could impact the entire Pacific Northwest (PNW) and Northern California. Recognizing this risk, the Oregon House of Representatives passed House Resolution 3 in 2011, which directed the Oregon Seismic Safety Policy Advisory Commission (OSSPAC) to prepare an Oregon Resilience Plan (ORP). The purpose of ORP is to help agencies set internal policy direction that will protect lives and maintain economic and commercial activity following a Moment Magnitude 9.0 (M9) CSZ earthquake and tsunami.

The City of Forest Grove (City), located approximately 40 miles from the Oregon coast, will be significantly impacted by a major earthquake on CSZ. The purpose of this study is to assess the seismic performance of the City's water system in an M9 earthquake and provide recommendations for improving the reliability of water supply to its approximately 25,000 residents. While the system could be impacted by an earthquake on the local Gales Creek fault, the likelihood of such an earthquake is significantly lower than the CSZ M9 earthquake. Therefore, consistent with ORP, the M9 earthquake on CSZ was selected for the development of Water System Seismic Resilience Plan (SRP). An overall time frame of 50 years is selected to implement the plan and improve water system performance to meet or exceed the performance goals outlined in ORP.

To develop the Water System SRP, the project team, including InfraTerra[1] and City[2] staff participated in a workshop to identify critical components of the City's water system to serve as the water system backbone. This SRP is based on the premise that the water system backbone reliably provides water throughout the City to meet the most critical needs in the aftermath of the M9 earthquake while damage to the remainder of the system is addressed. The Water System SRP selected the ORP's performance goal for the backbone to be 80 to 90 percent operational within 24 hours of the earthquake, and the entire system to be 80 to 90 percent operational approximately within 1 month after that.

The identified backbone system is shown in Plates E1 and E2, and includes the water treatment plant, 9.1 miles of raw water transmission main (RWTM), the 1.6 mile long 24-inch Joint Water Commission (JWC) finished water transmission lines, and 13.4 miles of distribution pipelines. The identified backbone distribution pipelines include

[1] Ahmed Nisar, Mike Greenfield and Charles Scawthorn

[2] Rob Foster, Rich Blackmun, Derek Robbins, Rick Vanderkin, Brian Dixon, and Dave Nemeyer

only existing pipelines. Backbone pipelines were prioritized such that water can be transported to (in descending priority) the City's central district, industrial district in the Northeast of town, and the loop up to David Hill Reservoir. Backbone pipelines with highest priority were identified as first-tier and the remaining as second-tier. In addition to the main water supply source from the Clear Creek watershed, the City supplements its water from the Joint Water Commission (JWC) water treatment plant. Seismic assessment of the assets owned by the JWC partners, except the 24-inch JWC Transmission Line, was outside of the scope of this study.

The estimated shaking from the M9 earthquake could trigger landslides in the Clear Creek watershed and soil liquefaction in many of the low-lying areas within the City. Much of the City's water transmission and distribution system has seismically vulnerable cast-iron and concrete cylinder pipes that are especially susceptible to damage from earthquake-induced ground deformations caused by liquefaction and landslides. It is estimated that there could be over 50 leaks and/or breaks in the backbone system and possibly a couple hundred leaks or breaks in the non-backbone water distribution system. The study has also identified potential seismic deficiencies in the City's 5 million gallon (MG) Water Treatment Plant (WTP) reservoir.

In its current condition and with limited internal resources, it is estimated that it will take about 2 weeks to 1 month following the M9 earthquake for the City to recover to 90 percent backbone operation. The entire system recovery to 90 percent level is estimated to be about 3 to 6 months. Due to the regional impact of the M9 earthquake, material and repair resources support from surrounding communities would be in short supply and transportation routes may be limited.

To upgrade the water system so that it is fully operational shortly after a major earthquake would be costly. Recognizing the potential expense, two mitigation options are considered that, if implemented, would significantly improve the resiliency of the City's water system. Potential impact of transportation, power, and other supporting infrastructure for the restoration of water supply following the earthquake were beyond the scope of this study. Mitigation options discussed in this report were developed for an M9 CSZ earthquake. Research into the frequency of past fault ruptures and the activity of the local Gales Creek fault is still underway at the time of the writing of this report. A detailed assessment of a Gales Creek fault scenario was outside the scope of this study.

The two mitigation options include:

Mitigation Option 1 – designed to achieve 80 to 90 percent operational status for the backbone within 24 hours following an earthquake, requires the following capital improvement program (CIP) projects:

- Emergency pumping equipment to pump water from Gales Creek at the existing Stringtown Road Bridge
- Backup power supply to the existing raw water pump station
- Replacement of approximately 1.2 miles of the RWTM pipeline
- Pipeline replacement and re-route of approximately 500 feet of RWTM near Forest Glen Park
- Seismic upgrade or replacement of the 5 MG WTP reservoir
- Assess anchorage of the electrical cabinet in the generator building and, if needed, anchorage to prevent sliding and overturning
- Replacement of approximately 4.0 miles of backbone cast iron pipes
- Detailed structural analysis of the Public Works Office Building and Maintenance Bays to assess Immediate Occupancy performance criteria and assess mechanical equipment and electrical panel anchorage
- Installation of isolation valve at strategic locations within the backbone system to minimize the risk of uncontrolled release of water from damaged pipelines

Mitigation Option 2 – (extension of Option 1) is designed to make substantial progress towards achieving the additional goal of 80 to 90 percent of the entire water distribution system being operational within 1 to 2 months. This option assumes that the City will have enough stockpile material and sufficient number of repair crews to bring the system back to its pre-earthquake levels in a reasonably short time. Since the City's repair resources are limited and regional recovery resources may become overextended following the M9 earthquake, Option 2 is designed to reduce the risk of system-wide pipeline breaks and allow City resources to focus on critical repair and recovery efforts elsewhere.

Mitigation Option 2 recommends the following CIP projects:

- Completion of Mitigation Option 1 projects
- Detailed structural evaluation of the Stringtown Road Bridge and, if needed, replacement or retrofit of the bridge or replacement of the RWTM pipeline crossing at the bridge
- Replacement of approximately 5.6 miles of the RWTM pipeline from the Watershed to Stringtown Road Bridge
- Seismic upgrade of the 24-inch JWC finished water transmission line and adding flexibility to the pipeline at the 10th Avenue Control Station (assuming water supply from JWC will be available)
- Detailed evaluation of liquefaction hazard and structural response of the 10th Avenue Control Station to assess ASCE 41-17 Immediate Occupancy (structural and non-structural) performance level
- Backup power supply to the David Hill pump station

- Structural seismic assessment of the David Hill reservoir
- Replacement of approximately 0.8 miles of additional cast iron pipes within the second-tier backbone water distribution system
- Replacement of approximately 15.5 miles of non-backbone distribution system cast iron pipes and development of long-term non-cast iron pipeline replacement plan that considers liquefaction severity, corrosion, and age of pipelines
- Additional system wide installation of isolation valves at strategic locations within the second-tier backbone and non-backbone distribution system

We also recommend the City stockpile enough repair resources for 10 workdays worth of repairs, establishing material procurement protocols and on-call contracts with suppliers, develop repair protocols for rapid reimbursement from Federal Emergency Management Agency (FEMA) and develop an Emergency Management Assistance Compact (EMAC) program with the state of Oregon for receiving mutual aid from other states. We also recommend implementing non-CIP projects including emergency response training and protocols for City employees, programs to periodically evaluate and test emergency response equipment, and develop and maintain regularly updated utility maps with locations of pipeline repairs.

1.0 INTRODUCTION

InfraTerra, Inc. (InfraTerra) is pleased to submit the Water System Seismic Resiliency Plan (SRP) to the City of Forest Grove (City). This study was performed with InfraTerra as the prime consultant and SPA Risk, LLC (SPA), Greenfield Geotechnical, and Cascade GIS and Consulting (Cascade) as sub-consultants.

The purpose of this study is to (1) assess the seismic performance of the City's water system in a Moment Magnitude (M_W) 9.0 (M9) earthquake on the Cascadia Subduction Zone (CSZ) and (2) develop mitigation recommendations to improve the water system performance such that it meets or exceeds the performance goals of the Oregon Resilience Plan (ORP). For planning purposes, a 50-year time frame, same as that in ORP, was selected for the implementation of the identified mitigations options.

1.1 PROJECT TEAM

A comprehensive water system seismic assessment requires multi-disciplinary input, including geology and seismology; geotechnical, structural and pipeline engineering; system operations; and hydraulic response. Evaluation of a geographically distributed water system in a major earthquake requires an understanding of this multi-disciplinary problem to realistically assess system vulnerability, and to develop practical mitigation solutions.

The InfraTerra team included specialists with multidisciplinary background and past experience with water system seismic resiliency studies. They have developed resiliency plans for several major water systems including that of the City of Portland. The project team worked with City's staff to assess seismic resilience of the City's water system and develop recommendations to meet the overall objectives of the ORP.

1.2 BACKGROUND

CSZ, a 600-mile fault that runs from northern California up to British Columbia poses the most significant earthquake hazard to the City of Forest Grove, which is located approximately 40 miles from the Oregon coast. There have been 41 earthquakes in the last 10,000 years on CSZ with the most recent on January 26, 1700, with an estimated Magnitude of 9.0 magnitude. CSZ has not produced an earthquake since 1700. Recent studies show a 16 percent to 22 percent probability of an earthquake with Magnitude 8.5 or greater on CSZ in the next 50 years (Goldfinger et al., 2016). It is expected that such an earthquake could impact the entire Pacific Northwest (PNW) and Northern California. Geological evidence suggests that a rupture of the entire CSZ can produce earthquakes as large as M9, and is generally used for most planning studies in the Pacific Northwest.

Recognizing the potential earthquake risk, in 2011, the Oregon House of Representatives passed House Resolution 3, which directed the Oregon Seismic Safety Policy Advisory Commission (OSSPAC) to prepare an ORP to help agencies set internal policy direction to protect lives and maintain economic and commercial activity following an M9 earthquake and tsunami.

OSSPAC formed eight task groups to address various aspects of seismic risk. Of these, the Water and Wastewater Task Group estimated that under present conditions, it may take one month to a year to restore water service following an M9 earthquake. The task group identified a broad set of goals, referred to as target states of recovery (TSoR), for the time required to achieve different levels of service for water systems in Oregon.

The City may also experience earthquakes from nearby local earthquake sources. The most significant of which is the Gales Creek fault. Compared to the CSZ, the Gales Creek fault has low seismic activity. However, recent studies suggest that the fault may be more active than previously believed (Horst, 2018). These studies are still ongoing and have not reached definitive conclusions. Due to a significantly higher probability and region wide impact of an M9 earthquake, the present study adopted the ORP's TSoR goals to evaluate seismic performance of the City's water system.

1.3 STUDY TASKS

The Water System SRP study included the following tasks:

- **Earthquake hazard maps:** Develop seismic hazard maps consisting of ground shaking, liquefaction and earthquake-induced landslide hazards for the study area.
- **Backbone system performance:** Identify a backbone system consisting of key transmission and distribution system facilities, and assess its seismic performance.
- **Distribution system performance:** Assess seismic performance of distribution system not part of the backbone.
- **Mitigation measures:** Recommend mitigation projects, which if implemented over the next 50 years, will meet the ORP's TSoR goals.

1.4 REPORT ORGANIZATION

The Water System SRP includes an Executive Summary that describes the scope and purpose of the study, provides a brief description of the City's water system and its expected seismic performance, and lists recommended mitigations.

The remainder of this report is organized into 9 chapters as follows:

- **Chapter 1.0 - Introduction:** provides an introduction and overall objectives of the study
- **Chapter 2.0 – System Description:** includes a description of the City water system
- **Chapter 3.0 – Performance Objectives:** includes a description of ORP goals and TSoRs used for this study
- **Chapter 4.0 Seismic Hazard Maps:** provides a description and quantification of relevant seismic hazards
- **Chapter 5.0 – Seismic Vulnerability Assessment:** includes details of the seismic assessment and performance of water system components in an M9 earthquake
- **Chapter 6.0 – Post-Earthquake Repair:** presents a discussion on the City's available resources to perform post-earthquake repair and restoration following an M9 earthquake
- **Chapter 7.0 – Mitigation Options:** presents a range of potential mitigation options based on results of the vulnerability assessment
- **Chapter 8.0 – Recommendations:** provides a set of recommended mitigation projects
- **Chapter 9.0 – References:** includes a list of technical references

2.0 SYSTEM DESCRIPTION

The City's water system serves residential, commercial, and industrial consumers primarily within the current City limits. It serves a population of 23,555 and covers the service area shown in Figure 1 (full extent maps shown in Plate 1 and Plate 2).

The following sections describe the major elements of the water system.

2.1 WATER SUPPLY SYSTEM

The main source of raw water for the City is the Clear Creek watershed located about 8 miles north of the City's Water Treatment Plant (WTP). The water supply is supplemented by treated water from the Joint Water Commission (JWC) WTP located on Spring Hill Road south of the City.

2.1.1 Clear Creek Watershed

The City owns 4,300 acres within the Clear Creek watershed that can provide as much as 3.7 million gallons per day (MGD) of raw water. Water from the watershed flows under gravity and is treated at WTP. A booster pump is located between the Clear Creek watershed and WTP, which is only operated when water demand exceeds the gravity capacity of the raw water transmission main (RWTM).

Within the watershed, the City has intake facilities on Clear Creek, Roaring Creek, Smith Creek, Deep Creek, and Thomas Creek. Figure 2 shows intake facilities at Deep Creek and Roaring Creek, facilities at other locations are generally similar. A typical river intake consists of a perforated pipe that collects water from a pool created by a small dam as shown in Figure 3. In addition, the City maintains a six-inch emergency intertie with the City of Cornelius, located at Heather Street at the City boundary.

2.1.2 Joint Water Commission Supply

The cities of Forest Grove and Hillsboro formed JWC in 1976 under Oregon Revised Statues 190 agreement. The current members of JWC include the cities of Forest Grove, Hillsboro, Beaverton and the Tualatin Valley Water District. JWC draws water from the Tualatin River during winter and has access to the 53,000 acre-feet Scoggins Reservoir during summer. JWC currently provides approximately 400 million gallons (MG) per year to the City, (approximately 36 percent of the City's total water supply needs), most of which is typically used during the peak water demand season from July through October. The City also uses the JWC water supply during the winter when the WTP requires maintenance, during high-turbidity events, or for other reasons.

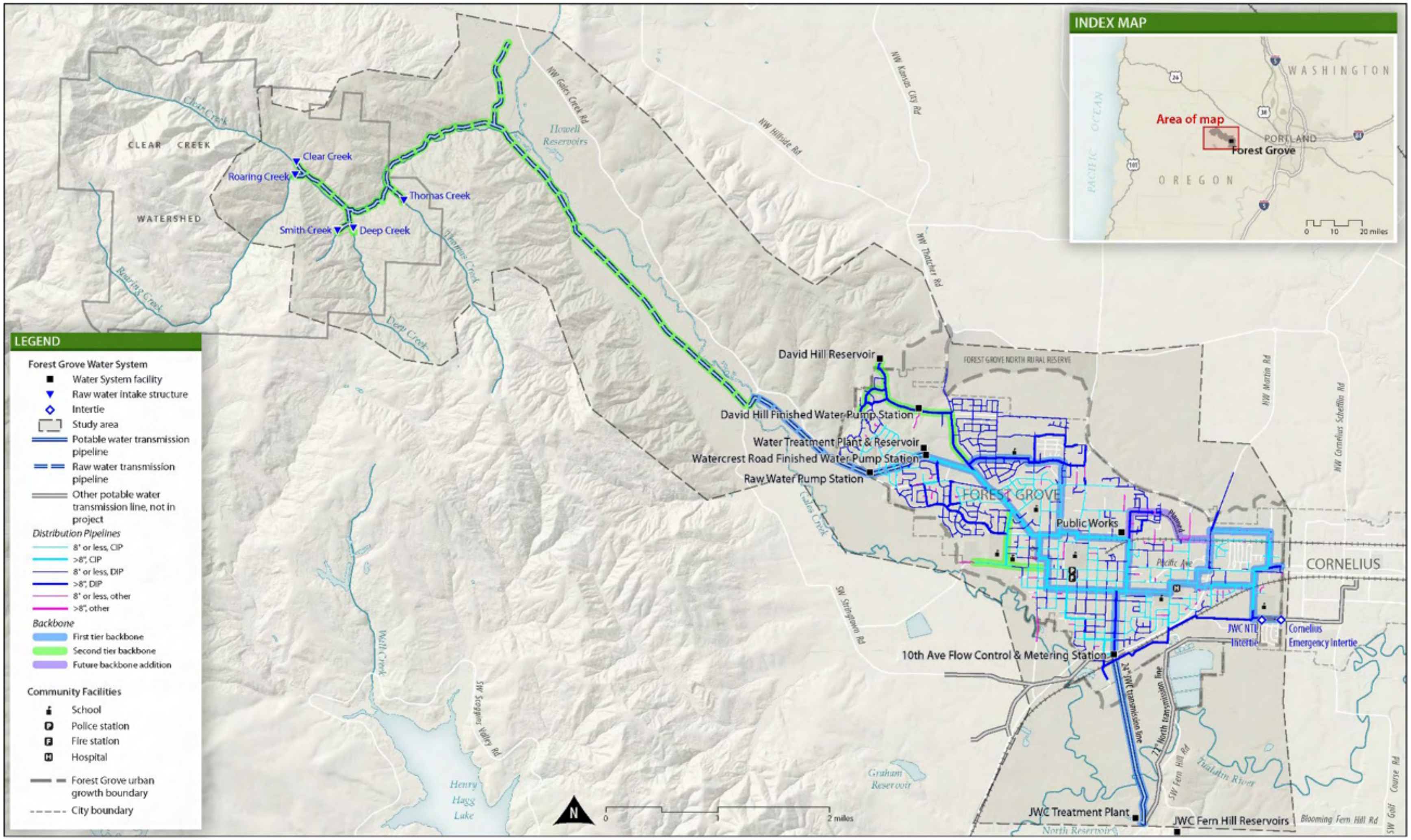


Figure 1: City of Forest Grove's Water System

River Intake – Deep Creek

River Intake – Roaring Creek

Figure 2: River Intake Facilities

Reservoir Pool and Dam

River Intake Perforated Pipe

Figure 3: River Intake Details - Typical

2.2 TRANSMISSION SYSTEM

2.2.1 RAW WATER TRANSMISSION MAIN

The raw water transmission system consists of two parts: (1) 8-inch cast iron transmission pipes from river intakes to the RWTM, and (2) a 16-inch RWTM that transports water from the Clear Creek watershed to the City's WTP.

The approximately 9.1-mile-long RWTM generally runs along Gales Creek and crosses the creek at the Stringtown Road Bridge. The bridge, located northwest of WTP is a two-lane reinforced concrete bridge owned and maintained by Washington County. At this location, the pipeline is suspended from the bridge as shown in Figure 4. In case of pipeline failure upstream of the Stringtown Road Bridge, there is provision to feed raw water from Gales Creek to the RWTM through a blind flange (Figure 4), and from there to the WTP.

16-inch RWTP at Stringtown Road Bridge

RWTP Blind Flange for Emergency Intake

Figure 4: Stringtown Road Bridge Crossing

2.2.2 24-INCH FINISHED WATER TRANSMISSION LINE

Water from the Tualatin River is treated at the JWC WTP located on Spring Hill Road south of the City. The JWC WTP expansion to a total capacity of 85 MGD was completed in the summer of 2019.

Treated water from the JWC WTP is stored in two 20 MG Fern Hill Reservoirs (located Southeast of the JWC WTP). The City owns 5.3 MG of storage in the Fern Hill Reservoirs. Finished water from the reservoirs is transported through the 24-inch JWC finished water transmission line (JWC TL) which is approximately 1.6-mile-long concrete cylinder pipe (CCP) to the City's 10th Avenue Control Station. The 24-inch JWC TL is jointly owned by the cities of Forest Grove and Hillsboro but operated by JWC/Hillsboro staff. However, in a major earthquake City's staff may be needed to perform repairs to this pipeline if JWC/Hillsboro staff become unavailable.

2.3 DISTRIBUTION SYSTEM

The City's water distribution system consists of a total of 91.5 miles of pipelines. Pipelines within the distribution system are primarily cast iron and ductile iron pipes with a small amount of polyvinyl chloride (PVC), copper, and galvanized steel. Pipeline types for the distribution system are summarized in Table 1 and Figure 5.

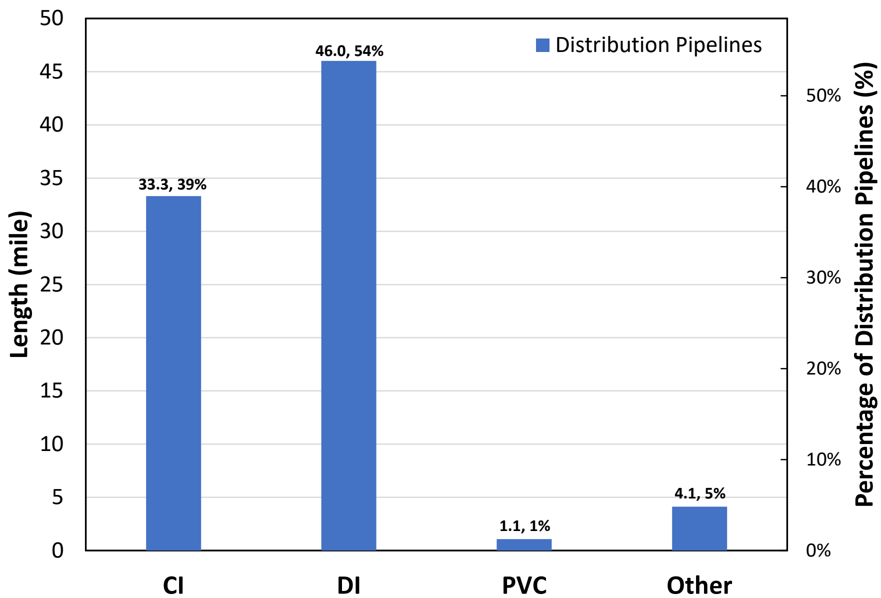
Pipeline lengths shown in Figure 5 are obtained from the GIS database provided by the City on June 5, 2018 (current at the time), and are somewhat different from the pipeline lengths shown in Table 1 and included in the Water System Master Plan (Murraysmith, 2020), which contains the most up-to-date data.

Table 1: City of Forest Grove Water System Pipeline Types and Lengths

Pipe Type	Distribution System (miles)[1]
Cast Iron (CI) Pipe	33.3
Ductile Iron (DI) Pipe	46.7
PVC Pipe	7.0
Other Pipe	4.6
Total[2]	91.5

Notes:

1. Pipeline lengths from the Water System Master Plan (Murraysmith, 2020).
2. Slight differences due to rounding.



Note:

1. Pipeline lengths are based on information in the City's GIS database provided on June 5, 2018.

Figure 5: Percentage of Significant Pipeline Types in City's Distribution System

2.4 STORAGE SYSTEM

The City's storage system includes two reinforced concrete reservoirs. The larger of the two is a buried 5 MG reservoir located at WTP. The second is a 1 MG partially buried reservoir on David Hill Road just outside the city limits to the northwest (Plate 1). General information about the two reservoirs is summarized in Table 2, with a brief description provided below.

Table 2: Summary of City Reservoirs

Reservoir Name	Latitude	Longitude	Structure Type	Construction Date	Approx. Dimensions (feet)	Height (feet)	Capacity (MG)
David Hill	45.546	-123.146	Buried concrete	1985	76 x 96	18.5 to 22	1
WTP	45.535	-123.137	Buried concrete	1948	150 x 300	19	5

The WTP Reservoir was constructed in 1948. It is approximately 17 feet deep and has plan dimensions of approximately 150 feet long by 300 feet. The original reservoir did not include a roof over the reservoir basin. The design anticipated the construction of a roof in the future and included footings and vertical reinforcement for future columns to support a roof. A roof with dimensions nearly identical to the original 1948 design was constructed in 1980. Figure 6 shows photos of the reservoir prior to roof construction and in its current state.

Prior to Roof Construction Roof (1980)

Existing with Roof (2018)

Figure 6: 5 MG WTP Reservoir

The David Hill Reservoir was constructed in 1985 on a sloping hillside (Figure 7). The reservoir is approximately 76 by 96 feet rectangular in plan and is embedded between 13 and 16 feet in the ground. The City also owns 5.3 MG of storage in the Fern Hill Reservoirs owned and operated by JWC. As the Fern Hill Reservoirs are owned by all JWC partners, a seismic evaluation of the reservoirs was not performed.

Partially Buried David Hill Reservoir

David Hill Reservoir Roof

Figure 7: 1 MG David Hill Reservoir

2.5 WATER TREATMENT PLANT

The City's WTP is located at 501 Watercrest Road and includes multiple structures identified in Figure 8. A brief description of the most significant structures at the City's WTP and their function is summarized in Table 3.

Figure 8: WTP and Reservoir Layout

Table 3: Summary of Structures within the WTP

Structure	Const. Date	Critical[1] (Y/N)	Stories	Approx. Size (feet)	Function
Chemical Building	1948	Yes	1	70 x 32	Part of chemical mixing and water treatment process
Office Building/ Pipe Gallery/ Filters	1948	Yes	Office on ground level Pipe Gallery and Filters on lower level	36 x 17.5	Office: Monitor/control of treatment system and testing. Pipe Gallery and Filters: Part of the water treatment process
Emergency Generator	Unknow n	Yes	N/A	7 x 13	Supply electricity to operate WTP at full capacity for 32 hours. Comes online automatically if power outage > 3 seconds
Sedimentation Basin	1910	Yes	N/A	60 x 110	Part of water treatment process
Backwash Lagoon	1978 – 1979	Yes	N/A	65 x 70	Part of water treatment process
Shop	1980s	No	1	25 x 35	Waste disposal; misc.
Den	2002	No	1	15 x 25	Storage - tractor and misc. tools
Storage Facility	Prior to 1978	No	1	40 x 60	Storage of office items (e.g. historic drawings and photos)

Note:

1. A structure is defined as critical to the WTP if its failure prevents water treatment at the WTP.

2.6 OTHER FACILITIES AND STRUCTURES

Other facilities and structures within the City's water system include three pumping stations, the Public Works facility, and the 10th Avenue control station.

2.6.1 PUMPING STATIONS

City's pump stations include the raw water pump station, the Watercrest Road finished water pump station, and the David Hill finished water pump station (Figure 9). The location of each pump station is shown in Plate 1 and Plate 2. A brief description of each pump station and their function is summarized in Table 4.

Table 4: Summary of Pump Stations in City Water System

Name	Construction Date	Latitude	Longitude	Total Capacity (GPM)	Pump Station Function
Raw Water Pump Station	1979	45.531	-123.147	700[1]	Increases flows to the WTP when needed
Watercrest Road Finished Water Pump Station	1978	45.533	-123.137	280	Primary pump station feeding the David Hill Reservoir
David Hill Finished Water Pump Station	1985	45.540	-123.139	400	Backup to Watercrest Road Finished Water Pump Station

Note:

1. The gravity capacity of the raw water main is estimated by the City to be approximately 2,150 gallon per minute (GPM), or 3.1 million gallons per day (MGD). The raw water pump station can increase flows to the plant up to approximately 3.7 MG. The raw water pump station capacity is estimated to be the difference of increased flow and natural gravity flow.

2.6.2 10TH AVENUE CONTROL STATION

The 10th Avenue Control Station is located at 2540 10th Avenue. The building was constructed in the late 1970s. It is a single-story structure with concrete masonry unit (CMU) walls and a wood frame roof (Figure 9). The facility is connected to the 24-inch JWC TL and is typically used during the periods of peak demand from July through October or when the WTP shuts down for maintenance.

Raw Water Pump Station

Watercrest Finished Water Pump Station

David Hill Finished Water Pump Station

10th Avenue Control Station

Figure 9: Pumping Stations and 10th Avenue Control Station

2.6.3 PUBLIC WORKS FACILITY

The Public Works facility is located at 2251 23rd Avenue and includes an office building, an equipment storage building, a machine shop, a supply storage building, and a covered storage structure. These structures are summarized in Table 5 and shown in Figure 10.

Table 5: Summary of Structures at Public Works Facility

Public Works Structure	Construction Date	Stories	Approx. Dimensions (feet)	Function
Office Building and Machine Shop	1989	1	50 x 115	Office and servicing of City vehicles
Covered Storage Structure	Unknown	1	20 x 100	Vehicle storage
Supply Storage Building	Mid-1990s	1	40 x 125	Supplies and tools storage
Equipment Building	Unknown, possibly oldest at facility	2	60 x 105	Vehicle, supplies, and tools storage

Office Building and Machine Shop

Covered Storage Structure

Equipment Building

Supply Storage Building

Figure 10: Public Works Facility

3.0 PERFORMANCE OBJECTIVES

3.1 ORP GOALS FOR WATER

Recognizing the nature and extent of inherent vulnerabilities in an existing water system and the substantial cost of seismic mitigation, ORP recommends a phased approach for system improvement. The approach consists of the identification and strengthening of a backbone system that can provide water for critical needs such as fire suppression, first aid, emergency response, community use, and normal health and hygiene soon after the event while damage to the remainder (non-backbone) of the system is being addressed.

The backbone system should consist of key supply, treatment, transmission, distribution, and collection elements that can be upgraded, retrofitted, or rebuilt to withstand the M9 CSZ earthquake. ORP assumes an overall time frame of 50 years as a goal to implement system upgrades so that a reliable supply of water is available for critical needs following an earthquake.

The ORP identifies a broad set of performance goals or TSoR for seven water system response categories and recommended a timeline associated with meeting different levels of operability (20 percent to 30 percent, 50 percent to 60 percent and 80 percent to 90 percent) for each category. The seven categories are described below:

1. Availability of finished water at supply source such as water treatment plants and wells
2. An operational backbone system
3. Availability of water supply to critical facilities
4. Availability of water at key supply points for fire suppression
5. Availability of water at fire hydrants
6. Availability of water at community distribution centers
7. Restoration of the distribution system

The TSoR identified in ORP are shown in Figure 11.

CSZ M_w 9.0 Event Occurs	Timeline					
ORP Category	0 - 24 hours	1 - 3 days	3 - 7 days	1 - 2 weeks	2 weeks - 1 month	1 - 3 months
Potable water available at supply source (WTP, wells, impoundment)	20 - 30% operational	50 - 60% operational		80 - 90% operational		
Main transmission facilities, pipes, pump stations, and reservoirs (backbone) operational	80 - 90% operational					
Water supply to critical facilities available	50 - 60% operational	80 - 90% operational				
Water for fire suppression--at key supply points	80 - 90% operational					
Water for fire suppression--at fire hydrants			20 - 30% operational	50 - 60% operational	80 - 90% operational	
Water available at community distribution centers/points		50 - 60% operational	80 - 90% operational			
Distribution system operational		20 - 30% operational	50 - 60% operational	80 - 90% operational		

Figure 11: Oregon Resilience Plan Target States of Recovery

In summary, TSoR require a high degree of reliability from the backbone system. According to ORP, the backbone should be 80 to 90 percent operational within 24 hours following the earthquake. The goal for the availability of water for fire suppression at key supply points is also 80 to 90 percent within 24 hours. Goals for availability of finished water at the source and distribution system are 80 percent to 90 percent operational within one to two weeks. Water supply to critical facilities such as hospitals, first-aid facilities, command and control centers, and essential industries is expected to be 80 percent to 90 percent operational within 1 to 3 days. Supply to community distribution sites is expected to be operational within 3 to 7 days. It is expected that within a month the system should be close to its pre-earthquake condition.

3.2 BACKBONE SYSTEM

The project team, including InfraTerra[3] and City[4] staff participated in a workshop to identify critical components of the City's system that can serve as the backbone. Considerations for identifying system components to serve as backbone included:

- Providing access to water to a large portion of town
- Providing sufficient capacity for post-earthquake demands
- Providing water to critical facilities such as the Forest Grove Tuality Urgent 3 Care Facility and schools which can serve as shelters following an earthquake
- Including redundant elements, such that the goals of the backbone system can still be met should some elements fail

Backbone pipelines were prioritized such that water can be transported to (in descending priority) the City's central district, industrial district in the Northeast of town, and the loop up to David Hill Reservoir. Backbone pipelines with highest priority were identified as first-tier and the remaining as second-tier.

The backbone system for this project is shown in Plate 1 and Plate 2, and includes WTP, 9.1 miles of RWTM, 1.6 mile long 24-inch JWC TL, and 13.4 miles of distribution pipelines (0.7 miles of which are planned for the future, pending construction of new pipelines). It is possible that the backbone system identified as part of this project may change depending on future growth.

The 7.3 miles of the RWTM upstream of Stringtown Bridge, including the cast iron pipelines from the river diversion structures in the Clear Creek Watershed, and water distribution lines near the David Hill Reservoir, were classified as second-tier because of City's ability to alternatively feed raw water in an emergency from Gales Creek. The 1.8-mile-long section of RWTM between the Stringtown Bridge and WTP was classified as first-tier because this section is the only source of raw water supply to the WTP.

The JWC TL and the 10th Avenue Control Station have also been identified as a first-tier backbone as they provide redundant treated water supply should the RWTM downstream of Stringtown Bridge or the WTP fail; however, it depends on the seismic reliability of the Fern Hill reservoirs and the 24-inch JWC TL. Seismic assessment of the reservoirs and the JWC TL were outside the scope of this study. Information provided by the City suggests that the JWC WTP is seismically vulnerable and JWC water supply may not be guaranteed. A summary of backbone transmission pipelines is presented in Table 6.

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[3] Ahmed Nisar, Mike Greenfield and Charles Scawthorn

[4] Rob Foster, Rich Blackmun, Derek Robbins, Rick Vanderkin, Brian Dixon, and Dave Nemeyer

Both the 1 MG David Hill and 5 MG WTP reservoirs were included as part of the backbone as they provide critical water storage for emergency needs following an earthquake. The 5 MG WTP reservoir was designated as part of the first-tier backbone, and the 1 MG David Hill reservoir was designated as part of the second-tier backbone.

The Public Works Office Building was also identified as a first-tier backbone structure as it is required to support repairs after the CSZ. The Office Building will serve multiple functions, including planning repairs, feeding staff, and housing staff.

Table 6: Transmission System Pipeline Types and Lengths

Pipe Type	First-Tier Backbone Raw Water Transmission Pipeline (miles)[1]	Second-Tier Backbone Raw Water Transmission Pipeline (miles)[1, 4]	First-Tier Backbone Finished water 24-inch JWC TL (miles)[1]
Concrete Cylinder Pipe[2]	1.8	6.0	1.6
Cast Iron Pipe[3]	-	1.2	-
Total	1.8	7.3	1.6

Notes:

1. Pipeline lengths are based on information in the City's GIS database provided on June 5, 2018, which have since been updated.
2. Concrete Cylinder Pipe includes pipelines marked as CCP in City GIS files. Engineering drawings show details for both welded and non-welded pre-stressed steel cylinder pipe and coal tar enamel lined and wrapped steel pipe.
3. Cast Iron Pipe includes pipelines marked as CI and CI TYTON in City GIS files.
4. Minor difference in total length of second-tier backbone raw water transmission pipelines due to rounding.

Approximately 12.6 miles of distribution system pipelines that provide city-wide coverage are also identified as part of the backbone. Out of the 12.6 miles, 8.0 miles were designated as first-tier backbone. The first-tier backbone in the distribution system was selected to provide water delivery throughout the City and serve as emergency water supply points to key facilities such as Public Works, schools, police station, and fire station. In an emergency, these locations can serve as delivery points for finished water. Approximately 4.6 miles of distribution system pipelines were identified as second-tier and include pipelines from the David Hill reservoir to the first-tier backbone and pipelines in the western portion of the City.

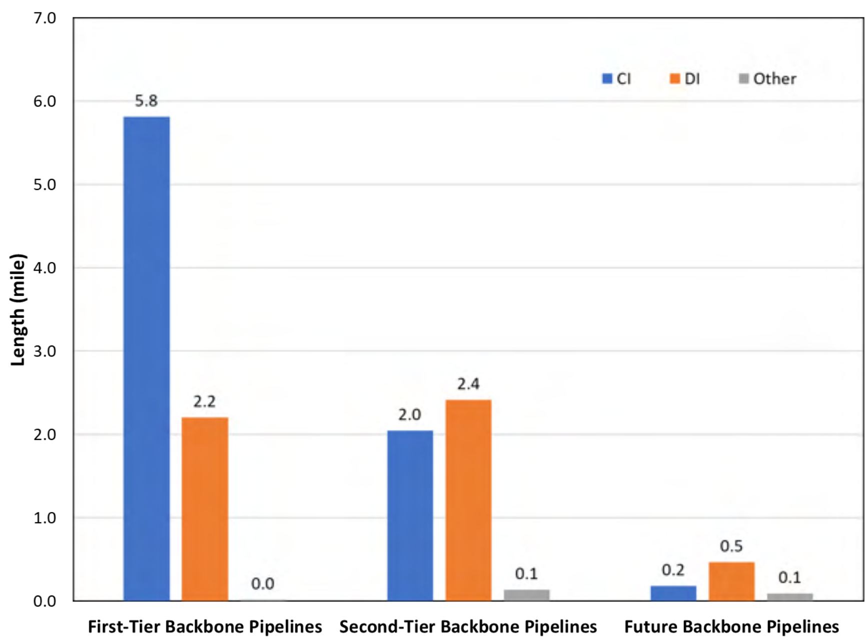
The backbone pipelines within the distribution system primarily include cast iron and ductile iron pipelines. An additional approximately 0.7 miles of pipelines are identified as future backbone, pending construction of new pipelines. The total lengths and pipe types of backbone pipelines within the distribution system are summarized in Table 7 and Figure 12 and shown in Plates 1 and 2.

Table 7: Distribution Backbone System Pipeline Types and Lengths[1]

Pipe Type	First-Tier Backbone System (miles) [1]	Second-Tier Backbone System (miles) [1]	Future Backbone System (miles)[6]
Cast Iron Pipe[2]	5.8	2.0	0.2
Ductile Iron Pipe[3]	2.2	2.4	0.5
Other Pipe[4]	<0.1	0.1	0.1
Total	8.0	4.6[5]	0.7[5]

Notes:

1. Pipeline lengths are based on information in the City's GIS database provided on June 5, 2018, which have since been updated.
2. Cast Iron Pipe includes pipelines marked as CIP in City GIS files.
3. Ductile Iron Pipe includes pipelines marked as DIP City GIS files.
4. Other Pipelines include pipelines marked as C900 (PVC) and unspecified in City GIS files.
5. Minor difference in total length and sum of lengths of second-tier backbone and future backbone systems due to rounding.
6. Future backbones only include existing pipelines. Planned pipelines are not in the scope of this project.



Note: Pipeline lengths are based on information in the City's GIS database provided on June 5, 2018, which have since been updated.

Figure 12: Pipeline Types in the Backbone Distribution System

3.3 POST-EARTHQUAKE FIRE DEMANDS

This section summarizes our assessment of post-earthquake fire demands for the City following an M9 earthquake. Although this study focuses on the M9 earthquake, fire demands from a Magnitude 6.8 (M6.8) local earthquake on the Gales Creek fault were also included for comparison. Additional details on post-earthquake fire demands are included in a technical memorandum (Appendix A).

3.3.1 Forest Grove Fire & Rescue Resources

The City's fire protection services are provided by the Forest Grove Fire & Rescue (FGFR) that also provides rescue, fire response, emergency medical services, operations level hazardous materials response, fire prevention, and life-safety services (FGFR, 2016). FGFR operates two fire stations: Station 4, located in downtown and Station 7, located in Gales Creek.

Based on the information obtained from FGFR in 2018, the total pumping capacity of all apparatus in Station 4 is 9,623 gallon per minute (GPM) and 1,323 GPM in Station 7. The total for Station 4 includes 2,000 GPM for water tenders WT4 and WT7, which might be used for water shuttling rather than on-scene firefighting following an earthquake. There are numerous known alternative sources of water supply in the City, such as Gales Creek, the Tualatin River, and Council Creek. Based on the probable maximum relay distance of 2,000 feet for FGFR, about half of the City may be supplied from alternative water supplies (assuming relay capacity which, in some cases, are the same fire engines required at the fire ground).

3.3.2 Assessment of Ignitions

Fire following an earthquake (FFE) is a highly non-linear process, which can only be modeled approximately (as discussed in Appendix A). In many cases the only clear result is the differentiation between a few small fires versus a major conflagration. Time is of the essence in successfully fighting FFE, because if unattended, small fires can develop into major conflagrations.

Estimation of FFE losses requires collection of data on building stock, ground conditions, water supply, fire services and estimation of earthquake shaking. The technical approach considers these factors in a stochastic framework to estimate (1) ignitions caused by the earthquake, (2) fire spread as a function of fuel (such as the building stock and contents), and (3) wind and firefighting activities (Scawthorn, 2018 and TCLEE, 2005).

The number of ignitions resulting from an M9 earthquake were estimated using the empirical relationships employed in HAZUS (SPA Risk, 2009). Due to relatively moderate levels of estimated ground shaking estimates in the City, the median number of ignitions from the M9 CSZ and M6.8 Gales Creek earthquakes were estimated to be 1 and 3, respectively, for an average time of day. A larger number of ignitions from the Gales Creek event are due to ground motions from this event due to its proximity to the study area. However, strong shaking from a Gales Creek earthquake has a much lower frequency of occurrence compared to that from the CSZ earthquake.

3.3.3 Assessment of Fire Impact

The City responds to about 35 fires per year (FGFR, 2016). Fires are typically reported via the Washington County Consolidated Communications Agency (WCCCA) dispatch center. In an earthquake the telephone system and dispatchers at WCCCA will likely be overloaded, and FGFR will probably learn of the fires by their own observations, citizen reports to Stations 4 and 7, and/or the engine companies during their post-earthquake survey. As a result, delay in response is likely. We estimate this delay will result in three incidents each impacting about 4,000 square foot of building floor upon first arrival of emergency services following an M6.8 earthquake the Gales Creek fault, and one incident with about 4,000 square foot for the M9 CSZ earthquake.

ORP recommends the fire hydrants to be 80 percent to 90 percent operational in two weeks to a month. Since most earthquake related fires occur within minutes to hours following an earthquake, fire water may not be available at fire hydrants immediately following the earthquake.

In the M9 CSZ earthquake, the Gales Creek Station 7 crew will most likely be required to remain in its vicinity and the City will have to rely on the resources of Station 4 and perhaps some state and federal wildland and private resources that cannot be quantified at present. Assuming the availability of current resources, it is likely that FGFR will be able to contain the fires resulting from the CSZ event.

The Gales Creek event is likely to result in one or two fires growing to large proportions if no outside resources are available. This is due as much to the limited resources of FGFR as to the damage and limitations of the City's water supply. The fires that grow to large proportions may each result in a loss of a city block, or several city blocks under adverse meteorological conditions. At this stage, fire defense would only be feasible at a fire break, such as a major street, and the fires would more than likely cease to further spread when they encounter an adequately large fire break (i.e., they exhaust available fuel).

Due to the regional nature of the CSZ event, limited resources may be available for firefighting, but for the local Gales Creek event resources will likely be available from surrounding areas. For planning purposes, water demands are estimated to be about 6,000 GPM for the Gales Creek event and about 2,000 GPM for the CSZ event.

3.4 PERFORMANCE GOALS FOR THE CITY OF FOREST GROVE

Using the guidance in ORP, key performance goals for City's water system components are recommended as shown in Figure 13.

CSZ M_w 9.0 Event Occurs CSZ M_w 9.0 Event Occurs

ORP Category	CFG Assets	Timeline 0 - 24 hours	1 - 3 days	3 - 7 days	1 - 2 weeks	2 weeks - 1	1 - 3 months
Potable water available at supply source (WTP, wells, impoundment)	1. RWTP from Stringtown Bridge to WTP 2. WTP facilities supporting treatment function 3. JWC transmission line	20 - 30% operational	50 - 60% operational		80 - 90% operational		
Main transmission facilities, pipes, pump stations, and reservoirs (backbone) operational	1. First-tier backbone distribution pipelines 2. 5MG reservoir at WTP	80 - 90% operational					
Water supply to critical facilities available	1. All backbone pipelines 2. David Hill Reservoir	50 - 60% operational	80 - 90% operational				
Water for fire suppression--at key supply points	1. FGFR fire department capability to utlize alternative water sources to suppress fires 2. David Hill Reservoir continued operation 3. 5MG WTP Reservoir continued opration	80 - 90% operational					
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	
Water available at community distribution centers/points	1. Backbone distribution pipelines		50 - 60% operational	80 - 90% operational			
Distribution system operational	1. All transmission and distribution pipelines 2. All pump stations		20 - 30% operational	50 - 60% operational	80 - 90% operational		

Figure 13: City of Forest Grove Target States of Recovery

4.0 SEISMIC HAZARD MAPS

This Section describes the methodology used to develop earthquake hazard maps for the City's service area. These maps were developed for the M9 CSZ earthquake, and include the (1) liquefaction susceptibility map, (2) permanent ground deformation (PGD) map for liquefaction-induced lateral spread, (3) PGD map for liquefaction-induced settlement and (4) PGD map for seismically-triggered landslides.

Seismic hazard maps for the study area were based on incorporating both publicly available and project specific data. Assessment of seismic hazards included technical research and observations from recent earthquakes, including the March 11, 2011 M9.0 Tohoku, Japan Earthquake and the 2010-2011 Canterbury Earthquake Sequence[5] (CES; also referred to as Christchurch earthquakes) in New Zealand. These earthquakes produced widespread liquefaction and yielded a large amount of high-quality data. Case histories from these earthquakes resulted in revisions and refinements to liquefaction assessment procedures, which were implemented in this study. Data from the Tohoku earthquake is especially relevant due to its size and understanding of the influence of long duration shaking on liquefaction and liquefaction-induced PGD.

4.1 EARTHQUAKE SCENARIOS

The magnitude and frequency of the M9 CSZ earthquake contributes most significantly to the seismic hazard in the City. Due to the proximity of the City to the Gales Creek fault, a preliminary assessment of the potential impact of a large but rare earthquake on the Gales Creek fault on the City's water system was performed to provide a general understanding of the risk. Detailed assessment of a Gales Creek scenario was beyond the scope of this study.

4.1.1 CASCADIA EARTHQUAKE SCENARIO

Studies by United Stated Geological Survey (USGS) show that there have been numerous large-magnitude earthquakes along CSZ (USGS, 2012). Data on sea-bottom deposits formed by massive slope failures from strong earthquake shaking (turbidites) from as far back as 10,000 years show an average recurrence of about 500 to 530 years for great earthquakes (greater than M8) that have ruptured the entire or nearly the entire length of CSZ. The geologic record also shows an average recurrence interval of about 240 years for smaller, but still very large-magnitude, earthquakes

[5] The Canterbury Earthquake Sequence (CES) includes: M7.1 Darfield Earthquake on September 4, 2011; M6.2 Christchurch Earthquake on February 22, 2011; M6.0 Earthquake on June 13, 2011; and M5.8 and M5.9 earthquakes in December 2011

(M7 to M8) along the southern margin of the subduction zone. These records correlate well with the most recent M9 earthquake that occurred in January 1700, more than 300 years ago.

USGS study shows that there is a 7 to 12 percent probability of a great earthquake affecting the entire PNW in the next 50 years and as much as 21 to 42 percent for an earthquake along southern Oregon and northern California (Goldfinger et al., 2012; OSSPAC, 2013). The earthquake probabilities for the central and northern Oregon coast have recently been revised upwards to 16 to 22 percent (Goldfinger et al., 2016) in the next 50 years.

4.1.2 GALES CREEK EARTHQUAKE SCENARIO

Local crustal faults have formed in the Willamette Valley due to compression and tension in the earth's crust. The Gales Creek fault zone forms the boundary between the Oregon Coast Range and the Willamette Valley, and is the longest fault in the region. The fault zone extends nearly 75 km and strikes north-northwest parallel to Gales Creek.

This fault zone has been active at least since the Miocene epoch (23 to 5.3 million years ago) and fault activity is evident in the displacement of the Miocene Columbia River basalt to the northwest of the study area. No evidence of deformation in Quaternary (2.6 million ago to present) deposits has been described, but evidence of displacement may be concealed by the thick sedimentary deposits that have buried the fault. The USGS assigned a characteristic magnitude of M6.8 on the Gales Creek fault at a rupture depth of 9.0 km. The USGS assigns an average recurrence interval of about 64,000 years (Haller et al., 2002) for such an earthquake.

Recent trenching by the US Bureau of Reclamation show the fault to be active (Banse, 2018). Current ongoing work by Portland State University, USGS and Lawrence Livermore National Laboratory have found evidence for two surface rupturing earthquakes in the Holocene (12,000 years ago to present) period (Horst et al., 2018). Additional work and 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.

4.2 GROUND SHAKING HAZARD

The estimated ground shaking from the M9 earthquake on CSZ event is based on maps published by the Oregon Department of Geology and Mineral Industries (DOGAMI) in Open File Report O-13-06 (Madin and Burns, 2013). These maps were made part of ORP. Plate 3 through Plate 6 show ground surface peak ground acceleration (PGA) and peak ground velocity (PGV) maps in the City's service area from the M9 earthquake on CSZ. For this earthquake, the median surface PGA and PGV ranges from about 0.20g to 0.27g (for PGA) and from 8 in/sec to 13 in/sec (for PGV), respectively. Most of the City urban growth boundaries have the PGA and PGV values close to the lower end of this range.

The USGS also simulated an M6.8 earthquake scenario with a rupture depth of 9.0 km on the Gales Creek fault zone. Ground surface PGA values from this earthquake ranges from about 0.42g to 0.61g in the study area (Plates 7 and 8). Although PGAs from the Gales Creek earthquake are significantly higher than the M9 CSZ earthquake, they have a much lower probability. The M9 CSZ earthquake is the primary hazard due to its higher probability of occurrence and region wide impact. The M9 CSZ earthquake will produce long duration shaking (lasting several minutes) that will result in significantly more damage than local, crustal faults of the same shaking amplitude.

Recently (when most of the work on this project had been completed), DOGAMI published updated surface ground shaking maps for the M9 CSZ earthquake in Open File Report O-18-02 (Bauer et al., 2018). These revisions resulted in significant changes from the 2013 maps. Near the WTP and David Hill Reservoirs, the 2018 PGA estimates are about 6 to 8 percent higher whereas in the southeast corner of the City boundary and in some areas along Gales Creek they are as much as 20 percent to 50 percent higher. The differences are largely due to the revised soil amplification factors (Federal Emergency Management Agency, 2015 and Appleby and others, unpublished) used in the 2018 study. These amplification factors are conservative and intended for use with the building design code. It is our opinion that the 2013 DOGAMI maps provide a more realistic estimates of ground shaking for the purposes of this study.

4.3 LIQUEFACTION HAZARD

Liquefaction is a process where strong ground shaking during an earthquake transforms granular soils from a solid state into a nearly fluid-like state, resulting in a reduced ability to support overlying soil layers and structures. Liquefaction occurs in loosely deposited saturated soils. When subjected to earthquake shaking that is strong enough or is repeated long enough, pore water pressure in saturated soils increase. When the excess pore water pressure exceeds the contact stresses between the soil particles, it results in a loss of soil structure and frictional resistance between particles causing the soil to lose its strength and flow like a liquid (hence the term, "liquefaction").

PGD from liquefaction is the primary cause of damage to water systems in large earthquakes. Recent examples of liquefaction-related ground deformation caused by earthquakes include large-scale damage produced during the 1989 Loma Prieta, California, 1994 Northridge, California, 1995 Kobe, Japan, 1999 Duzce, Turkey, 2001 Bhuj, India, and 2010/2011 CES in New Zealand. Liquefaction-induced lateral spread displacement can be on the order of several feet, especially near free faces, as observed in several past earthquakes (Figure 14).

Lateral spreading in Parking Lot – September 4, 2010 M7.1 Darfield Earthquake (Source: McSaveney)

Lateral spreading of Railroad Embankment in February 28, 2001 M6.8 Nisqually Earthquake in Capitol Lake, WA (Source: PEER)

Figure 14: Example Historic Occurrences of Lateral Spreading

Assessment of liquefaction hazard and its impact on water system components consists of two key steps; (1) assessment of liquefaction susceptibility and probability of its occurrence, and (2) estimation of ground deformation resulting from liquefaction.

Assessment of liquefaction susceptibility depends on the nature of subsurface soil, presence of ground water and the intensity of shaking. Liquefaction evaluations across a wide geographic area include a large amount of uncertainty because soil and groundwater conditions are not well-defined at that scale. Therefore, the potential for liquefaction is often described in probabilistic terms for regional scale analyses. The probabilities are typically grouped in generally descriptive categories such as low, moderate, high or other similar descriptors. However, such descriptions do not provide the necessary information for engineering assessment of structural or pipeline vulnerability, which require quantification in terms of the expected amount of PGD.

Sections below describe liquefaction susceptibility in the City's service area and estimation of ground deformation for use in pipeline vulnerability assessment.

4.3.1 LIQUEFACTION SUSCEPTIBILITY AND PROBABILITY OF LIQUEFACTION

Liquefaction susceptibility of soils in the City's service area was assessed based on recent updates to liquefaction assessment procedures (Boulanger and Idriss, 2014), additional details are provided in Appendix B. Although multiple other approaches are available, Boulanger and Idriss (2014) present the latest revisions and refinements to the procedure and include high-quality liquefaction case histories from recent earthquakes. The methodology also accounts for long-duration shaking from large subduction-zone earthquakes and the liquefaction potential of fine-grained soils such as silts.

For liquefaction assessment, a geologic map of the study area was first developed using existing data and observations from a geological reconnaissance of the study area on July 27 and 28, 2017. The existing data includes surficial geology mapping by DOGAMI (Smith and Roe, 2015), geotechnical borings from publicly available sources including the Oregon Department of Transportation (ODOT), DOGAMI, and the Oregon Water Resources Department and geotechnical reports provided by the City. The resulting geologic map for the study area is shown in Figure 15.

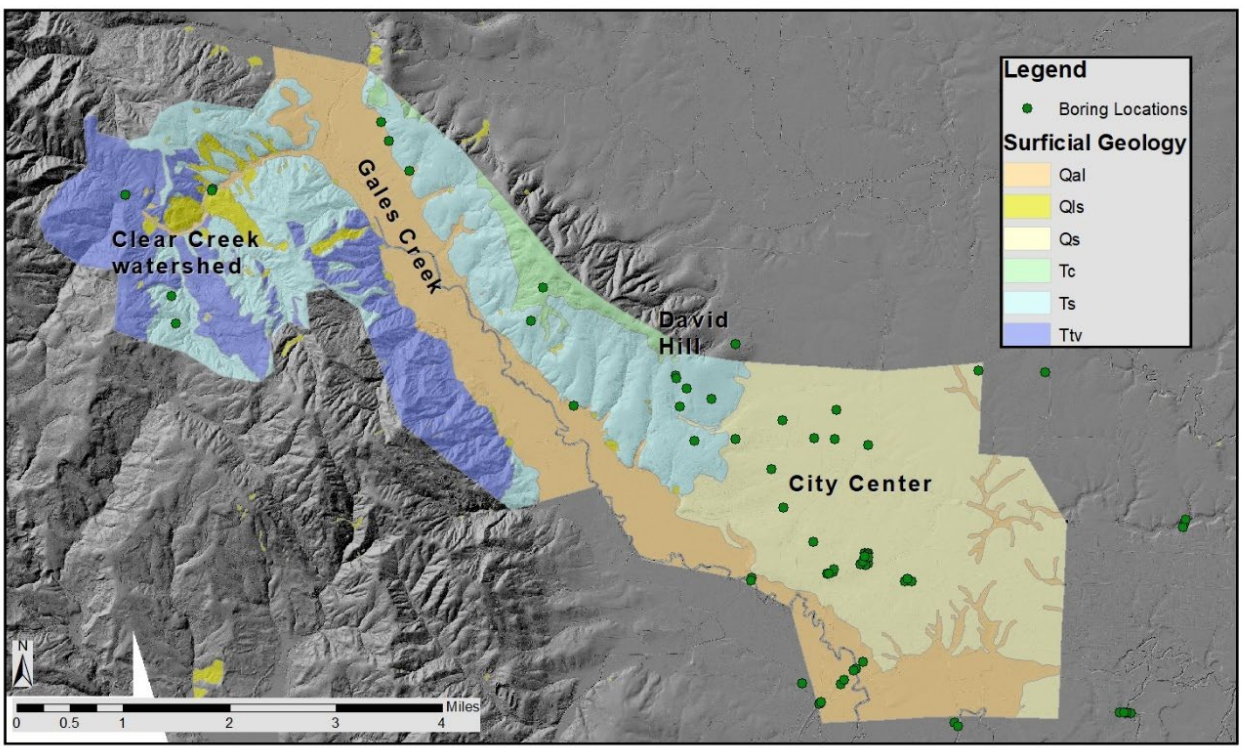


Figure 15: Study Area Geologic Map and Boring/Well Locations

Based on the data reviewed, only recent alluvium (Qal) and Willamette Silt (Qs) geologic units are found to be susceptible to liquefaction. These units are typically encountered along Gales Greek and within the City center, as shown in Figure 15. The probability of liquefaction for each of the susceptible geologic units was calculated using the available subsurface data, the estimated depth to groundwater, and the estimates of the ground shaking. Rasters of liquefaction probability were developed in ESRI Geographic Information Systems (GIS). The severity of liquefaction was then estimated using classifications described by Maurer et al. (2014), which are provided in Table 8. The liquefaction severity classification for the project area is shown in Plate 9 and Plate 10. The plates show that liquefaction hazard in the study area ranges from very little to moderate. There were no areas found in the Forest Grove evaluation area that were classified as having severe liquefaction.

Table 8: Liquefaction Severity Classification

Classification	Probability of Liquefaction
Very little liquefaction	0 to 0.15
Marginal liquefaction	0.15 to 0.30
Moderate liquefaction	0.30 to 0.60
Severe liquefaction	0.60 to 1.0

4.3.2 LIQUEFACTION-INDUCED DEFORMATION

Liquefaction-induced PGD include lateral spreading and settlement. Lateral spreading is the permanent horizontal movement of a liquefiable soil deposit with non-liquefied crust in an area at or near a slope or a topographic feature. PGD from lateral spread can range from a few inches to several feet. It occurs predominantly in gradual slopes or at sites situated near riverbanks, shorelines, bulkheads, or wharves. Lateral spreading accounted for much of the damage to port facilities during the 1995 M6.9 earthquake in Kobe, Japan.

Liquefaction-induced ground surface settlement can occur through multiple mechanisms following liquefaction, including: (1) ejecta in the form of sand boils, (2) differential shearing due to lateral spreading, (3) lateral squeezing of very soft liquefied soil below foundations or embankments, and (4) dissipation of excess pore pressure from layers of liquefied soil as the soil densifies. Settlement due to pore pressure dissipation can occur over a period of days after an earthquake. Detailed analytical procedures (Boulanger and Idriss, 2014, Zhang el al., 2004; and Chu et al., 2016) with local subsurface and groundwater data were used to develop estimates for liquefaction-induced PGD for the study area. A discussion of the methodology used in this project to estimate liquefaction-induced deformations is provided in Appendix B.

Estimated liquefaction-induced deformations were incorporated in GIS to develop a liquefaction-induced lateral spread and settlement map for City service area as shown in Plates 11 through 14. The plates show that, except for locations along the RWTM and the JWC pipelines, there is very little lateral spread hazard in the City. The liquefaction-induced settlement estimates are also relatively small (generally less than 3 inches). The PGD estimates developed for this study are median values. Since subsurface conditions are poorly defined at a regional scale, these PGD estimates include a significant amount of uncertainty.

For the study area, PGD estimates of about 2 inches or greater approximately correspond to areas classified as having marginal liquefaction severity. Areas where lateral spreading hazards become more likely are classified as having moderate liquefaction severity. The correlation between the probability of liquefaction and PGD estimates is difficult to accurately quantify because it depend on the soil behavior characteristics, depth of groundwater, soil density, and earthquake ground shaking intensity; all areas of significant uncertainty.

The PGD estimate in the study area are generally consistent with those shown in the 2013 DOGAMI Open-File Report O-13-16 (Madin and Burns, 2013). However, PGD estimates in the recent 2018 DOGAMI Open-File-Report O-18-02 (Bauer et al., 2018) show that at some locations these estimates are significantly larger in O-18-02 than those in O-13-06 and in our study. In some areas, these difference are as much as an order of magnitude. Likely reason for these difference is that O-18-02 used stronger ground shaking estimates through the use of conservative site amplification factors more applicable for code-based design. It is our opinion that liquefaction-induced PGD estimates in the 2013 DOGAMI study are more representative because they are based on local subsurface and groundwater data, whereas the O-18-02 used region-wide data and an assumed groundwater depth of 5.0 feet throughout.

4.4 EARTHQUAKE-TRIGGERED LANDSLIDES

Strong shaking from an M9 earthquake could also trigger landslides within the study area. Earthquake-triggered landslides are most likely to occur in areas of previous landslides activity. DOGAMI's Statewide Landslide Information Database for Oregon (SLIDO) project (Burns and Watzip, 2014) mapped historic and pre-historic landslides. Most existing mapped landslides within the study area are in the Clear Creek watershed or near David Hill as shown in Figure 16 and Figure 17. The figures show landslide deposits (identified as SLIDO deposits in the figure) and margins of the landslide (identified as SLIDO Scarp Flanks in the figure).

The DOGAMI landslide maps were used to supplement the earthquake-triggered landslide PGD maps developed for this study. Estimated strengths of surficial geologic units (Keefer 2000, Burns et al. 2013, and Dreyfus et al. 2013) were combined with available subsurface data to estimate the strength and thickness of the geologic materials. The factor of safety and yield acceleration were calculated using Scoops3D, a 3-dimensional limit equilibrium slope stability program published by the USGS (Reid et al., 2015). The results were used to calibrate the estimated geologic strengths with observed conditions in order to refine and update the slope stability analyses. Earthquake-triggered landslide deformations were estimated on a regional basis using empirical correlations to rigid-block deformation analyses, which are conditioned on the yield acceleration, PGA, and earthquake magnitude. Additional details are provided in Appendix B.

The seismically-triggered landslide deformation maps developed for this project are shown in Plate 15 and Plate 16. The maps show that the overall landslide 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.

In addition to the regional level landslide map (Plates 15 and 16), site-specific analysis of landslide hazard for the David Hill and WTP Reservoirs were performed and briefly described in Section 5.2 with details in Appendix C.

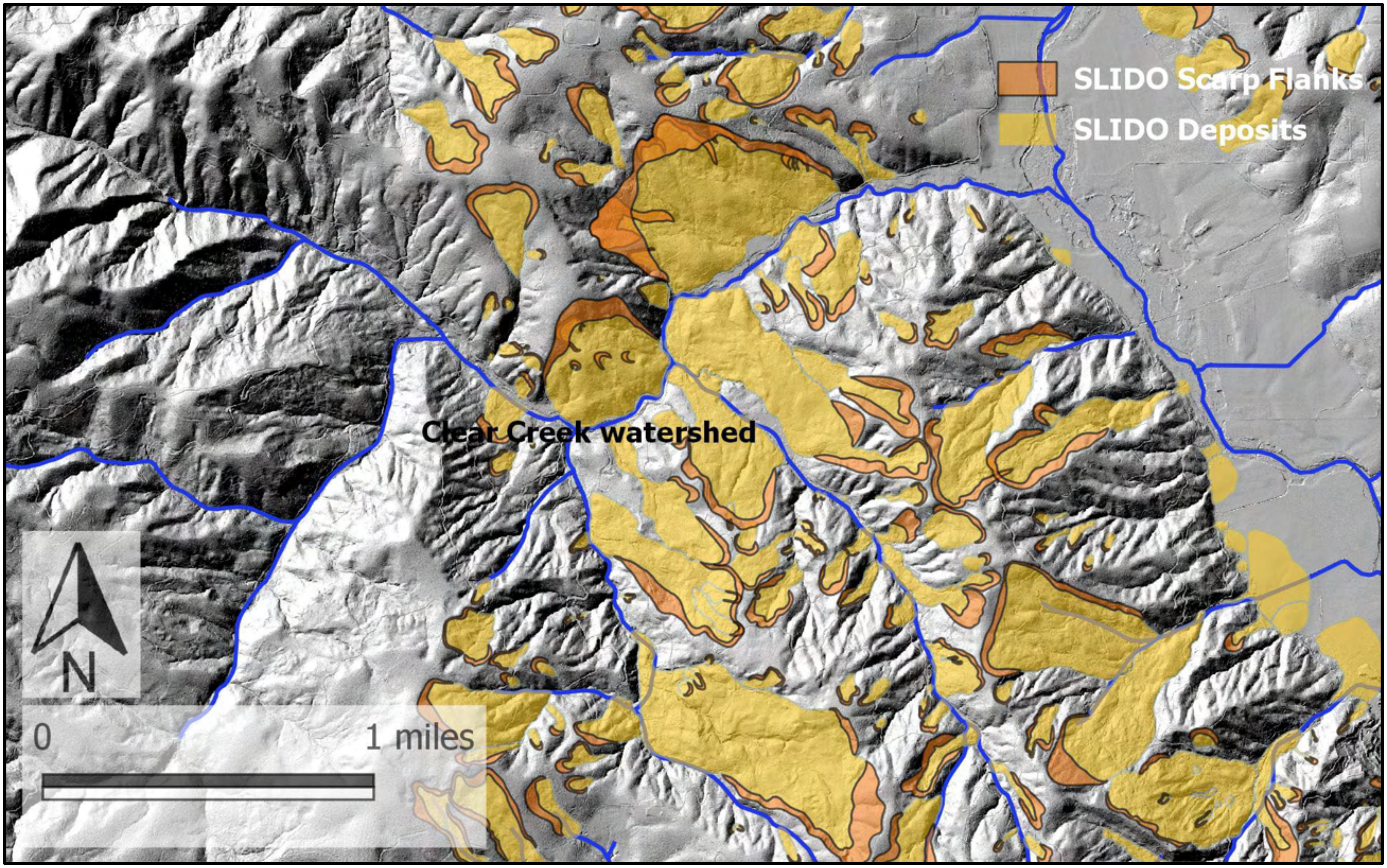


Figure 16: Mapped Landslides in SLIDO within the Clear Creek Watershed

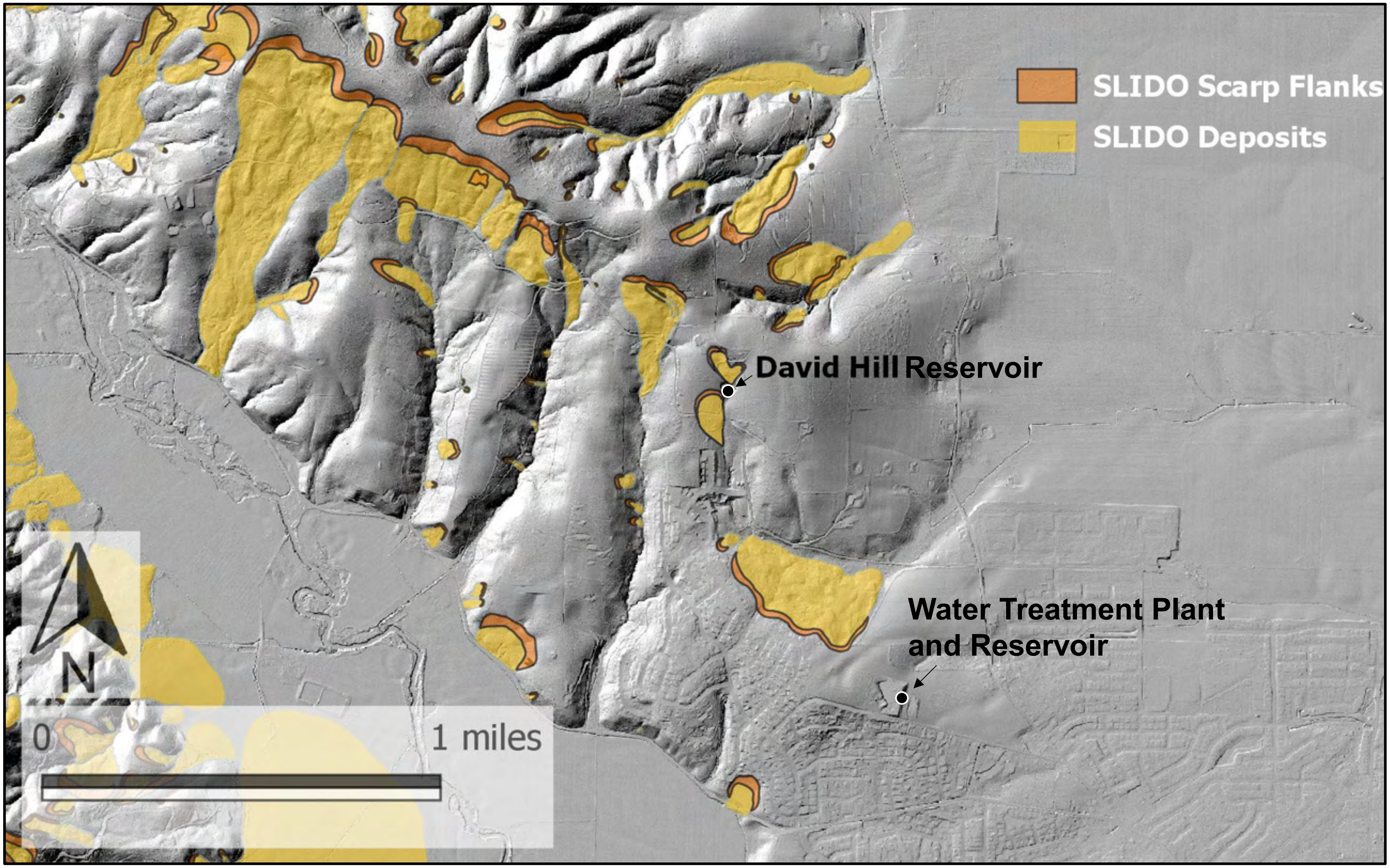


Figure 17: Mapped Landslides in SLIDO within David Hill

5.0 SEISMIC VULNERABILITY ASSESSMENT

This section describes seismic vulnerability assessment of City's water system assets including pipelines, reservoirs, WTP facilities, pump stations and public works facility.

5.1 PIPELINE SYSTEM

5.1.1 PIPELINE ASSESSMENT METHODOLOGY

The seismic response of buried pipelines depends on their complex interaction with the adjacent soil. It is a function of both the imposed ground deformation and the type of pipeline construction, especially joints. The imposed ground deformation include both permanent and transient components referred to as permanent ground deformation (PGD) and transient ground deformation (TGD), respectively. Ground failure from liquefaction, landslide or fault rupture results in PGD. Ground strains from seismic wave propagation causes TGD, which is a function of PGV. Distribution of PGV and PGD for the M9 earthquake in the City's service area is shown in Plates 5 through Plate 6 and Plate 9 through Plate 16, respectively.

Pipeline repairs are generally estimated using repair data from past earthquakes as a function of PGV and PGD expressed in the form of empirically derived pipeline fragility relationships. The empirical pipeline fragility relationships are developed using statistical analysis of pipe repair data from past earthquakes.

Some of the commonly available empirical fragility relationships for buried pipelines include the American Lifelines Alliance (ALA, 2001), Jeon and O'Rourke (2005); O'Rourke et al. (2014); and Bouziou and O'Rourke (2015). These fragility relationships are further discussed in Appendix D. Although close to 20 years old, the ALA relationships are still commonly used because of their simplicity. ALA uses mostly engineering judgment as a basis for repair estimates for different pipe types, and has a large amount of scatter in the data due to limited number of data points used to develop the relationships. For the purposes of this study the uncertainty range was taken as ±1 lognormal standard deviation (provided in ALA) around the median. In addition to uncertainty in repair estimates from pipeline fragility relationships, other sources of uncertainty include variability in ground motion and ground deformation due to unpredictability of earthquake shaking and its effects such as liquefaction and liquefaction-induced ground deformations.

Repair estimates typically include both leaks and breaks. A leak results from the loss of a pipeline's pressure boundary from joint pullout, a round or longitudinal crack, a local loss of pipe wall, or a local tear in the pipe wall (Shi, 2006), whereas a break is a complete disengagement of pipe with water flowing out to the atmosphere from the full cross-section of the pipe. Observations from past earthquakes suggest that leaks are more common and generally constitute 80 percent to 90 percent of total repairs (Ballantyne 2008).

For the City's pipeline network, the number of repairs was estimated using the PGD and PGV maps developed for this project. Based on sensitivity studies described in Appendix D, ALA's PGD-based pipeline fragility relationship was used for areas with estimated PGD values of greater than about 1 inch, and for all other areas, ALA's PGV-based pipeline fragility relationships (representing wave propagation effects) were used. For areas with PGD estimates greater than 1-inch, the largest deformation estimate resulting from lateral spreading, settlement, or landslides was used to estimate total number of pipeline repairs.

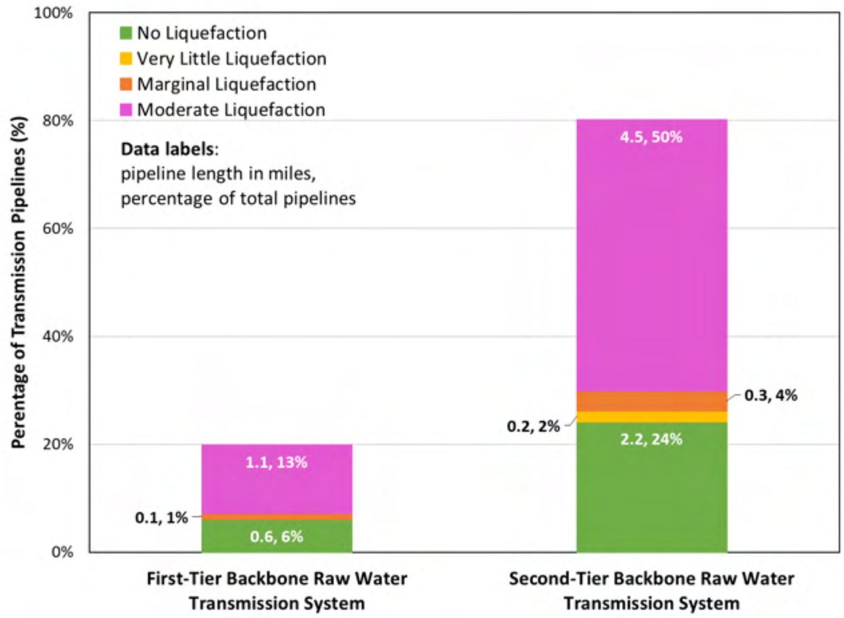
The total number of pipeline repairs were estimated based on the computed repair rates (repair/km) and the pipeline length in the City's water system using the pipeline lengths in the GIS database, dated June 5, 2018. Differences between the pipeline lengths presented in this report and in Murraysmith (2019) occur only in distribution pipelines and not in the backbone pipelines.

5.1.2 BACKBONE PIPELINES

The City's backbone water system includes 9.1 miles of RWTM, 1.6 miles of the 24-inch JWC TL and 13.4 miles of distribution system pipelines. The following sections summarize estimated repairs for different components of backbone pipelines.

5.1.2.1 Raw Water Transmission Main (Backbone)

The RWTM runs almost parallel to Gales Creek and is subjected to the significant liquefaction hazard along the creek. About 6.3 miles (70 percent) of the RWTM and feeder pipelines from river intakes to the RWTM are located within zones of very little and greater liquefaction hazard, and about 2.8 miles of transmission pipelines (30 percent) are in areas where liquefaction is unlikely to occur in the M9 earthquake. Figure 18 shows the length and percentage of raw water transmission pipeline located within different liquefaction susceptibility zones.



Note:

1. Minor differences in pipeline lengths in figure and in-text total due to rounding.

Figure 18: Raw Water Transmission System Pipelines in Different Liquefaction Susceptibility Zones

Using the approach described in Appendix D, median repair estimates for the first-tier (from Stringtown Road Bridge to WTP) and the second-tier (from river intakes to the Stringtown Road Bridge) backbone pipelines in an M9 earthquake are presented in Table 9 and Figure 19. The figure also shows the uncertainty in the estimated repairs by considering ±1 lognormal standard deviation around the median. As shown in the figure, the uncertainty in repair estimates is large. Variability in pipeline response to earthquake effects and the empirical nature of pipeline fragility relationships contributes to this uncertainty. For example, the first-tier backbone pipeline has a median estimate of 2 repairs but could be up to about 3 times larger, as shown in Figure 19. Similarly, a median of 11 repairs are estimated for the second-tier backbone pipeline, but could also be up to about 3 times larger.

Table 9: Median Estimate Raw Water Transmission System Pipelines Total Repairs

Pipeline Type	First-Tier Backbone		Second-Tier Backbone	
	Total Length[1] (miles)	Total Repairs	Total Length[1]	Total Repairs
Concrete Cylinder Pipe[2]	1.8	2	6.0	11
Cast Iron[3]	-	N/A	1.2	-
Total[4]	1.8	2	7.3	11

Note:

1. Pipeline lengths are based on information in the City's GIS database provided on June 5, 2018, which have since been updated.
2. Concrete Cylinder Pipe includes pipelines marked as CCP in City GIS files
3. Cast Iron pipe includes pipelines marked as CI and CI TYTON in City GIS files
4. Minor differences in total length of pipelines due to rounding

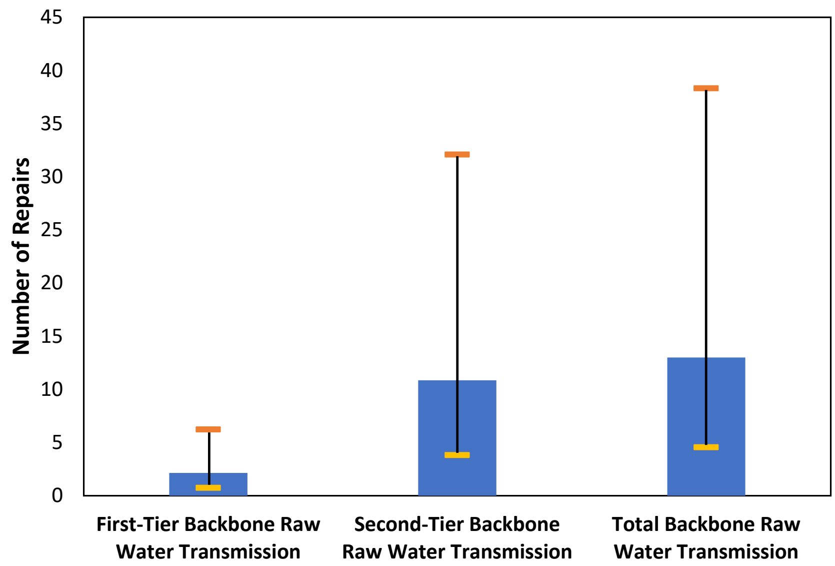
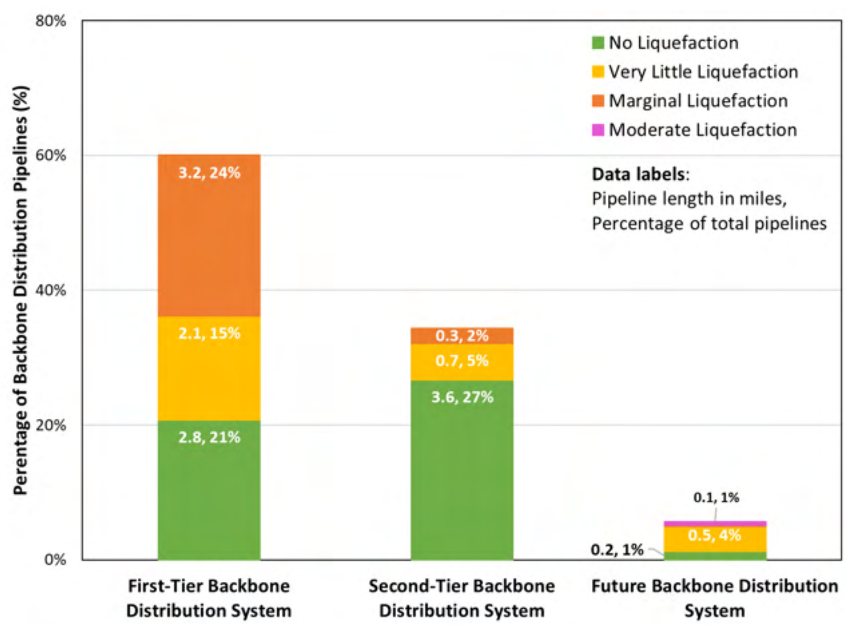


Figure 19: Raw Water Transmission System Pipelines Repair Median and Uncertainty Range

5.1.2.2 Backbone Distribution System

The City's backbone distribution pipelines are primarily cast iron and ductile iron. Cast iron pipelines are particularly vulnerable to damage in earthquakes. About half of all of the backbone distribution pipelines (6.9 miles) are located within zones of very little and greater liquefaction hazard. Of these, the majority (39 percent) consist of first-tier backbone pipelines, whereas the second-tier and future backbone pipelines constitute 8 percent and 5 percent, respectively, as shown in Figure 20.



Note:

1. Minor differences in pipeline lengths and percentages in figure and in-text totals due to rounding.

Figure 20: Backbone Distribution Pipelines in Different Liquefaction Susceptibility Zones

The lengths and estimated median repairs for the different classifications of backbone distribution pipelines are presented in Table 10. Figure 21 presents the median repair estimates and the uncertainty range around the median. As shown in the figure, we estimate a median of 29 repairs for the first-tier backbone pipelines, but could be up to about 3 times larger. Most of these repairs are in cast iron pipelines that have shown to be vulnerable to seismic damage in past earthquake. For the second-tier backbone pipelines, the median number of repairs is estimated to be 6 (could be up to about 3 times larger) and that for pipelines identified as future backbone the median repair estimate is 2 (could be up to about 3 times larger) repairs.

Table 10: Median Estimate Backbone Distribution Pipelines

Pipeline Type	First-Tier Backbone		Second-Tier Backbone		Future Backbone	
	Length (mi)[1]	Total Repairs	Length (mi)[1]	Total Repairs	Length (mi)[1]	Total Repairs
Cast Iron[2]	5.8	25	2.0	5	0.2	< 1
Ductile Iron[3]	2.2	4	2.4	1	0.5	< 2
Other[4]	< 0.1	0	< 0.1	0	< 0.1	0
Total[5]	8.0	29	4.6	6	0.8	2

Note:

1. Pipeline lengths are based on information in the City's GIS database provided on June 5, 2018, which has since been updated.
2. Cast Iron pipe includes pipelines marked as CIP in City GIS files
3. Ductile Iron pipe includes pipelines marked as DIP City GIS files
4. Other pipelines include pipelines include unspecified pipelines in City GIS files.
5. Minor differences in total repairs due to rounding.

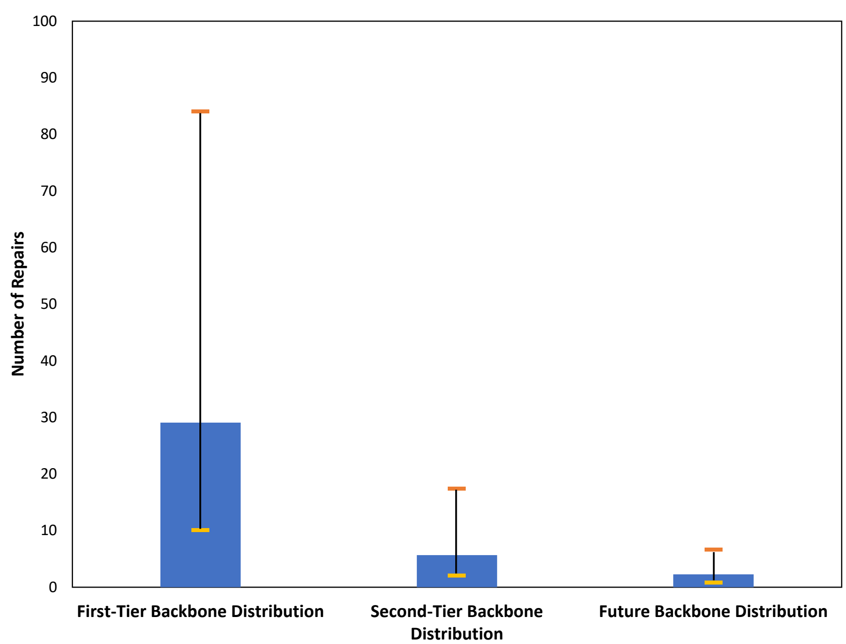


Figure 21: Backbone Distribution Pipelines Repairs Median and Uncertainty Range

5.1.2.3 24-inch JWC Finished Water Transmission Line (Backbone)

As shown in Plate 9 and Figure 22, most of the 24-inch CCP JWC TL (approximately 1.3 miles out of a total length of 1.6 miles) is subject to liquefaction hazard. Using the same approach as that for the raw water transmission system and backbone distribution system pipelines, a median value of 10 repairs (but could be up to about 3 times larger) are estimated. The median and uncertainty range for repairs is shown in Figure 23.

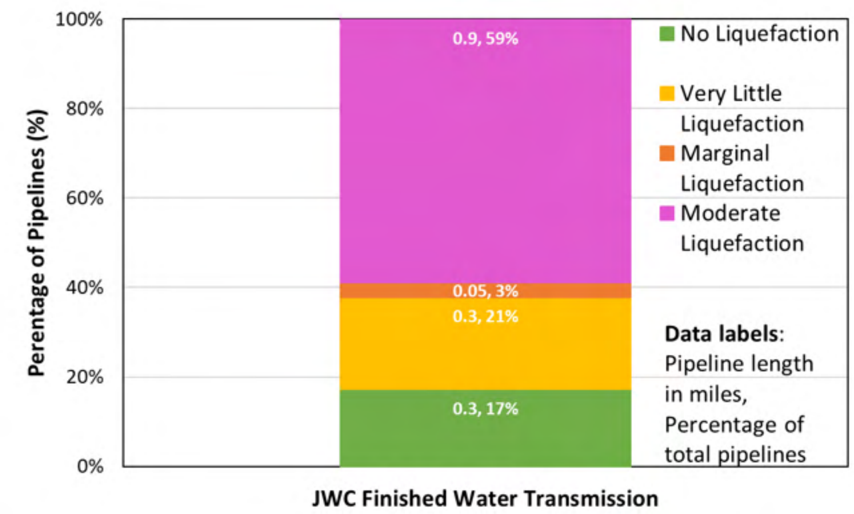


Figure 22: JWC Pipeline in Different Liquefaction Susceptibility Zones

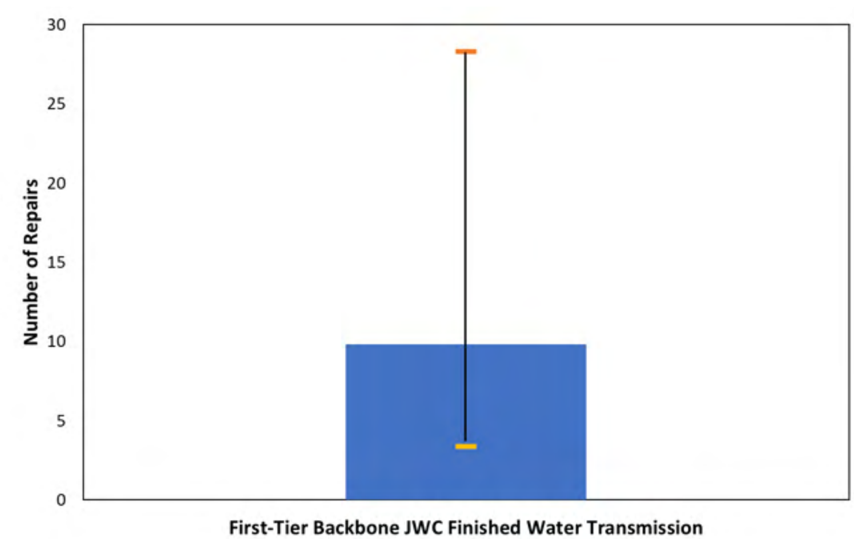
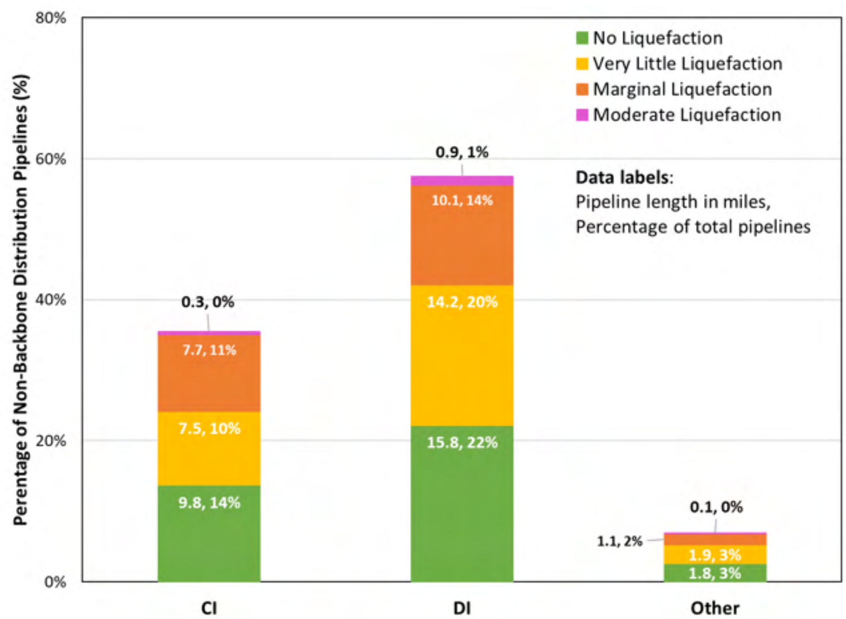


Figure 23: JWC Pipeline Repairs Median and Uncertainty Range

5.1.3 NON-BACKBONE DISTRIBUTION SYSTEM PIPELINES

Most of the non-backbone distribution system pipelines (43.7 miles[6], approximately 61 percent of total) are located within zones of marginal and greater liquefaction hazard (Plate 9). The total percentage of distribution pipelines in different liquefiable severity areas as a function of pipe type are presented in Figure 24.



Note:

1. Minor differences in pipeline lengths in figure and in-text total due to rounding.

Figure 24: Distribution System Pipelines in Different Liquefaction Susceptibility Zones

For the distribution system pipelines, a median of 213 repairs are estimated. Considering uncertainty, the total number of repairs could be up to about 3 times larger. The estimated repairs for different pipeline types are summarized in Table 11 and Figure 25. Approximately 50 percent of the estimated repairs are in cast iron pipes, 40 percent in ductile iron pipes and 10 percent in other pipeline types such as PVC, copper and steel. Most of the pipelines in the ‘other’ category are located in areas of very little and greater liquefaction hazard. The median repair estimate and ±1 standard deviation range is shown in Figure 25.

[6] Pipeline lengths are based on information in the City’s GIS database provided on June 5, 2018, which have since been updated.

Table 11: Median Estimate Non-Backbone Distribution Pipelines Repairs

Pipeline Type	Length (mi)[1]	Total Repairs
Cast iron[2]	25.3	106
Ductile iron[3]	40.9	86
Other[4]	4.9	22
Total[5]	71.1	213

Note:

1. Pipeline lengths are based on information in the City's GIS database provided on June 5, 2018, which have since been updated.
2. Cast Iron pipe includes pipelines marked as CIP in City GIS files
3. Ductile Iron pipe includes pipelines marked as DIP City GIS files
4. Other include pipelines marked as C900, (PVC), PVC, COPPER (Copper), GALV/GALVINIZED (Galvanized Steel), GI (Galvanized Iron), POLY (Polyethylene), STEEL (Steel), and unspecified in City GIS Files
5. Minor difference in total repairs due to rounding.

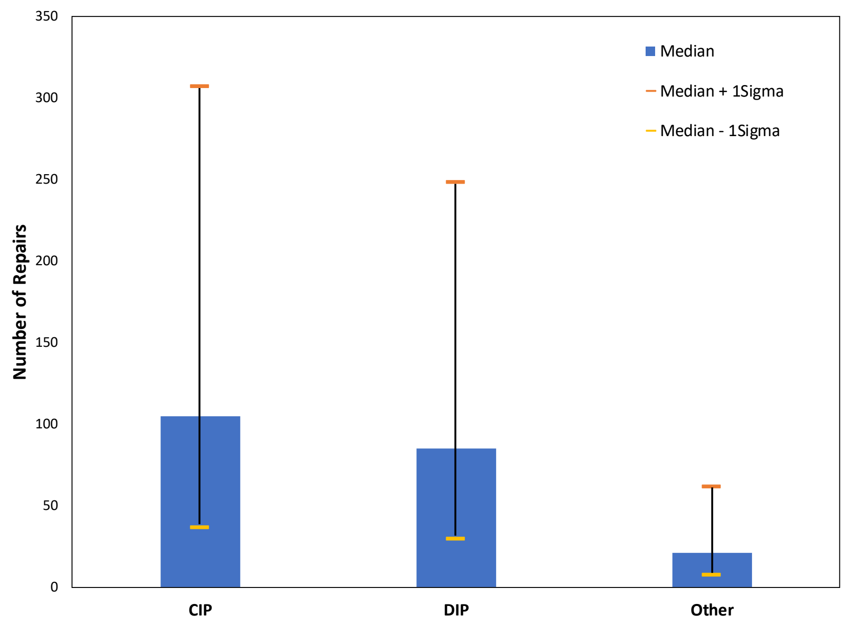


Figure 25: Distribution Pipelines Repairs Median ± 1-Standard Deviation

5.1.4 Summary and Discussion of Results

Table 12 provides a summary of the median estimated repair and an estimate of uncertainty for all pipelines within the City's pipeline network. This includes estimates for liquefaction-induced and landslide-triggered PGD and wave propagation-induced TGD. These estimates are based on conservative interpretation of pipeline construction especially the type of joints used. The largest concentration of repairs is estimated to be in areas susceptible to liquefaction with repairs occurring more frequently in areas with higher estimated PGD and older cast iron pipes.

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

5.2 RESERVOIRS

Seismic assessments of the 5 MG reservoir at the WTP and 1 MG reservoir at David Hill were based on simplified structural calculations. The assessment was performed using existing data. No new geotechnical investigations were performed. The seismic hazard assessment considered ground shaking, liquefaction-induced lateral spreading and ground settlement, and slope stability. The structural assessment followed the guidelines of ACI 318-14 and ACI 350.3-06. A technical memorandum documenting these analyses is included in Appendix E and is summarized in the following sections.

5.2.1 Water Treatment Plant Reservoir

5.2.1.1 Seismic Hazards Assessment

The 5 MG WTP reservoir was constructed in 1948. The reservoir is underlain by stiff clean to sandy clays that are not susceptible to liquefaction.

The static slope stability analyses show that the factor of safety of the fill slope at the WTP is approximately 1.7 for average groundwater conditions and approaches 1.0 for high groundwater conditions. The analyses show that the fill slope below the WTP reservoir could deform about 2 inches (median estimate) in an M9 CSZ earthquake and about 0.5 inches (median estimate) in an M6.8 Gales Creek earthquake. These deformations would likely extend to the depth of the 20-inch supply line and possibly damage the line. Our analyses also show that the PGD at the reservoir is likely to be less than ½ inch in either the CSZ or the Gales Creek earthquake.

5.2.1.2 Structural Assessment

A structural assessment of the WTP reservoir was performed using the American Concrete Institute’s standards ACI 318-14 and ACI 350.3-06. The reservoir is a critical element of the backbone and should maintain its storage capacity for emergency and firefighting needs. Due to its critical nature, an importance factor, *I*, of 1.25 was used for the assessment as described in the ACI standards.

Details of the structural/seismic assessment are provided in a separate technical memorandum included in Appendix E, with a summary presented in Table 13. The results show that the reservoir interior wall, exterior wall and roof support columns are vulnerable to damage in an M9 CSZ scenario earthquake.

Table 13: Summary of Structural Assessment for the WTP Reservoir

Structural Element	Failure Mode	Acceptable Performance?
Roof Support Columns	Compression	Yes
	Shear	Yes
	Bending	No
Central Wall	Compression	Yes
	Out-of-Plane Bending	No
Perimeter Walls	Compression	Yes
	Out-of-Plane Bending (Reservoir Empty)	No
	Out-of-Plane Bending (Reservoir Full)	No
Roof Slab	Sliding	Yes

5.2.2 DAVID HILL RESERVOIR

The partially buried 1 MG David Hill Reservoir was constructed in 1985. The reservoir roof consists of an 8.5-inch thick reinforced concrete slab supported by 14-inch thick reinforced concrete walls and a 3-by-4 array of reinforced-concrete columns. The columns are 20-inch in diameter and are spaced 20-feet on centers. The floor slab is 6 inches thick and is underlain by a 12-inch thick layer of drain rock over the native material.

5.2.2.1 Seismic Hazards Assessment

The reservoir is underlain by stiff silt over siltstone, and is not susceptible to liquefaction. Landslides near David Hill have been previously mapped by DOGAMI and incorporated in DOGAMI's SLIDO project (Burns and Watzip, 2014). The SLIDO maps show locations of recent, historic, and pre-historic landslides near David Hill. Photographs provided by the City show evidence of small, relatively shallow landslides in the slope above the reservoir in the 1996 flood event (Figure 26). These landslides appear to be in man-made cuts and oversteepened slopes constructed as part of the road bench above the reservoir. Surficial raveling and severe erosion were observed along the road and at nearby slopes reservoir during the geology field reconnaissance performed by InfraTerra.

The static slope stability analyses for the fill slopes at the reservoir show that the reservoir has a factor of safety of about 1.4 for global stability with normal ground water conditions and approaching 1.0 for high groundwater conditions, indicating that the slope may be unstable. A low factor of safety at high groundwater conditions is consistent with the observed historic landslides during prolonged periods of wet weather. The results of the seismic slope stability analyses show that the fill slope could deform about 4 inches in an M9 CSZ earthquake and about 1.5 inches in an M6.8 Gales Creek earthquake. Relative deformation between the reservoir and the fill slope could damage any piping that cross the deformation zone.

Landslide Behind Reservoir

Landslide Near Reservoir

Figure 26: David Hill Reservoir- Historic Landslides during 1996 Flood

5.2.2.2 Structural Assessment

A simplified and conservative analysis of the David Hill reservoir was performed. Similar to the WTP reservoir, an importance factor of 1.25 was used because the reservoir is a critical element of the backbone. Results of the seismic analysis for this reservoir are presented in a separate technical memorandum included in Appendix E, and summarized in Table 14. The results show that the bending moment capacity of the perimeter walls is exceeded for seismic loading.

Table 14: Critical Structural Elements and Failure Modes Considered in Assessment

Structural Element	Failure Mode	Acceptable Performance (Yes/No)
Roof Support Columns	Compression	Yes
	Shear	Yes
	Bending	Yes
Perimeter Walls	Compression	Yes
	In-Plane Shear	Yes
	Out-of-Plane Bending	No

The reservoir has good seismic detailing with the walls anchored into the roof and base slab with continuous reinforcement. The walls are also tied into the perpendicular walls with continuous reinforcement. It is likely that more refined calculations would show that the reservoir meets the imposed seismic demands. Therefore, additional more detailed seismic analysis is recommended.

5.2.3 Discussion and Summary of Results

The WTP and David Hill Reservoirs are critical elements of the City's backbone system and should maintain critical water storage for emergency use and fire fighting in a major seismic event.

Structural assessments of both reservoirs show seismic vulnerabilities. The WTP reservoir is the largest reservoir in the City's water system and was constructed in 1948. The reservoir roof support columns and walls (interior and exterior) are vulnerable to damage in an M9 CSZ event. It is recommended that the reservoir be seismically upgraded or replaced to the continued operation performance level to meet the City's performance objectives. A separate seismic evaluation performed by OBEC Consulting Engineers also recommended a retrofit of the columns and column footings of the reservoir (OBEC, 2018).

Simplified analysis of the David Hill reservoir walls shows potential vulnerability. However, the reservoir has good seismic detailing and more detailed analysis may show that the reservoir meets the performance requirement. Therefore, it is recommended that an additional detailed analysis be performed. If the results of such analysis still show vulnerability, then a seismic upgrade should be performed.

5.3 OTHER FACILITIES

Other facilities within the City's water system include pump stations, a treatment plant, 10th Avenue Control Station, and a Public Works facility. Site visits to these facilities were performed on March 19 and 20, 2018. Observations from the site visit are briefly discussed in the following sections, with photo documentation, structure descriptions, and details of seismic assessments included in Appendix F.

5.3.1 Water Treatment Plant

The WTP site is underlain by medium stiff clayey silt and stiff silt. These soils are not susceptible to liquefaction. A slope stability analysis of the adjacent slopes show that the WTP site is unlikely to be impacted by significant landslide deformation in an M9 CSZ event. Expected deformation of fill slope below the WTP reservoir is on the order of 2 inches in an M9 CSZ earthquake and about 0.5 inches in an M6.8 Gales Creek earthquake.

The TSoR for availability of finished water at supply source is 20 to 30 percent within 24 hours, 50 to 60 percent within 1 to 3 days and 80 to 90 percent in one to two weeks. Therefore, the WTP structures considered essential for water treatment were evaluated for the Immediate Occupancy performance level as defined in ASCE 41-17.

In ASCE 41-17, performance objectives are based on a pairing of seismic hazard levels and target structural and non-structural performance levels. ASCE 41-17 consists of six discrete structural performance levels as shown in Figure 27. Tables C2-4 of ASCE 41-17 illustrates the nature of the anticipated probable damage for these structural performance levels. For the “Immediate Occupancy (S-1)” performance level, considered for structures critical for treatment operations, there is expectation of limited structural damage, with the structural system retaining almost all of its pre-earthquake strength and stiffness. The risk of life-threatening injury as a result of structural damage is low, and although some minor structural repairs might be required, these repairs would generally not be required before re-occupancy.

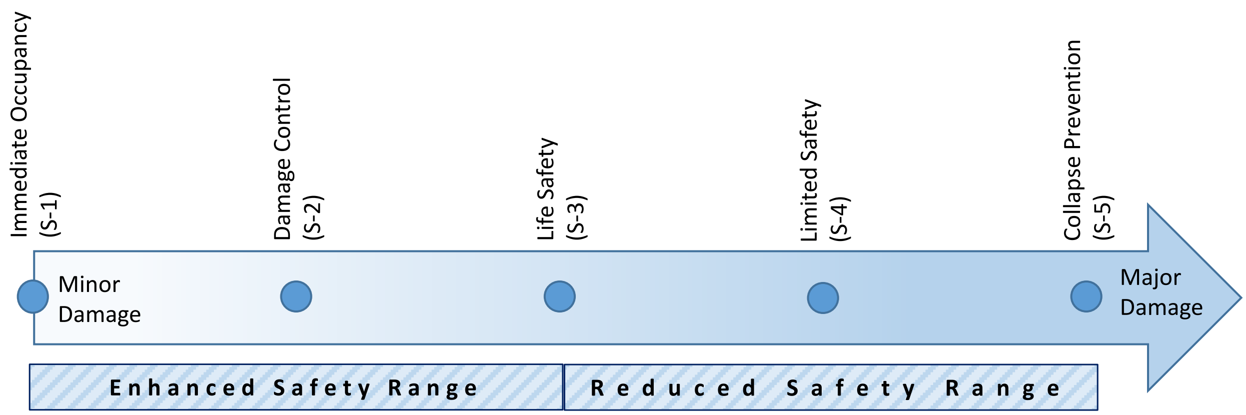


Figure 27: ASCE 41-17 Structural Performance Levels

The seismic assessment of these structures was based on a review of available drawings and simplified structural calculations for the estimated PGA of 0.21g for an M9 CSZ earthquake (Madin and Burns, 2013). The corresponding short period spectral acceleration S_s and one second spectral acceleration S_1 for the site are 0.52g, and 0.24g, respectively. Results of the structural/seismic assessments are summarized in Table 15 with details provided in Appendix F.

Our assessment shows that all of the structures at the WTP that are identified by the City as essential for operation of the plant meet the Immediate Occupancy performance criteria of ASCE 41-17. Some structural and non-structural damage is possible, but it is unlikely that such damage will result in significant disruption on plant operation in an M9 CSZ event.

Table 15: Structural Assessment Summary of WTP Structures

WTP Structure	Structure Type	Critical to WTP?[1] (Y/N)	Structural Vulnerabilities and Assessment (M9 CSZ Earthquake)
Chemical Building	Northeast section: reinforced concrete walls with wood-frame roof; Southwest section: concrete masonry unit walls and wood-frame roof	Yes	• The NE and SW sections have separate foundations - pounding damage is possible. • Multiple door/window openings, diagonal cracking likely near the corners of openings. However, the building's structural system has sufficient redundancy to limit the risk to life safety and structural collapse. • Sodium fluoride and sodium hypochlorite tanks are unanchored. Damage to tanks and piping is possible. • The building meets the base shear and roof anchorage checks of ASCE 41-17. • The building meets the Immediate Occupancy performance level of ASCE 41-17.

Office Building/Pipe Gallery/Filters	Reinforced Concrete	Yes	• Office Building
			  • Multiple window openings at the ground level.
			  • Cracking in reinforced concrete walls adjacent to window openings may occur.
			  • The building meets the Immediate Occupancy performance level of ASCE 41-17.
			• Pipe Gallery
			  • Partially buried reinforced concrete structure.
			  • Minor cracks in the walls may develop.
			  • Buried structures in competent soils (i.e. no liquefaction or ground failure) generally perform well in earthquakes, and; therefore, meets Immediate Occupancy performance level of ASCE 41-17.
			• Filters
			  • Partially buried reinforced concrete structure.
			  • Minor cracks in the walls may develop.
			  • Buried structures in competent soils (i.e. no liquefaction or ground failure) generally perform well in earthquakes, and; therefore, meets Immediate Occupancy performance level of ASCE 41-17.

WTP Structure	Structure Type	Critical to WTP?[1] (Y/N)	Structural Vulnerabilities and Assessment (M9 CSZ Earthquake)
Generator	N/A	Yes	• Generator is anchored to the base slab using four small-diameter anchor bolts along each longer dimension. These anchor bolts may fail in shear or yield in tension but are expected to prevent significant sliding or overturning. • Anchorage of the larger electrical cabinet could not be confirmed. It is recommended that anchorage should be checked. If the cabinet is not adequately anchored, limited sliding on the base slab is possible, overturning is less likely because of moderate levels of shaking and the width to height ratio approximately 2 to 3
Sedimentation Basin	Buried concrete structure	Yes	• Walls supported by counterforts, which are buttress-like elements that provide lateral strength and stability to the walls. • Minor cracking of the perimeter walls is possible, but is unlikely to significantly impact the structure's operation.
Backwash Lagoon	Buried concrete structure	Yes	• Moment-axial force interaction check for the divider wall completed. Capacity of the divider wall is not exceeded. • Minor cracking of the dividing wall between the two ponds is possible, but the operations of the Backwash Lagoon are not expected to be impacted.
Shop	Single-story concrete Masonry Unit (CMU) walls and a wood frame roof.	No	• Wide garage door opening and a door opening in the east wall • Cracking of the CMU walls, particularly in the corners at the door openings in the east wall is likely. • Building's structural system has sufficient redundancy that minimizes the risk to life safety risk and structural collapse. Immediate Occupancy performance level of ASCE 41-17 was not evaluated as the building is not critical to WTP operations. Additional assessment is needed to assess Immediate Occupancy performance level.
Den	Non-engineered single-story wood frame	No	• No significant vulnerability.
Storage Facility	Single-story wood frame	No	• Little information available. • More detailed inspection needed if structural assessment is necessary.

Note:

1. A structure is defined as critical to the WTP if its failure prevents the treatment of water at the WTP

5.3.2 Pump Stations

The City's pump stations include the David Hill finished water pump station, the Watercrest Road finished water pump station, and the raw water pump station on the RWTM. Emergency power is supplied to the Watercrest Road finished water pump station via the WTP backup generator. The regional liquefaction hazard study shows that liquefaction and liquefaction-induced ground deformations are not anticipated at the pump stations. No historic landslides have been mapped near the pump station locations and our regional earthquake-triggered landslide analyses do not indicate a significant landslide hazard.

A structural assessment was performed to identify structural vulnerabilities of the pump stations and is summarized in Table 16. Detailed observations and photographs are attached in Appendix F.

Table 16: Pump Station Structural Assessment Summary

WTP Structure	Structure Type	Critical to WTP?[1] (Y/N)	Structural Vulnerabilities (M9 CSZ Earthquake)
David Hill Finished Water Pump Station	Single-story structure with concrete masonry unit walls and vertical (#5 bars, spaced 48 inches) and horizontal (#5 bars, unknown spacing) reinforcement	No	• Cracking near the corners at the door opening in the east wall is possible in anM9 CSZ event. • The building meets base shear and roof anchorage checks of ASCE 41-17 • The building meets Immediate Occupancy performance level of ASCE 41-17.
Watercrest Road Finished Water Pump Station	Buried reinforced concrete	No	• None significant
Raw water Pump Station	Buried reinforced concrete	No	• None significant

Note:

1. A structure is defined as critical to the WTP if its failure prevents the treatment of water at the WTP

5.3.3 Public Works Facility

The City's Public Works Facility includes the Office Building and Machine Shop, Covered Storage Structure, Supply Storage Building, and Equipment Building.

The Public Works Facility is underlain by silty soils (Qs), which may be susceptible to liquefaction. Based on our regional study, we estimate about 2 inches of liquefaction-induced ground settlement in an M9 CSZ earthquake. Because the site is relatively flat, earthquake-induced landslides are not a hazard. A structural assessment was performed to identify structural vulnerabilities, which are summarized in Table 17. Detailed observations and photographs are attached in Appendix F. Structural drawings were not available and thus, detailed structural analyses could not be performed.

Table 17: Public Works Facility Structural Assessment Summary

Public Works Structure	Structure Type	Structural Vulnerabilities (M9 CSZ Earthquake)
Office Building and Machine Shop	Single-story structure with CMU walls; the material used for the framing of the pitched roof could not be established during site visit	• Multiple openings in walls, including three large garage door openings in the Machine Shop part of the building. Cracking of the CMU walls is possible, particularly near the openings in the walls. • Oil storage containers inside the Machine Shop observed to be unbraced and may topple. • Due to difference in height, structural damage is possible at the interface between the Office Building and the machine Shop section of the building. • The building structural system has sufficient redundancy to limit collapse and life safety risk. • Recommended more detailed structural assessment to evaluate the Immediate Occupancy performance level of ASCE 41-17.
Covered Storage Structure	Single-story simple wood frame	• No lateral bracing along the open front side. • Could be at risk of significant lateral deformations and structural damage, leading to potential collapse.
Supply Storage Building	Single-level light steel frame	• Large garage door openings in one of the walls. • Multiple shelves and their content present a falling hazard. • Not expected to sustain significant structural damage. • Expected to meet Life Safety and Immediate Occupancy performance levels of ASCE 41-17.
Equipment Building	Two-story structure with CMU walls; wood framing material could not be established during the site visit	• Multiple large openings in the CMU walls, including large garage doors, doors, and windows. • Cracking of the CMU walls, particularly near the corners of the door openings, is likely. • Recommended more detailed structural assessment to evaluate the Life Safety and Immediate Occupancy performance levels.

5.3.4 10TH AVENUE CONTROL STATION

The 10th Avenue Control Station is underlain by recent alluvium (Qal), which may be susceptible to liquefaction. Based on the regional study, we estimate up to 2 inches of ground settlement in an M9 CSZ event. Because it is located on relatively flat ground, earthquake-induced landslides are not a hazard at this site.

The building is a single-story structure with concrete masonry unit (CMU) walls and a wood frame roof. Diagonal cracking in the north CMU wall was observed near the large diameter pipe penetration in the wall. While cracking of the CMU walls, particularly near the locations of existing cracks is possible in a major earthquake, the building structural system has sufficient redundancy to limit collapse and life safety risk. However, given the importance of this facility as it connects the JWC TL to the City's distribution system, it is recommended a detailed evaluation of liquefaction hazard and structural response be performed to assess the ASCE 41-17 Immediate Occupancy performance level. In addition to the structural evaluation, the facility has rigid pipe penetrations in the floor slab and the exterior wall. Due to the potential risk of liquefaction, it is recommended that flexibility be provided to the rigid pipe to wall and pipe to slab penetrations.

5.3.5 STRINGTOWN ROAD BRIDGE CROSSING

The Stringtown Road Bridge is owned and maintained by Washington County. The bridge is a two-lane reinforced concrete bridge that crosses Gales Creek just outside of the northwest corner of the City's urban growth boundary. The bridge deck is supported on two reinforced concrete piers on either side of Gales Creek. Two pipelines (one of which is the 16-inch backbone RWTP) are suspended from the bridge using 24-inch steel rods.

The bridge piers are likely founded on rock below alluvial soils (Qal). Recent alluvium is susceptible to liquefaction and due to the proximity of the bridge abutment to the bank of Gales Creek, up to 3 feet of liquefaction-induced lateral spreading may occur in an M9 CSZ earthquake.

Due to the length of the span and the steel rods supporting the pipelines, limited force and deformation transfer is expected to occur between the bridge and the pipelines. Potential cracking of the reinforced concrete bridge in an M9 CSZ earthquake is not expected to directly affect the pipelines. ODOT (1995) performed a seismic vulnerability study to prioritize local agency bridges for seismic retrofit. The study assigned Group 2B to the Stringtown Road Bridge owned by Washington County. According to the study, Group 2B includes bridges that have three substructure deficiencies consisting of (1) inadequate splices of main longitudinal column reinforcement to the footing dowels, (2) inadequate confinement of main longitudinal reinforcement in concrete columns, and (3) inadequate footing anchorage or absence of reinforcement in the top of footing. In addition to these identified deficiencies the bridge will likely experience liquefaction-induced permanent ground deformation. It is recommended that the City considers 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.

6.0 POST-EARTHQUAKE REPAIR

Restoration of the water system following a major earthquake requires consideration of system operation and repairs. Operational response requires that the damaged portions of the system are rapidly identified and isolated to minimize the loss of water. Estimation of restoration time is based on availability of equipment, materials, and manpower resources to complete repairs and bring the system to its pre-earthquake condition.

6.1 CITY REPAIR RESOURCES

6.1.1 EQUIPMENT

The City owns a range of equipment needed for pipeline repair and replacement including one backhoe, one excavator, two hydro-excavators, and one water service pickup truck to support the hydro-excavator. The hydro-excavator is operational without the water service pickup truck but would require more preparation time. Thirteen of the City staff are trained to operate the hydro-excavators. Additionally, the electric power group has an additional backhoe and mini-excavator that may be available but could also be needed for repairs to the electrical system.

All of the City's construction equipment and vehicles are located at the Public Works yard.

6.1.2 STOCKPILE MATERIAL

Construction materials and spare parts are stockpiled at the City's Public Works yard with other City infrastructure. As shown in the liquefaction hazard map (Plate 14), the Public Works facility may experience some liquefaction-induced settlement of up to 2 inches.

Stockpile materials for pipelines primarily include smaller diameter pipe that could be used for a limited number of repairs in the distribution system but not in the larger pipes of the backbone. At present, the City does not have sufficient stockpile to repair all of the estimated pipeline damage.

A breakdown of repair estimates distribution of sizes for the backbone and non-backbone distribution system is shown in Table 18 and Table 19. Figure 28 shows the median estimate of repairs in the backbone (transmission and distribution) and distribution system pipelines. The number of repairs shown in the tables is a reasonable estimation of material needed for post-earthquake pipeline repairs. Approximately 10 percent of these repairs can be considered to be breaks, and the remaining as leaks. The raw water transmission system is not shown in these figures since 99 percent of the repairs are estimated to be on the 16-inch CCP. The JWC pipeline consists only of the 24-inch CCP and therefore is also not shown.

The current stockpile of clamps and sleeves are for smaller pipe sizes. Additional stockpile material for larger pipe sizes will be required to meet the recovery goals of the ORP. However, there are challenges associated with stockpiling significant quantities of repair materials due to space restrictions and damage/deformation that can occur over time as the material is not frequently used.

Table 18: Total Median Repairs in Backbone Distribution System

Material	6-inch	8-inch	10-inch	12-inch	16-inch	20-inch	24-inch
CIP	1	11	7	8	1	2	--
DIP	--	1	5	1	--	--	1

Note:
1. Repairs rounded to the nearest whole number, may differ slightly from values in previous tables

Table 19: Total Median Repairs in Distribution System

Material	2-inch	4-in	6-inch	8-inch	10-inch	12-inch
CIP	3	1	68	32	2	1
DIP	--	1	20	52	8	5

Note:
1. Repairs rounded to the nearest whole number, may differ slightly from values in previous tables

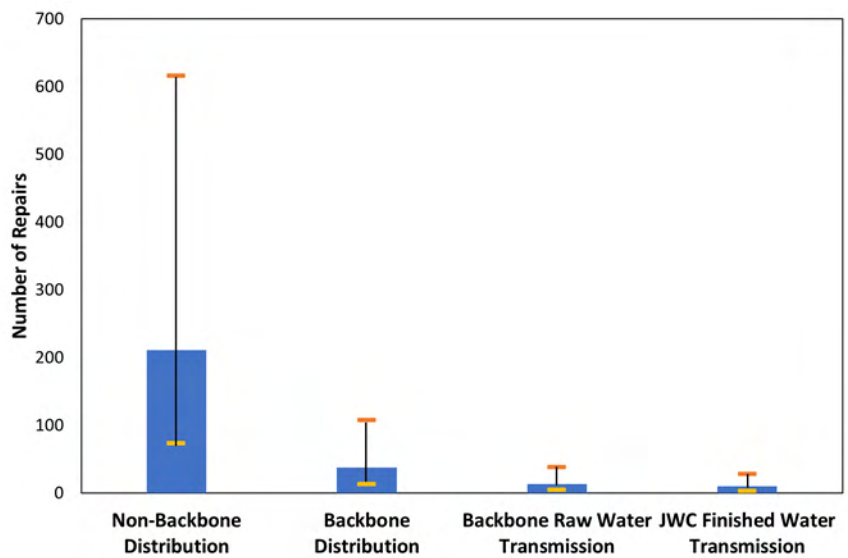


Figure 28: Pipeline Repair Estimates

6.2 PIPELINE REPAIR

The number of post-earthquake repairs that can be completed in a single day is dependent upon availability of crew, equipment, material and access. The most time-consuming elements of a repair are excavation, hauling, and backfill, which are all typically performed by a single repair crew, which may include a backhoe operator, a dump truck operator, a mechanic, and two utility workers. To rapidly respond to a significant number of pipeline repairs, post-earthquake pipeline repair protocols need to be established. This could include separating the hauling and backfilling operations from the excavation and repair operations. The crew responsible for excavation and repair could side cast the excavated material, perform the repair, and move on to the next repair, while a separate crew performs the haul and backfill operations.

The City has the capability of repairing small diameter pipelines (generally less than 12 inches in size). It is estimated that the time required to repair a single leak is at least 4 hours for smaller pipes (8 to 10 inches or less) and could take at least a day for larger pipes. For minor repairs such as leaks, it is estimated that on average, a single crew can make approximately three repairs to smaller pipes and one repair to a large pipe in a single 12-hour shift (assuming material availability). These estimates assume an expedited repair procedure with temporary side-casting and proper backfilling at a later time.

Repair of larger pipes and significant breaks can take 12 to 24 hours if material is readily available. If material needs to be special ordered and shipped to the City it could take longer, especially if transportation routes are impacted. Material availability could also be a problem in an M9 CSZ earthquake due to its region-wide impact.

Assuming three repairs per day for 12 inches or smaller pipelines and one repair per day for larger pipelines, the time required to complete all of the median estimated repairs are shown in Table 20. The table also shows median repair estimates and uncertainty. Repair estimates for the 24-inch JWC TL are shown in Table 21. These estimates assume one or two crews working in 12-hour shifts. The number of crews available is limited by the current equipment owned by the City.

As shown in Table 20, if there is one crew per day, it is estimated that it may take a little over a month (34 days) to complete the median estimate of repairs to the existing backbone pipelines and an additional two and a half months (75 days) to complete the median estimate of repairs to the existing non-backbone distribution system. It is estimated that the median repairs for the JWC TL would take a little over a week (10 days) to complete. If there are two crews per day, it may take a little over two weeks (18 days) to complete the median estimate of repairs to the existing backbone pipelines and an additional month (38 days) to complete the median repairs to the existing non-backbone distribution system. It is estimated the median repairs for the JWC TL would take a little under a week (5 days) to complete.

Assuming material equipment and crew availability, median estimate of repairs for the existing water system (City backbone and non-backbone as well as the JWC TL) can be completed in about 2 to 4 months (assuming 1 to 2 crews per day). However, given the regional impact of M9 earthquake and associated limitations, for planning purposes, we estimate that the pipeline repairs may be completed in about 3 to 6 months.

Table 20: Number of Days to Complete Pipeline Repairs for City Pipelines

System	Pipeline		Number of Estimated Repairs[2]	No. of Days to Complete Repairs[1,3]	
				1 Crew/Day[1]	2 Crews/Day[2]
Backbone (BB)	Raw Water Transmission Main	Lower Estimate	5	5	3
		Median Estimate	13	13	7
		Upper Estimate	38	38	19
	Backbone Distribution	Lower Estimate	13	8	4
		Median Estimate	37	21	11
		Upper Estimate	108	61	31
Non-BB	Distribution System	Lower Estimate	74	26	13
		Median Estimate	213	75	38
		Upper Estimate	616	216	108
TOTAL		Lower Estimate	91	39	20
		Median Estimate	263	109	56
		Upper Estimate	763	315	158

Note:

1. One crew shift is 12-hours
2. Based on conservative estimate of total repairs as discussed in Section 5.0.
3. Assumes 1 repair/crew/day for large diameter (12 inches or larger) pipelines and 3 repairs/crew/day for smaller diameter pipelines.
4. Backbone distribution repair estimates also include future backbone.
5. Repairs rounded to the nearest whole number, may differ slightly from values in previous tables.

Table 21: Days to Complete Pipeline Repairs for the 24-inch JWC Finished Water Pipeline

Pipeline		Number of Estimated Repairs[2]	No. of Days to Complete Repairs[1,3]	
			1 Crew/Day[1]	2 Crew/Day[1]
24-inch JWC TL	Lower Estimate	3	3	2
	Median Estimate	10	10	5
	Upper Estimate	28	28	14

Note:

1. One crew shift is 12-hours
2. Based on conservative repair estimate of total repairs as discussed in Section 5.0
3. Assumes 1 repair/crew/day due to larger diameter pipeline.

6.3 OTHER FACILITIES

The 5 MG reservoir at the WTP has significant structural vulnerabilities. The potential damage is such that the reservoir may not be operational following an M9 CSZ earthquake. Due to limited available resources following such a large earthquake, it may take several months to repair and restore the reservoir to full operations. For this study, we have assumed 3 months to put the reservoir back into operation.

Potential damage to other facilities at the WTP is not expected to be catastrophic and is likely to be such that it could be repaired over time without significantly impacting treatment operations.

The other potentially significant impact to the City's facilities could be damage to the Equipment Building and the covered storage structure, which could impair the City's ability to immediately mobilize its repair crews.

6.4 MUTUAL AID

Oregon Water/Wastewater Agency Response Network (ORWARN) has 118 Oregon water and wastewater utilities. ORWARN member utilities provide voluntary assistance to each other during an emergency incident. In case of a natural or manmade hazard, ORWARN member utilities provide emergency services in the form of personnel, equipment, and materials. Due to the regional nature of the CSZ earthquake with impacts from Vancouver B.C. to parts of northern California, it is unlikely that any of the geographically closest ORWARN member utilities would be able to provide assistance to the City immediately following the M9 CSZ earthquake.

Consideration should be given to the interstate Emergency Management Assistance Compact (EMAC), which is a national interstate mutual aid agreement that enables states to share resources during times of disaster. EMAC is administered by the National Emergency Management Association (NEMA). Because EMAC is an interstate agreement, it can only be established by the state. However, once established, the City will be able to rely on aid from utilities unlikely to be significantly impacted by the Cascadia event. Some of the major water utilities in California that are unlikely to be impacted by the Cascadia event, such as the Los Angeles Department of Water and Power (LADWP), San Francisco Public Utilities Commission (SFPUC), East Bay Municipal Utility District (EBMUD), Municipal Water District of Orange County (MWDOC), and Contra Costa Water District (CCWD), can provide substantial aid.

Structural and traffic conditions of the inter-state transportation network following a major earthquake on the CSZ should be considered in planning for the arrival of out-of-state assistance. Several transportation methods, including highway, rail, water, and air should be considered as possible means of delivering materials, equipment, and workers to the City. For planning purposes, multiple alternative transportation mechanisms should be considered due to likelihood of damage to the airport, roads, bridges and docks.

6.5 POTENTIAL IMPEDIMENTS TO POST-EARTHQUAKE REPAIR

The City has limited resources available for post-earthquake repair and does not have sufficient material stockpiled to complete the estimated repairs, which will need to be special ordered and shipped. During normal business conditions, it may take about one business week to procure and ship material and after the CSZ, this time is likely to increase significantly.

Damage to the transportation system is also a significant impediment to timely restoration of the City's water system. A detailed assessment of the impact of transportation infrastructure restoration of the water system was beyond the scope of this study.

It is expected that there will be numerous citizen and customer call-ins reporting leaks and breaks, with multiple calls reporting the same damage. This will likely overwhelm the City's system for handling leak calls and dispatching repair crews. In addition, there is a strict protocol for documentation and repair of earthquake-related damage to obtain reimbursements from Federal Emergency Management Agency (FEMA). It is our understanding that the City does not currently have established procedures for documentation that meets FEMA reimbursement requirements.

6.6 EXISTING SYSTEM RECOVERY TIME

Based on our median estimates of repair times and the City's ability to restore system to pre-earthquake levels, it may take much longer compared to the TSoRs in the ORP. Our estimate of time required to bring the system back to its pre-earthquake condition compared to ORP's TSoRs is presented in Figure 29. The figure shows that in its existing state, the City's system would not meet the ORP's TSoRs.

CSZ M_w 9.0 Event Occurs

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 utlize alternative water sources to suppress fires 2. David Hill Reservoir continued operation 3. 5MG WTP Reservoir continued opration	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	

Figure 29: Existing System Estimated Recovery Time

7.0 MITIGATION OPTIONS

The City is located in an area of moderate seismic hazard and would be impacted by earthquake-induced ground shaking, liquefaction and landslides in an M9 earthquake on CSZ. The City could also be impacted by an earthquake on the nearby Gales Creek fault, which poses a surface fault rupture hazard in addition to strong shaking, liquefaction and landslides. However, the probability of a Gales Creek earthquake is low compared to an M9 earthquake on CSZ. Therefore, this report's primary focus is on the M9 earthquake.

Although the overall seismic hazard in the City is moderate, the risk of significant service interruption in water supply is high given the use of seismically vulnerable pipeline construction. The risk is further exacerbated by the regional nature of the CSZ earthquake. Areas designated as having very little and greater liquefaction severity are the most likely to require repairs of leaking or broken pipes. While some pipeline breaks may occur outside of this zone, it is our opinion that targeting the most vulnerable cast iron pipelines in areas with very little and greater liquefaction hazards is a cost-effective solution to improve the performance of the transmission and distribution system.

We estimate that in its existing state, it may take between 3 and 6 months following an M9 earthquake to bring the entire system back to its pre-earthquake condition. The estimated time range to restore various components of the system as they relate to the ORP's TSoR is shown in Figure 29. As shown in the figure, the range is broad and should be treated as a planning level estimate.

A list of recommendations to improve system performance in an M9 CSZ earthquake is developed as part of this report. The recommendations are developed with the intent that there is reliable supply of water for emergency use and firefighting immediately following the earthquake and that the water system for daily use and economic activity is restored in a reasonably short time.

7.1 BACKBONE

A system backbone is critical to collect and treat raw water and deliver treated water to the distribution network. Following the ORP's TSoR, the backbone system components should be 80 to 90 percent operational within 24 hours after an earthquake. Capital improvement projects to achieve this level of service are described in terms of first and second-tier improvement priorities. Completion of the first-tier backbone improvement projects will allow the City to draft emergency water from Gales Creek and distribute water to much of the City. Completion of the second-tier backbone improvement projects will also allow the City to collect raw water from the Clear Creek watershed with additional storage at the David Hill Reservoir. The backbone system as defined in this study is shown in Plate 1.

7.1.1 First-Tier Backbone

Components of the first-tier backbone include:

- RWTM from the Stringtown Road Bridge to the WTP
- City WTP, including the 5 MG WTP Reservoir
- 24-inch JWC TL
- 10th Avenue Control Station
- Public Works Office Building
- A treated water backbone pipeline network within the City

7.1.1.1 RWTM from Stringtown Road Bridge to the WTP

The first-tier backbone RWTM between the Stringtown Road Bridge and the WTP consists of about 1.8 miles of 16-inch CCP pipeline. Approximately 1.2 miles (67 percent) of the RWTM, from Stringtown Bridge to the raw water pump station, lies within an area of very little and greater liquefaction hazard. Because the 16-inch RWTM is an older pipeline and is critical for the water supply, we recommend that the City consider replacing sections of the pipeline within areas of very little and greater liquefaction hazard.

Butt-welded steel pipelines have historically been considered to be highly reliable in resisting large PGDs. In addition, recent testing at Cornell University (Stewart et al., 2015; Pariya-Ekkasut et al., 2017) has shown that seismic-resistant ductile iron pipes, such as US Pipe Ductile Iron TR-XTREME or Kubota Earthquake-Resistant Ductile Iron, also perform well in conditions where large ground deformations may occur. We recommend replacing the existing first-tier backbone with seismic-resistance ductile iron pipes or welded steel pipes in areas of very little and greater liquefaction hazards. For areas where there is no liquefaction potential (confirmed through future geotechnical evaluations), pipelines that are generally used for water systems in competent soils can be used.

Very limited subsurface information is available along the RWTM alignment. It is recommended that prior to a pipeline replacement program, a geotechnical study be performed to investigate subsurface conditions and characterize the soil's susceptibility to liquefaction. A geotechnical study could substantially reduce the length (and cost) of pipeline replacement.

The current RWTM alignment is close to an existing landslide near Forest Glen Park. City's maintenance staff have indicated that the transmission line near the park has been repaired previously, which suggests ongoing landslide activity. The landslide hazard area is relatively small and could be avoided as part of a pipeline replacement program. We recommend an additional 500 feet (0.1 mile) of the RWTM be replaced and re-routed away from the landslide near Forest Glen Park.

7.1.1.2 WTP and 5MG Reservoir

The 5MG WTP Reservoir is critical to provide treated finished water to the City. A separate recently completed detailed structural evaluation of the 5 MG reservoir recommended a complete replacement or retrofit of the WTP column and column footings. Simplified calculations performed for this study show that in addition to the columns, the walls also do not meet seismic demands for a continued operation performance criteria. Therefore, we recommend that the City considers a retrofit or replacement of the reservoir.

7.1.1.3 24-inch JWC TL

The 24-inch JWC TL pipeline is approximately 1.6 miles long. Approximately 1.3 miles (81 percent) lies in an area of very little and greater liquefaction hazard. The 24-inch JWC TL provides a redundant source of treated water supply. However, this redundant supply is only available if the Fern Hill Reservoirs and the pipelines from the Fern Hill reservoirs to the JWC WTP are operational following a CSZ event. A seismic resiliency study of these elements was outside of our scope of work. If it can be established that water supply from JWC is reliable, we recommend replacement of JWC TL in areas of very little and greater liquefaction hazard with seismic-resistant ductile iron or welded steel pipes for a reliable transmission of water to the City.

Limited subsurface information is available along the JWC alignment. We recommend a geotechnical study be performed to investigate subsurface conditions and characterize the soil's susceptibility to liquefaction prior to pipeline replacement.

7.1.1.4 10th Avenue Control Station

The 10th Avenue Control Station is part of the first-tier backbone because it connects the JWC TL to the City's distribution system. The station may be susceptible to liquefaction. A detailed evaluation of liquefaction hazard and structural response to assess the ASCE 41-17 Immediate Occupancy performance level is recommended.

7.1.1.5 Public Works Office Building

The Public Works Office Building is part of the first-tier backbone because it is required to support repairs of the water system after the CSZ. The Public Works Office Building may be susceptible to liquefaction. Although it appears that the structural system has sufficient redundancy to limit collapse and life safety risk, a detailed evaluation of liquefaction hazard and structural assessment to assess the ASCE 41-17 Immediate Occupancy performance level is recommended.

7.1.1.6 First Tier Backbone Distribution System

The first-tier backbone distribution system within the City is approximately 8.0 miles long and consists of about 5.8 miles of cast iron pipelines and 2.2 miles of ductile iron pipelines. A total of approximately 4.0 miles (50 percent of total) of cast iron pipelines are in areas identified as having very little and greater liquefaction hazard. Approximately 29 repairs (median estimate) are estimated in the first-tier backbone distribution system with a majority of these repairs (median estimate of 25) in the seismically vulnerable cast iron pipelines. Since the TSoR for the backbone is 90 percent operational within 24 hours following an earthquake, we recommend the City consider replacing the cast iron pipelines in the backbone distribution system with seismic resistant pipeline material. Within the backbone distribution system, multiple locations cross areas of liquefaction hazard, and until the cast iron pipelines are replaced, the City should consider installing isolation valves at various pressure zones to isolate damage if some segments of the backbone distribution system fail.

Table 22 provides a summary of the recommended first-tier backbone improvements.

Table 22: First-Tier Backbone Capital Improvement Projects

System component:	Description[1,2]
RWTM pipeline	
Geotechnical investigation	Recommended for site-specific assessment of hazard to potentially reduce pipeline replacement length
Structural Study	Detailed structural evaluation of the Stringtown Road Bridge to assess potential impacts to the suspended RWTM and evaluate between bridge retrofit or a new pipeline crossing
Pipeline replacement	Estimated pipeline replacement: 1.2 miles
Forest Glen Park re-route	Pipeline replacement and re-route: 500 feet (0.1 miles)
Submersible pump, power supply, and backup power supply at raw water pump station	Infrastructure needed to draft water from Gales Creek at Stringtown Road Bridge
City WTP	
5MG WTP Reservoir	Recommendations in a separate study[3]. As recommended in this study retrofit or replace reservoir.
Structural Studies	More detailed study to assess the anchorage of the electrical cabinet (part of the generator)
24-inch JWC TL	
Geotechnical investigation	Recommended for site-specific assessment of hazard to potentially reduce pipeline replacement length
Pipeline replacement[4]	Estimated pipeline replacement: 1.3 miles
10th Avenue Control Station	Recommend a detailed liquefaction and structural evaluation to assess the ASCE 41-17 Immediate Occupancy (structural and non-structural) performance level.
Public Works Office Building and Maintenance Bays	Detailed structural analysis of the Public Works Office Building to assess the Immediate Occupancy performance criteria and to assess mechanical equipment and electrical panel anchorage
Backbone distribution system	Estimated pipeline replacement: 4.0 miles
Isolation valves	Addition of isolation valves at strategic locations within the first-tier backbone to minimize the risk of uncontrolled release of water from damaged pipelines. Recommend a study to identify location and type (manual, remote operated or seismically-triggered) of valves. This includes valves at the reservoirs to minimize the risk of uncontrolled release of water.

Note:

1. Pipeline lengths are based on information in the City's GIS database provided on June 5, 2018, which have since been updated.
2. It is assumed that the pipelines would be replaced with the same diameter pipeline.
3. OBEC, 2018
4. Up to 50% of the cost for the 24-inch JWC TL replacement may be paid for the city of Hillsboro.

7.1.2 SECOND-TIER BACKBONE

Components of the second-tier backbone include:

- Raw water intake structures and collection pipelines
- RWTM upstream of the Stringtown Road Bridge
- David Hill Reservoir and pump station
- Extension of the first-tier backbone distribution network within the City

Many historic and prehistoric landslides have been mapped within the Clear Creek watershed near the raw water intake structures and RWTM. Some of the mapped landslides are currently only marginally stable and could potentially become unstable and fail in an earthquake. The Smith Creek, Deep Creek, Thomas Creek, and Roaring Creek raw water intake facilities are downslope of large, potentially unstable landslides. These creeks could experience increased sediment loads or could temporarily become dammed by landslides following an earthquake. The Clear Creek raw water intake structure is generally outside the area of mapped historic landslides. Based on its location, turbidity may be less severe at the Clear Creek raw water intake structure than at the other intake structures.

Raw water collected at the intake structures is fed through the collection lines to the RWTM. The second-tier backbone collection lines and RWTM consists of about 1.2 miles of cast iron pipelines and about 6.0 miles of CCP. Both cast iron pipelines and CCP are vulnerable to earthquake-triggered landslides. Figure 30 shows areas of high landslide susceptibility and historic landslide deposits near the second-tier backbone RWTM. About 1.9 miles of the second-tier backbone lies within an area of high landslide hazard or within a historic landslide deposit.

At a regional scale, the depth, extent, and deformation of earthquake-triggered landslides is highly uncertain. Additional site-specific geotechnical investigations are recommended along the alignment designated as high hazard in Figure 30. Depending on the depth and extent of the possible landslides, capital improvement projects may range from re-routing the pipeline alignment around the landslide, mitigating the landslide, or microtunneling under the landslide. Future investigations should focus on characterizing the subsurface conditions, defining the extent and magnitude of potential landslides, and recommending seismic mitigation alternatives. For planning, it can be assumed that about 40 percent of the second-tier backbone pipelines within the area of high landslide hazard will require microtunneling under active landslides and 60 percent will require pipeline rerouting and replacement. A geotechnical investigation with site-specific landslide hazard assessments could substantially reduce the scope and cost of the second-tier backbone RWTM improvement project.

There are some segments of the RWTM from Clear Creek to the Gales Creek Cemetery that are susceptible to both liquefaction and landslide hazards. Between the Gales Creek Cemetery and the Stringtown Road Bridge, approximately 3.5 miles of the second-tier backbone RWTM lies within an area of very little and greater liquefaction hazard. About 0.2 miles of the Gales Creek fire line extension also lies within an area of very little and greater liquefaction hazard. Similar to the first-tier backbone RWTM, we recommend replacing backbone pipelines in areas of very little and greater liquefaction hazard with seismic-resistant ductile iron or welded steel pipes. Very limited subsurface information is available along the RWTM alignment. Because of the lack of subsurface information, we recommend a geotechnical investigation be performed prior to planning a pipeline replacement program. Such a program could substantially reduce the length of pipeline replacement.

The RWTM crosses Gales Creek at the Stringtown Road Bridge. Lateral spreading along the banks of Gales Creek could impact the bridge and a detailed structural evaluation of the bridge is recommended. Preliminary assessment by ODOT (1995) identified possible deficiencies in the substructure. The study should also evaluate the feasibility of bridge retrofit versus a separate new crossing of the pipeline.

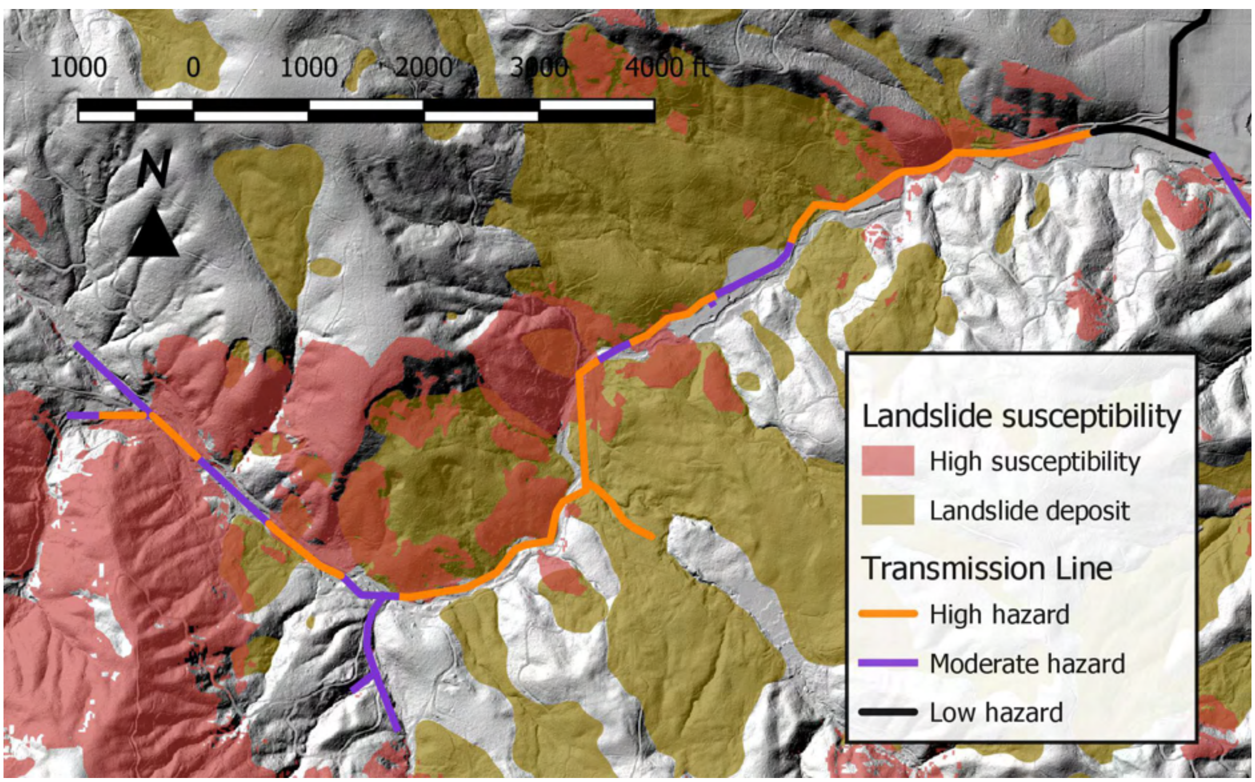


Figure 30: Landslide Hazards along RWTM within the Clear Creek Watershed

The second-tier backbone also includes the David Hill Reservoir. Our assessment based on simplified calculations and conservative assumptions shows that the perimeter walls of the David Hill Reservoir do not meet the estimated seismic demands. Therefore, it is recommended that a more detailed seismic analyses of the David Hill Reservoir be performed to assess the potential for significant damage resulting in the loss of water in an M9 earthquake. A portion of the second-tier backbone distribution pipeline near the intersection of NW David Hill Road and the service road leading to David Hill reservoir is also at risk from earthquake-triggered landslide hazard. This area is approximately 400 feet-long and appears to be related to an oversteepened road cut. We recommend mitigating the landslide or re-routing the pipeline around the potential landslide.

The second-tier water distribution backbone consists of about 2 miles of cast iron and about 2.4 miles of ductile iron pipelines. A total of about 1 mile of the second-tier backbone distribution pipelines lies within an area of very little and greater liquefaction hazard. We recommend that approximately 0.8 miles of cast iron pipelines in areas of very little and greater liquefaction hazard be replaced with seismic resistant pipeline material. In the interim, the City should consider installing isolation valves at various pressure zones (backbone and distribution system) to isolate damage and minimize the risk of uncontrolled release of water. A summary of the recommended second-tier backbone improvements is provided in Table 23.

Table 23: Second-Tier Backbone Capital Improvement Projects

System component:	Description
RWTM pipeline	
Clear Creek geology and geotechnical investigation	Recommended for site-specific assessment of hazard to potentially reduce pipeline replacement length
Clear Creek to Gales Creek Cemetery pipeline replacement	Estimated pipeline replacement: 1.9 miles Mitigation method defined following a geotechnical investigation
Gales Creek geotechnical investigation	Recommended for site-specific assessment of hazard to potentially reduce pipeline replacement length
Gales Creek Cemetery to Stringtown Road Bridge pipeline replacement	Estimated pipeline replacement: 3.7 miles
Stringtown Rd. Bridge pipeline crossing structural assessment	Seismic assessment of the bridge such that the pipeline suspended from the bridge is not damaged or a study to consider new pipeline creek crossing separate from the bridge
David Hill Reservoir	Structural evaluation
Backbone distribution system	Estimated pipeline replacement: 0.8 miles
Emergency Power Supply	Provide emergency power at David Hill pump station
System-wide	Isolation valves at strategic locations within the second-tier backbone and non-backbone system to minimize the risk of uncontrolled release of water from damaged pipelines. Recommend a study to identify location and type (manual, remote operated or seismically-triggered) of valves. This includes valves at the reservoirs to minimize the risk of uncontrolled release of water.

7.2 DISTRIBUTION PIPELINES

The non-backbone distribution pipeline system consists of approximately 25.3 miles (35.5 percent) of cast iron and 40.9 miles (57.5 percent) of ductile iron pipelines, of which 15.5 miles of cast iron and 25.1 miles of ductile iron pipelines are located in areas of very little and greater liquefaction hazard. Median estimate of repairs in different liquefaction susceptibility zones is summarized in Table 24.

Table 24: Median Estimate Non-Backbone Distribution Pipelines Repairs

Pipeline Type	Length (mi)[1]	Pipelines <12-inch in Liquefaction Severity Zones[6]				Repairs[6] (<12-in)	Repairs[6] (≥12-in)	Total Repairs[6]
		No Liq.	Very Little Liq.	Marginal Liq.	Moderate Liq.			
Cast iron[2]	25.3	1	47	55	2	106	0	106
Ductile iron[3]	40.9	1	43	35	2	81	5	86
Other[4]	4.9	0	12	9	0	22	0	22
Total[5]	71.1	2	102	99	5	208	5	213

Note:

1. Pipeline lengths are based on information in the City's GIS database provided on June 5, 2018, which have since been updated.
2. Cast Iron pipe includes pipelines marked as CIP in City GIS files
3. Ductile Iron pipe includes pipelines marked as DIP City GIS files
4. Other include pipelines marked as C900, (PVC), PVC, COPPER (Copper), GALV/GALVINIZED (Galvanized Steel), GI (Galvanized Iron), POLY (Polyethylene), STEEL (Steel), and unspecified in City GIS Files
5. Minor difference in total repairs due to rounding.
6. Rounded to the nearest whole number.

As shown in Table 24, seismically vulnerable cast iron pipelines that constitute approximately 35.5 percent of all pipelines in the system and contribute to about half of all pipeline repairs, and ductile iron pipelines that constitute approximately 57.5 percent of all pipelines have about 40 percent of median estimated repairs. Assuming that the City can perform three repairs/day (subject to material availability) for pipelines sizes less than 12 inches and one repair/day for larger sizes, it could take about two and a half months to perform a median estimate of 213 repairs with one crew working 12-hour shifts. Additional crews will reduce the time to restoration to a little over one month with two crews working 12-hour shifts.

To meet the ORP goal of bringing the distribution system back to pre-earthquake levels in one to two weeks would require a substantial investment by the City in terms of distribution system pipeline replacement. It is our recommendation that the City considers replacement of cast iron pipelines in very little and greater liquefaction areas as part of a seismic improvement program. Priority should be given to replacement of large diameter and older cast iron pipelines. In addition, the City should include liquefaction severity as one of the criteria in its long-term asset management plan for pipeline replacement for non-cast iron pipelines so that older ductile iron and other pipelines in high liquefaction severity zones are replaced on a priority basis.

While this approach will not fully satisfy the ORP goals, the recommended system upgrades coupled with emergency operations planning will significantly improve the resiliency of the City's water system. To meet the ORP goal of bringing the distribution system back to pre-earthquake levels in one to two weeks would require a substantial investment by the City in terms of distribution system pipeline replacement.

It is recommended that within the liquefaction areas, the replacement pipelines should be designed to accommodate liquefaction-induced PGD. Depending on the magnitude of expected PGD, pipelines such as butt-welded steel pipes, earthquake resistant ductile iron, TR-XTREME, and restrained joint ductile iron pipelines can be selected during the design process.

Since the estimated repairs are a function of liquefaction, a refinement in the liquefaction hazard mapping within the City's service area is recommended. Liquefaction maps developed as part of this study are based on regional level assessment; therefore, they have inherent uncertainties and are generally conservative. We recommend that the City develops a long-term geotechnical program to maintain a central database of geotechnical investigations within the City's service area and use this information to periodically update liquefaction hazard maps using site-specific data. This will help in identifying the most vulnerable segments of the City's pipeline system.

8.0 RECOMMENDATIONS

Results of this study show that several key components of the water system are seismically vulnerable and could sustain significant damage in an M9 CSZ earthquake. Structures critical for the continued supply of water to the system have been identified as backbone facilities. TSoRs in ORP provide a target for the backbone structures to be 80 percent to 90 percent operational within 24 hours and for the entire system to be at 80 percent to 90 percent operational level within 1 month. In its current condition, we estimate the City will recover to 90 percent backbone operation in about 2 weeks to 1 month and 90 percent of the entire system in about 3 to 6 months. This estimate assumes that damage to 5MG WTP reservoir is such that it does not result in uncontrolled release of water. Repair time estimate can be significantly higher if damage to the reservoir is excessive. A replacement or seismic retrofit of the reservoir is, therefore, recommended, as discussed in OBEC (2018).

The total cost of all mitigations described in Section 7.0 could be significant. However, we believe many critical TSoR goals could be achieved at substantially lower costs. We propose two packages of mitigation options for the City to consider. Option 1 is a lower cost option designed to achieve TSoRs for the first-tier backbone and critical water supply elements. Option 2 is an extension of Option 1 and while it will not fully satisfy the ORP goals, the recommended system upgrades coupled with emergency operations planning will significantly improve the resiliency of the City's water system. To meet the ORP goal of bringing the distribution system back to pre-earthquake levels in one to two weeks would require a substantial investment by the City in terms of distribution system pipeline replacement.

8.1 MITIGATION OPTION 1: FIRST-TIER BACKBONE AND CRITICAL WATER SUPPLY

Access to water from the watershed and JWC following the M9 CSZ earthquake require extensive pipeline upgrades since the pipelines cross large areas of moderate liquefaction hazard. Alternatively, water could be drafted from Gales Creek using the blind flange tee at the Stringtown Road Bridge crossing. It is recommended that City invest in infrastructure required to reliably draft water from Gales Creek such as submersible pump and power supply that could begin pumping water shortly after an earthquake. To maintain a reliable pipeline from the Stringtown Road Bridge to the WTP, section of the existing RWTM pipeline between the bridge and WTP should be replaced with seismic-resistant pipe. Seismic deficiencies in the WTP should also be mitigated.

Leaks and breaks within the first-tier backbone distribution system may cause the system to temporarily lose pressure. Cast iron pipes in areas identified as having very little and greater liquefaction hazard are at the highest risk of failing and we recommend replacing these pipes. Isolation valves should be installed near locations where pipelines cross areas of very little and greater liquefaction hazard to prevent uncontrolled release of water from damaged pipelines.

Table 25 provides a summary of Mitigation Option 1.

Table 25: Mitigation Option 1 Capital Improvement Projects

System component:	Description
Emergency pumping equipment	
Stringtown Road Bridge pump and power supply	Considerations should be given for a permanent pump station
Raw water pump backup power supply	
RWTM Pipeline from Stringtown Road Bridge to WTP	
Geotechnical investigation	Recommended for site-specific assessment of hazard to potentially reduce pipeline replacement length.
Liquefaction zone pipeline replacement	Estimated pipeline replacement length: 1.2 miles.
Forest Glen Park re-route	Pipeline replacement and re-route: 500 feet.
WTP	
5 MG WTP Reservoir	Retrofit or replace reservoir.
Generator	Assess anchorage of the electrical cabinet and if needed, anchorage to prevent sliding and overturning.
First-Tier Backbone distribution system	Replace cast iron pipelines in very little and greater liquefaction severity zones. Replace cast iron pipelines in marginal and greater liquefaction zones (estimated pipeline replacement of 2.6 miles) as highest priority followed by cast iron pipelines in very little liquefaction severity zones (estimated pipeline replacement of 1.4 miles)
Public Works Office Building and Maintenance Bays	Detailed structural analysis of the Public Works Office Building to assess the ASCE 41-17 Immediate Occupancy performance criteria and to assess mechanical equipment and electrical panel anchorage.
Isolation valves	Isolation valves at strategic locations within the first-tier backbone to minimize the risk of uncontrolled release of water from damaged pipelines. Perform study to identify location and valve types (manual, remote operated or seismically-triggered).

As per ORP, the goal would be to implement these projects over a 50-year timeline. In order of priority, these projects include WTP reservoir retrofit, the RWTM pipeline mitigation and emergency pumping equipment, detailed structural analysis of the Public Works Office Building and Maintenance Bays, followed by backbone distribution system mitigation.

8.2 MITIGATION OPTION 2: FIRST-TIER BACKBONE, SECOND-TIER BACKBONE AND NON-BACKBONE DISTRIBUTION SYSTEM

Without mitigation, dozens of leaks and breaks could occur along the first- and second-tier backbone system and a couple hundred leaks and breaks elsewhere in the water distribution system.

To expedite the repair process, we recommend replacing all cast iron pipelines along the second-tier distribution backbone that are in areas designated as very little and greater liquefaction severity. These upgrades substantially reduce the risk of pipeline breaks along the backbone system and allow the City's resources to focus on repairing other aspects of the distribution system following an earthquake. We also recommend upgrading the 24-inch JWC TL to seismic-resistant pipe in areas designated as very little and greater liquefaction severity to achieve redundancy in supply.

A structural evaluation of the David Hill reservoir should also be performed as part of Mitigation Option 2. Backup power supply should be installed at the David Hill pump station to reliably supply water to the second-tier backbone.

We also recommend replacement of cast iron non-backbone distribution pipelines in very little and greater liquefaction areas, with priority given to replacement of large diameter and older cast iron pipelines. The City should also consider developing a long-term asset management plan for non-cast iron pipeline replacement of all distribution pipelines that considers liquefaction severity, as well as corrosion conditions and age of the pipelines, as part of the criteria for establishing replacement priorities.

Table 26 provides a summary of Mitigation Option 2, which also includes the mitigation projects in Mitigation Option 1. If Mitigation Option 2 is selected, priority should first be given to the Mitigation Option 1 projects.

Table 26: Mitigation Option 2 Capital Improvement Projects

Option 1 mitigation required before proceeding with Mitigation Option 2

System component:	Description
RWTM from Watershed to Stringtown Road Bridge	
Structural Study	Detailed structural evaluation of the Stringtown Road Bridge to assess potential impacts to the suspended RWTM and, if needed, replacement or retrofit of Stringtown Bridge. Alternatively, constructing a new pipeline crossing separate from the bridge.
Geotechnical investigation	Recommended for site-specific assessment of hazard to potentially reduce pipeline replacement length.
Pipeline Replacement	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
10th Avenue Control Station	
Structural Evaluation	Recommend a detailed evaluation of liquefaction hazard and structural response be performed of the 10th Avenue Control Station to assess the ASCE 41-17 Immediate Occupancy (structural and non-structural) performance level
Modify Pipe Penetrations	Due to the potential risk of liquefaction, it is recommended that flexibility be provided to the rigid pipe to wall and pipe to slab penetrations.
24-inch JWC TL	
Geotechnical investigation	Recommended for site-specific assessment of hazard to potentially reduce pipeline replacement length
Pipeline replacement	Estimated pipeline replacement length: 1.3 miles
David Hill reservoir seismic structural evaluation	Additional analysis could show the reservoir performance to be acceptable
Emergency power supply	
David Hill pump station	Provide emergency power at David Hill pump station
Second-tier backbone upgrades	Estimated pipeline replacement: 0.8 mile
Non-backbone distribution pipelines	Replace cast iron pipelines in very little and greater liquefaction severity zones (15.5 miles). Additionally, develop a long-term non-cast iron pipeline replacement plan that considers liquefaction severity, corrosion, and age of pipelines.
System-wide	Isolation valves at strategic locations within the second-tier backbone and non-backbone distribution system to minimize the risk of uncontrolled release of water from damaged pipelines. Perform study to identify location and valve types (manual, remote operated or seismically-triggered).

8.3 OTHER NON-CIP MITIGATION CONSIDERATIONS

To improve the time of system restoration to pre-earthquake levels following an earthquake, we recommend stockpiling enough repair resources (pipe, clamps, etc.) for at least 10 workdays worth of repairs. Emergency equipment, including pumps, backup power supply, and emergency water treatment facilities, should be fully tested on a biannual basis. Such tests may be incorporated into employee training and emergency response drills.

The City should also work to develop the EMAC program through the State of Oregon to secure mutual aid from utilities in California that are unlikely to be impacted by a CSZ event.

Other programs include anchoring and restraining all vital electrical and communication equipment. Finally, the City should consider developing long term plans to isolate the backbone from the distribution system.

Additional non-CIP considerations could help expedite recovery following an earthquake. These considerations are organized by priority and include:

Priority 1

- Establishing material procurement protocols and on-call contracts with suppliers for rapid delivery in an emergency.
- Working with the state government to establish EMACs.
- Developing a procedure to track calls and identify leaks.

Priority 2

- Developing and conducting annual training events for all City employees addressing 1) personal earthquake safety; and 2) City emergency response procedures following a major earthquake.
- Establishing protocols for all City employees, including repair crew members, to report to their respective City facilities following a major earthquake. Step-by-step logistics must be taken into account, such as minimizing the distance each repair crew member must travel from their residence to the assigned City facility.
- Establishing repair protocols that result in a permanent repair, rather than an initial temporary repair followed by permanent repair. This has multiple benefits of cost savings and FEMA reimbursement.

Priority 3

- Developing and maintaining regularly updated utility maps to minimize the need to locate utilities in an emergency.

- Since the estimated repairs are a function of liquefaction, a refinement in the liquefaction hazard mapping within the City's service area is recommended. We recommend that the City develops a long-term program to maintain a central database of geotechnical investigations within the City's service area and use this information to periodically update liquefaction hazard maps using site-specific data. For example, the City could implement a system that includes sharing of geotechnical investigations conducted for development sites as part of the permitting process, as is done with other municipalities. This will help in identifying the most vulnerable segments of the City's pipeline system.

Simple actions during the repair process after an earthquake could improve the recovery rate. Such post-event actions include:

- Locating smaller leaks using sonic sensors or other methods once the obvious breaks and leaks have been located.
- Isolating breaks and major leaks.
- Confirming leak.
- Prioritizing repairs.
- Documentation to help expedite cost recovery from FEMA.
- Detailed documenting of repairs, photos, parts, and labor.

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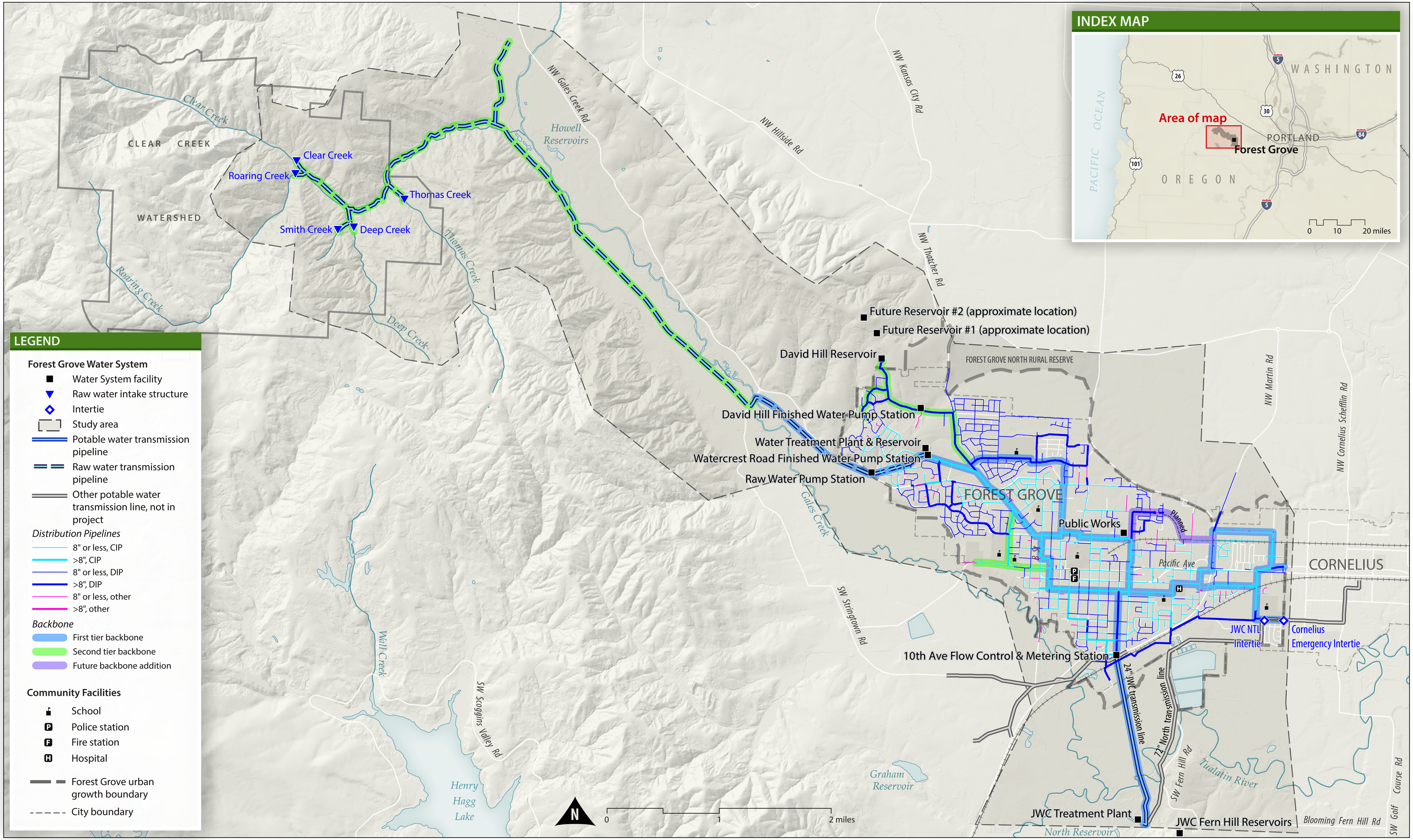
Plates



Map projection: NAD 1983 HARN State Plane Oregon North

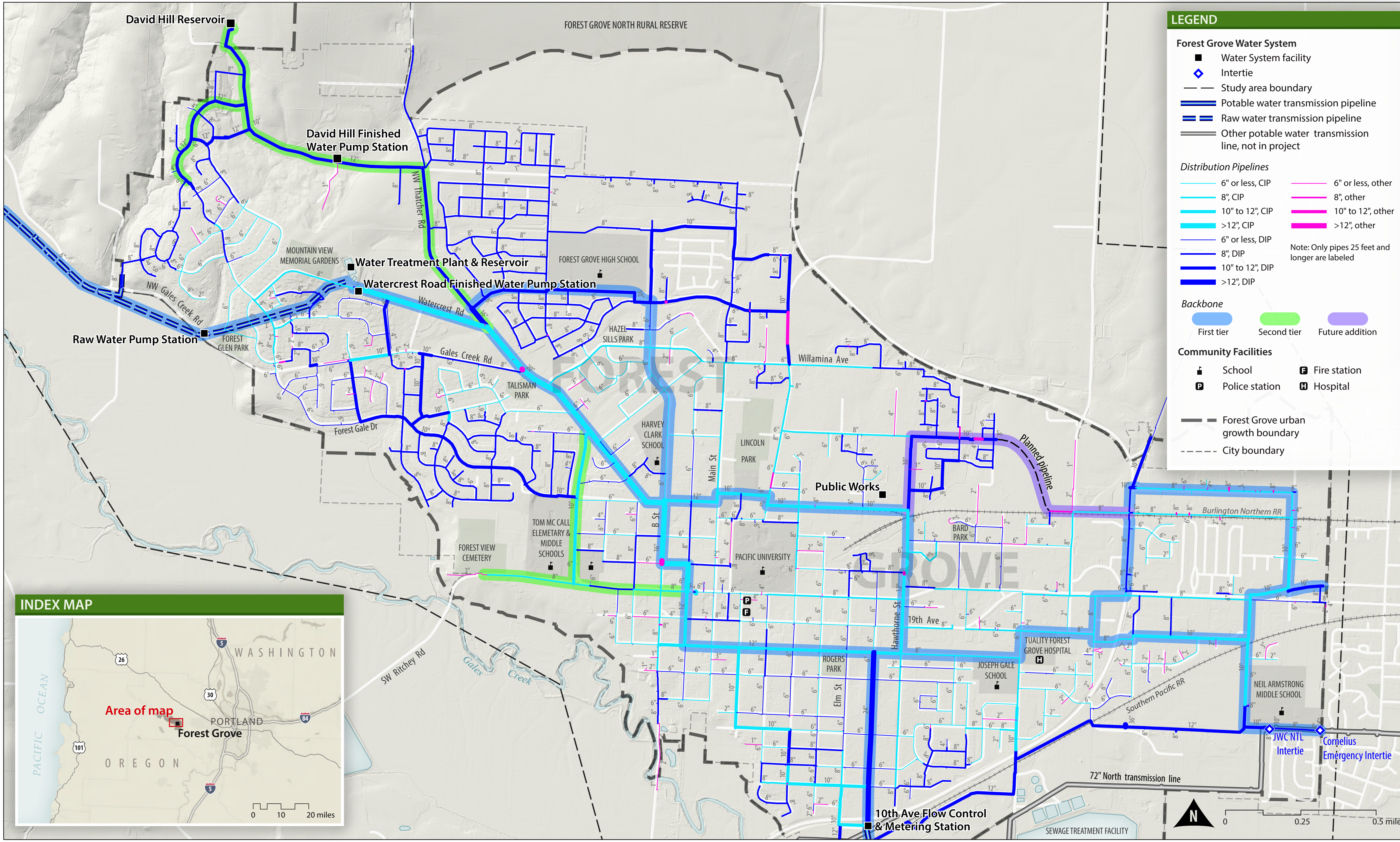
InfraTerra

City of Forest Grove Water Transmission and Distribution System and Study Location Map

CITY OF FOREST GROVE WATER SYSTEM SEISMIC RESILIENCY PLAN

Plate 1

OCT 2018



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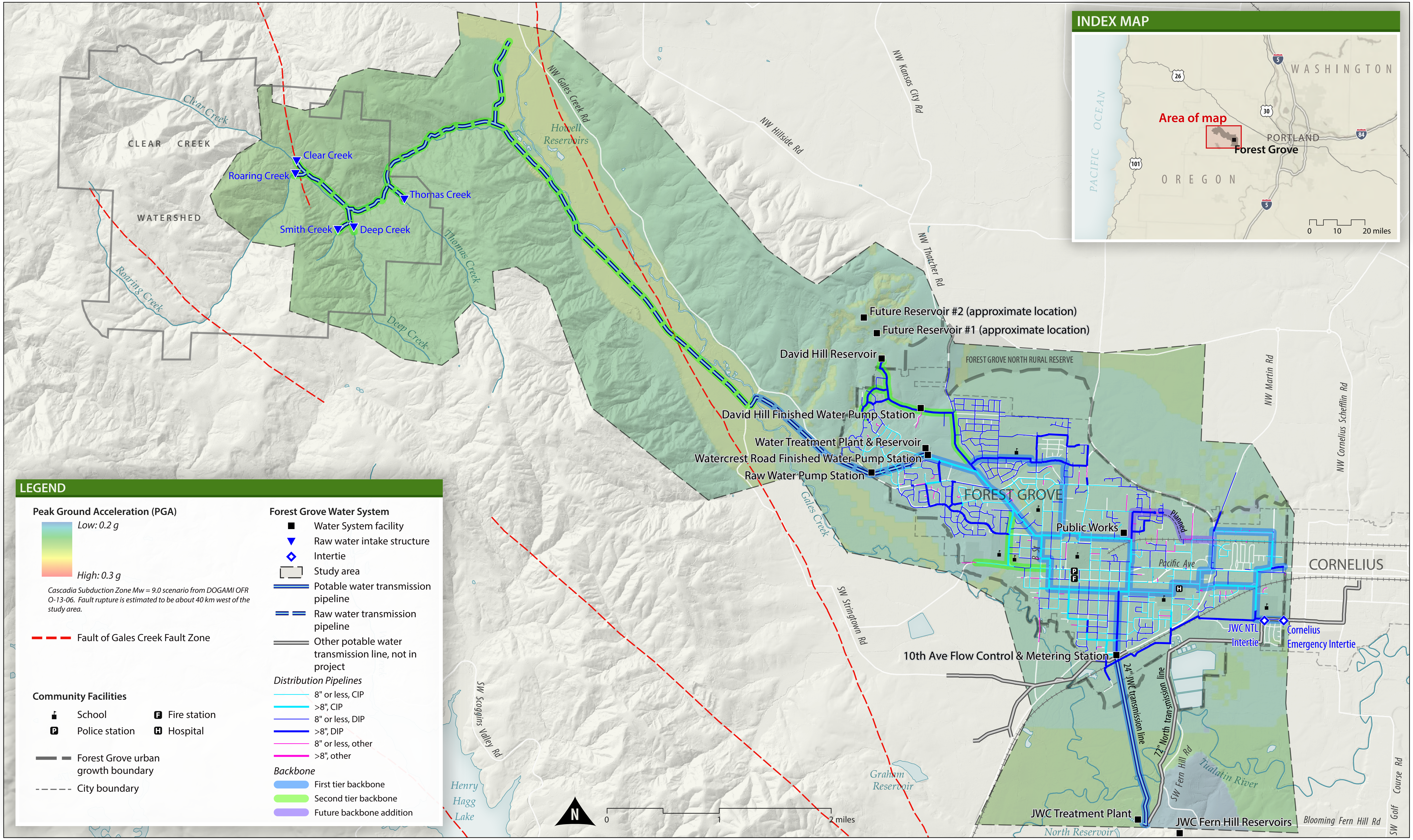
City of Forest Grove Water Distribution System and Study Location Map

CITY OF FOREST GROVE WATER SYSTEM SEISMIC RESILIENCY PLAN

Plate 2

OCT 2018



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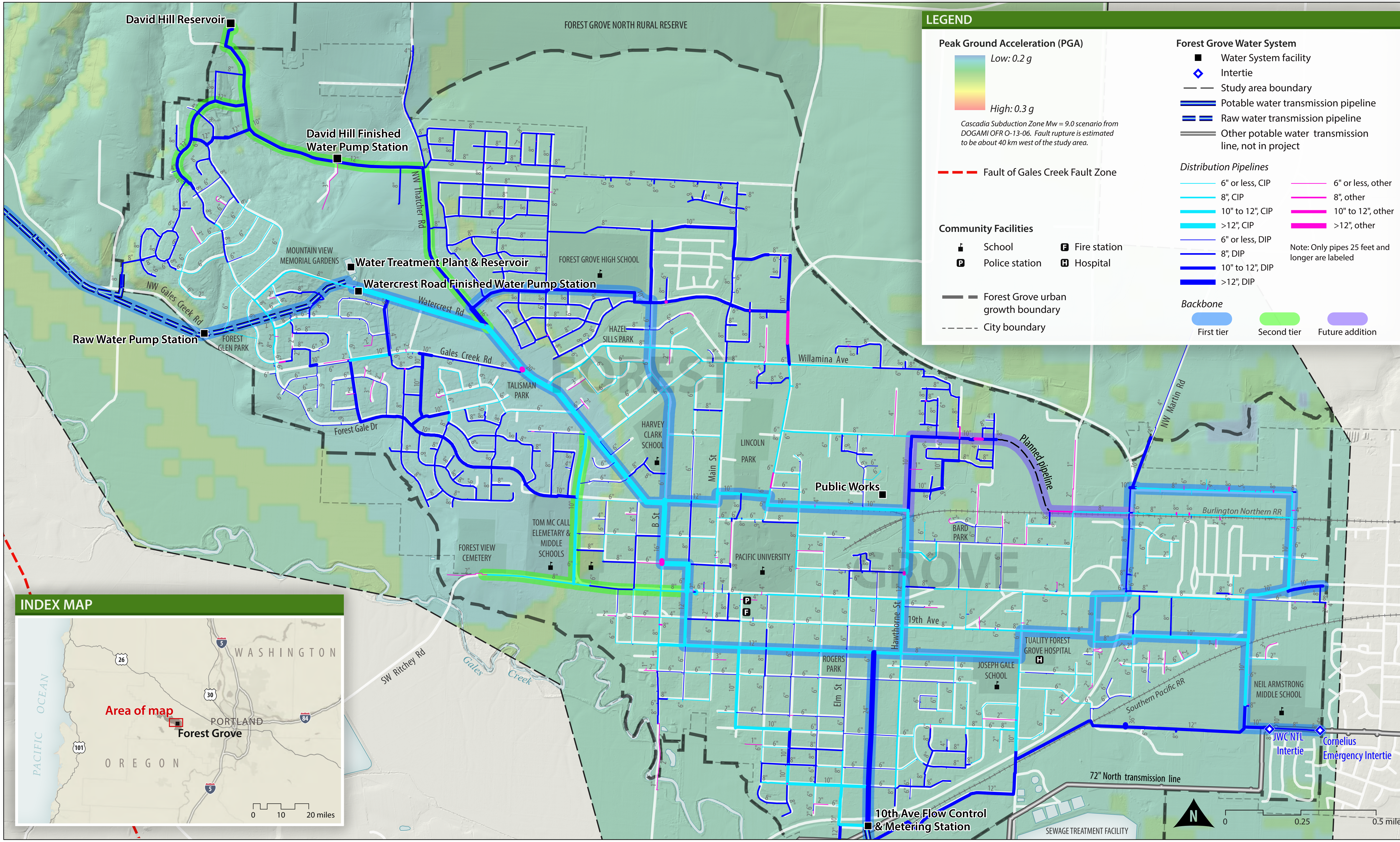
Peak Ground Acceleration for Mw 9.0 CSZ Earthquake
Water Transmission and Distribution System

CITY OF FOREST GROVE WATER SYSTEM SEISMIC RESILIENCY PLAN

Plate 3

OCT 2018



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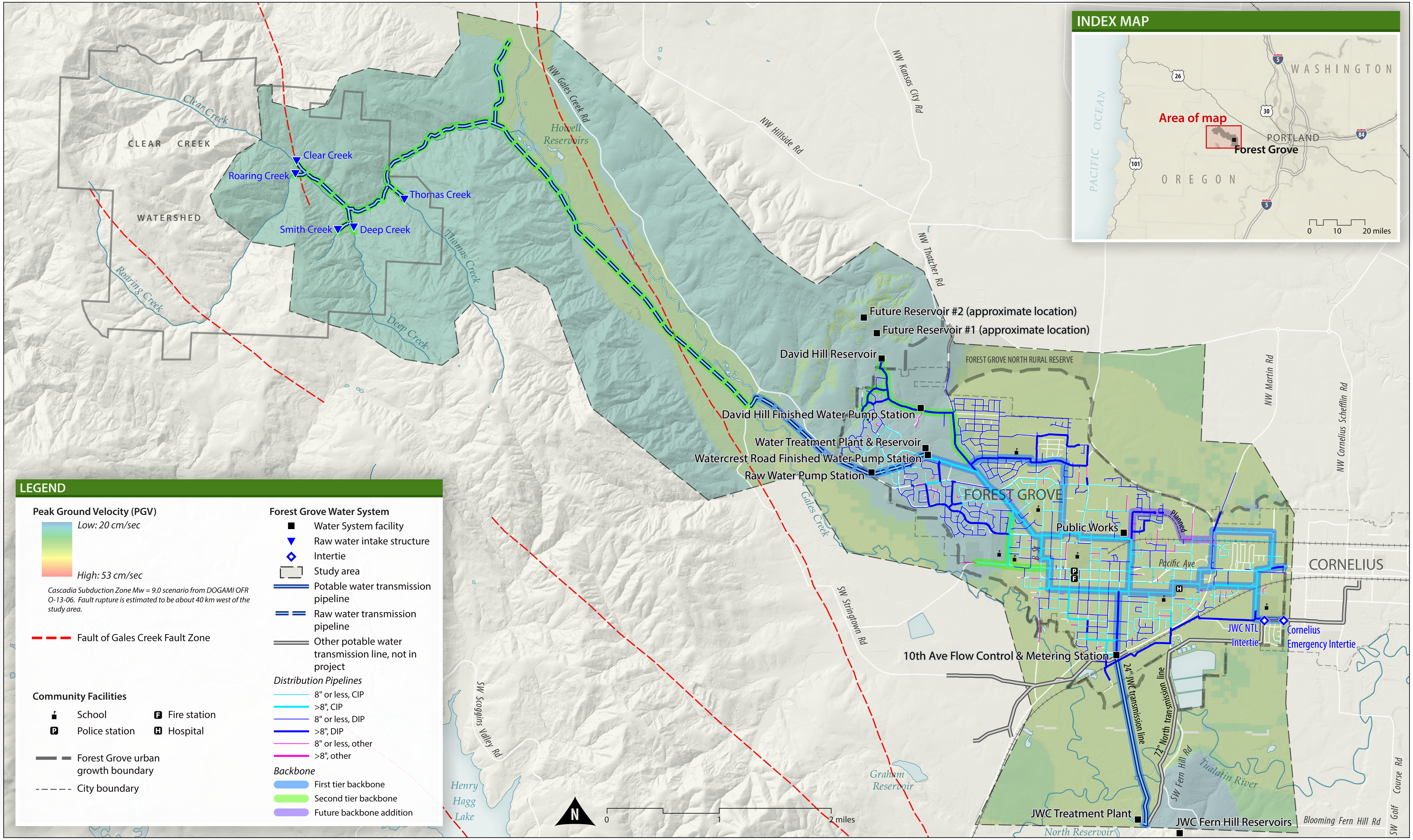
InfraTerra

Peak Ground Acceleration for Mw 9.0 CSZ Earthquake
Water Distribution System

CITY OF FOREST GROVE WATER SYSTEM SEISMIC RESILIENCY PLAN

Plate 4

OCT 2018



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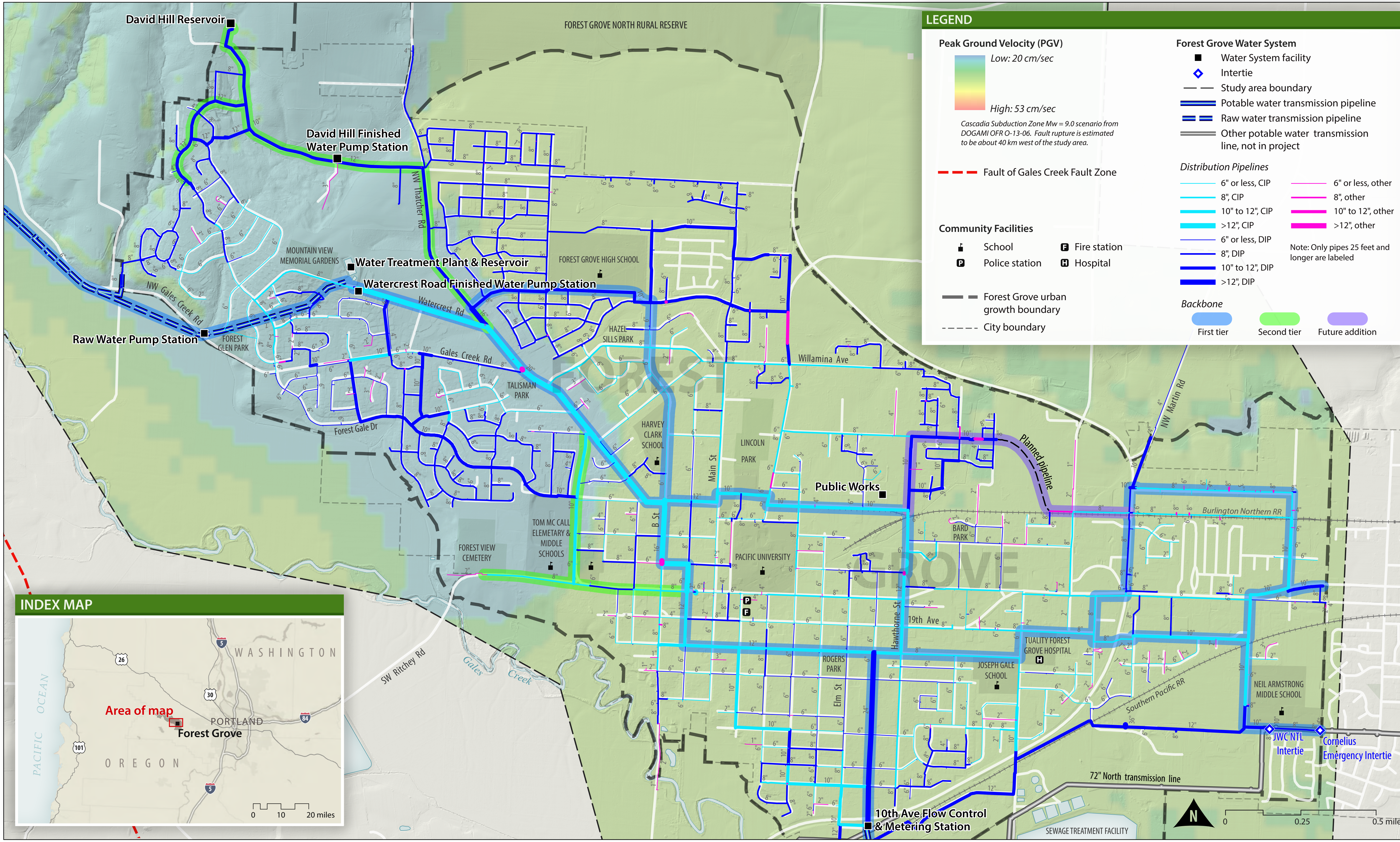
InfraTerra

Peak Ground Velocity for Mw 9.0 CSZ Earthquake
Water Transmission and Distribution System

CITY OF FOREST GROVE WATER SYSTEM SEISMIC RESILIENCY PLAN
Plate 5

OCT 2018



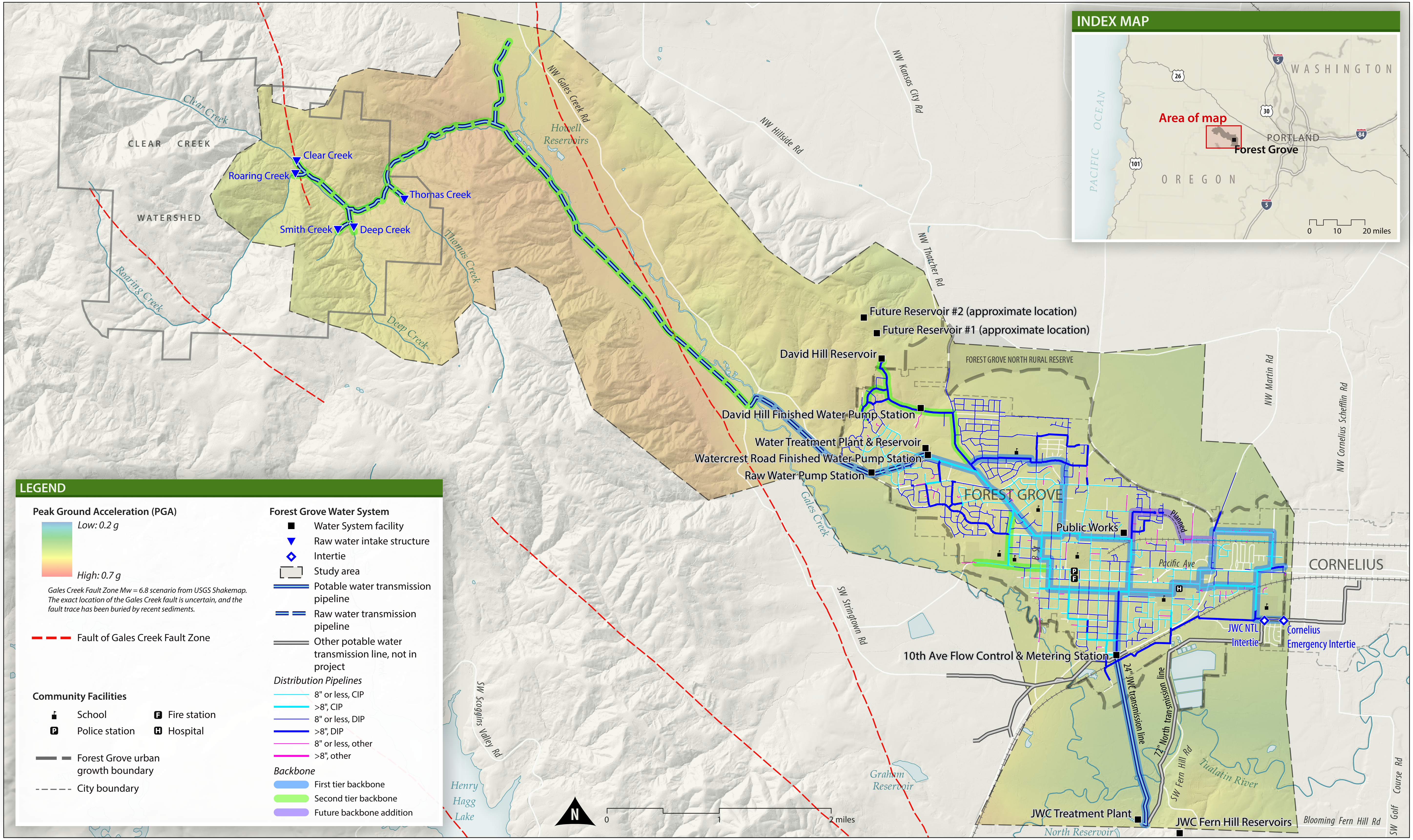
InfraTerra

Peak Ground Velocity for Mw 9.0 CSZ Earthquake
Water Distribution System

CITY OF FOREST GROVE WATER SYSTEM SEISMIC RESILIENCY PLAN

Plate 6

OCT 2018



Map projection: NAD 1983 HARN State Plane Oregon North

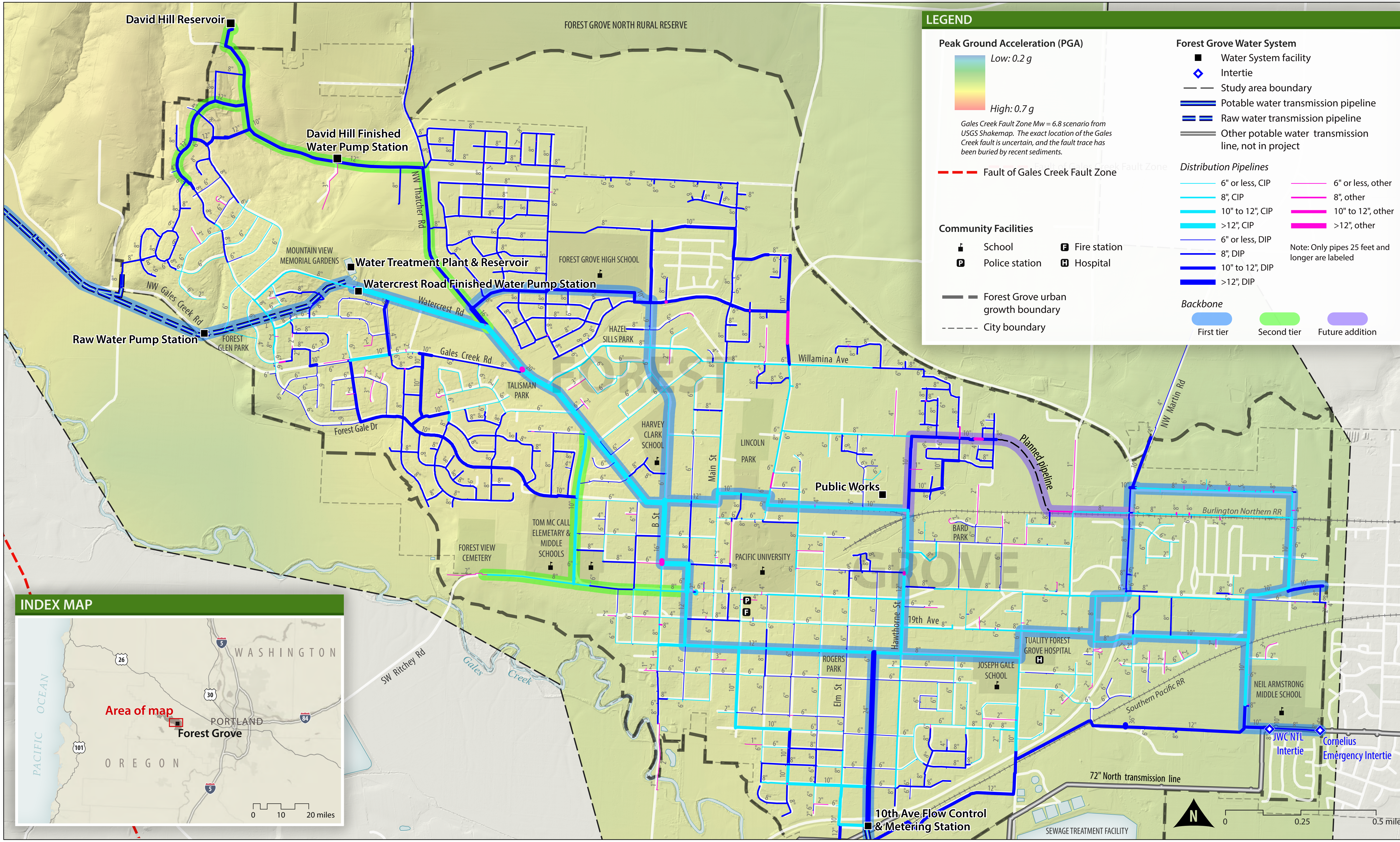
InfraTerra

Peak Ground Acceleration for Mw 6.8 Gales Creek Earthquake
Water Transmission and Distribution System

CITY OF FOREST GROVE WATER SYSTEM SEISMIC RESILIENCY PLAN

Plate 7

OCT 2018



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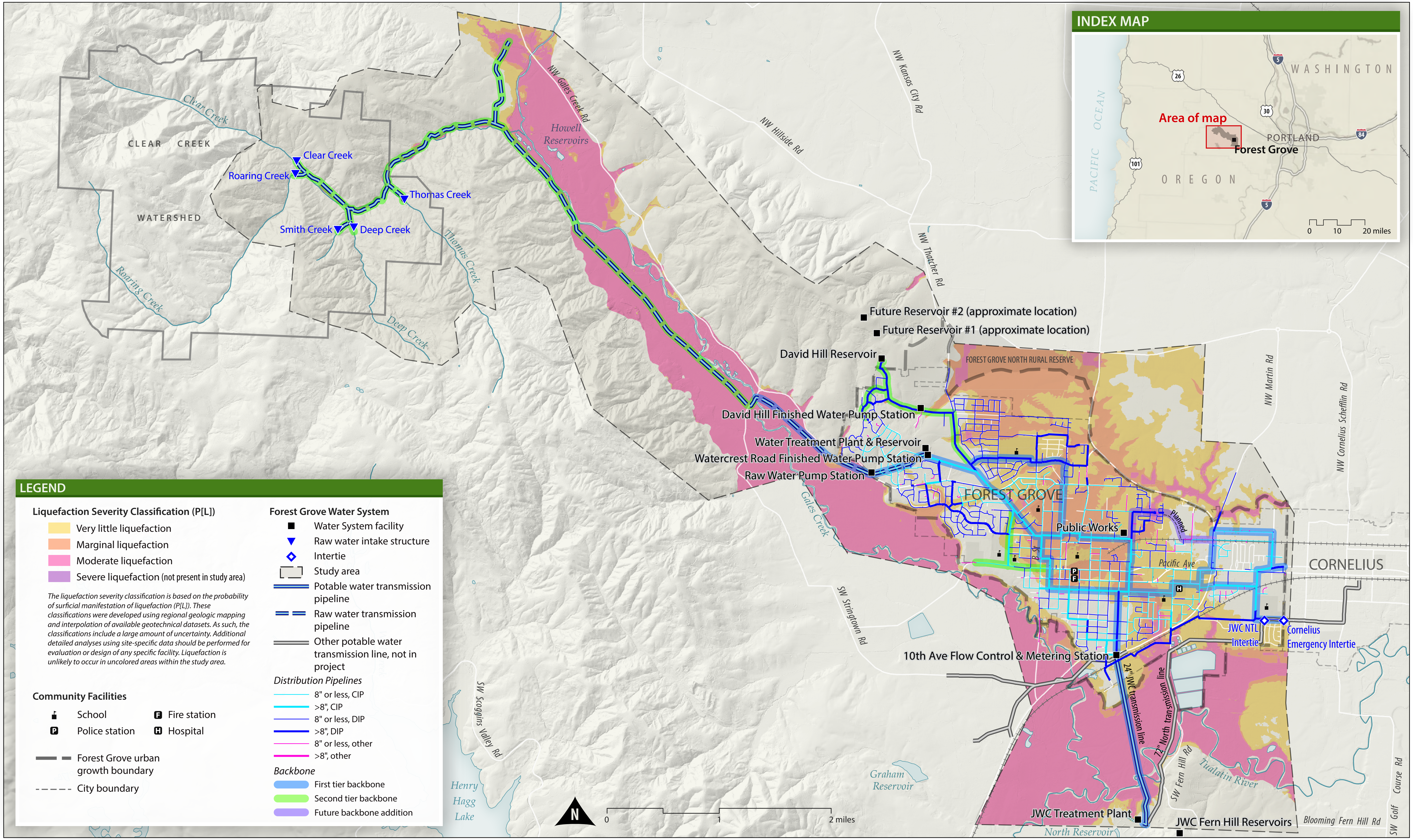
InfraTerra

Peak Ground Acceleration for Mw 6.8 Gales Creek Earthquake
Water Distribution System

CITY OF FOREST GROVE WATER SYSTEM SEISMIC RESILIENCY PLAN
Plate 8
OCT 2018



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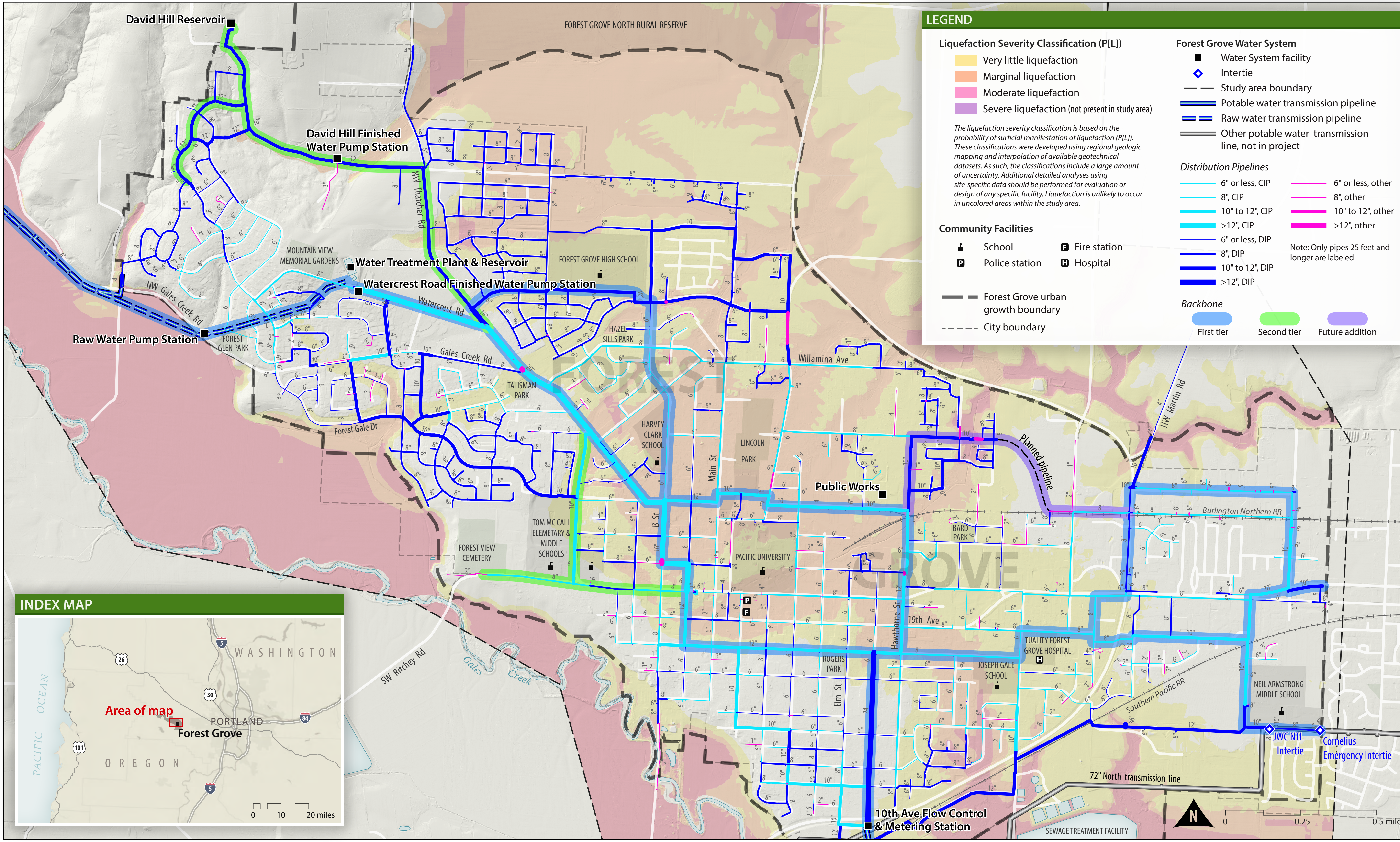
Liquefaction Susceptibility for Mw 9.0 CSZ Earthquake
Water Transmission and Distribution System

CITY OF FOREST GROVE WATER SYSTEM SEISMIC RESILIENCY PLAN

Plate 9

OCT 2018



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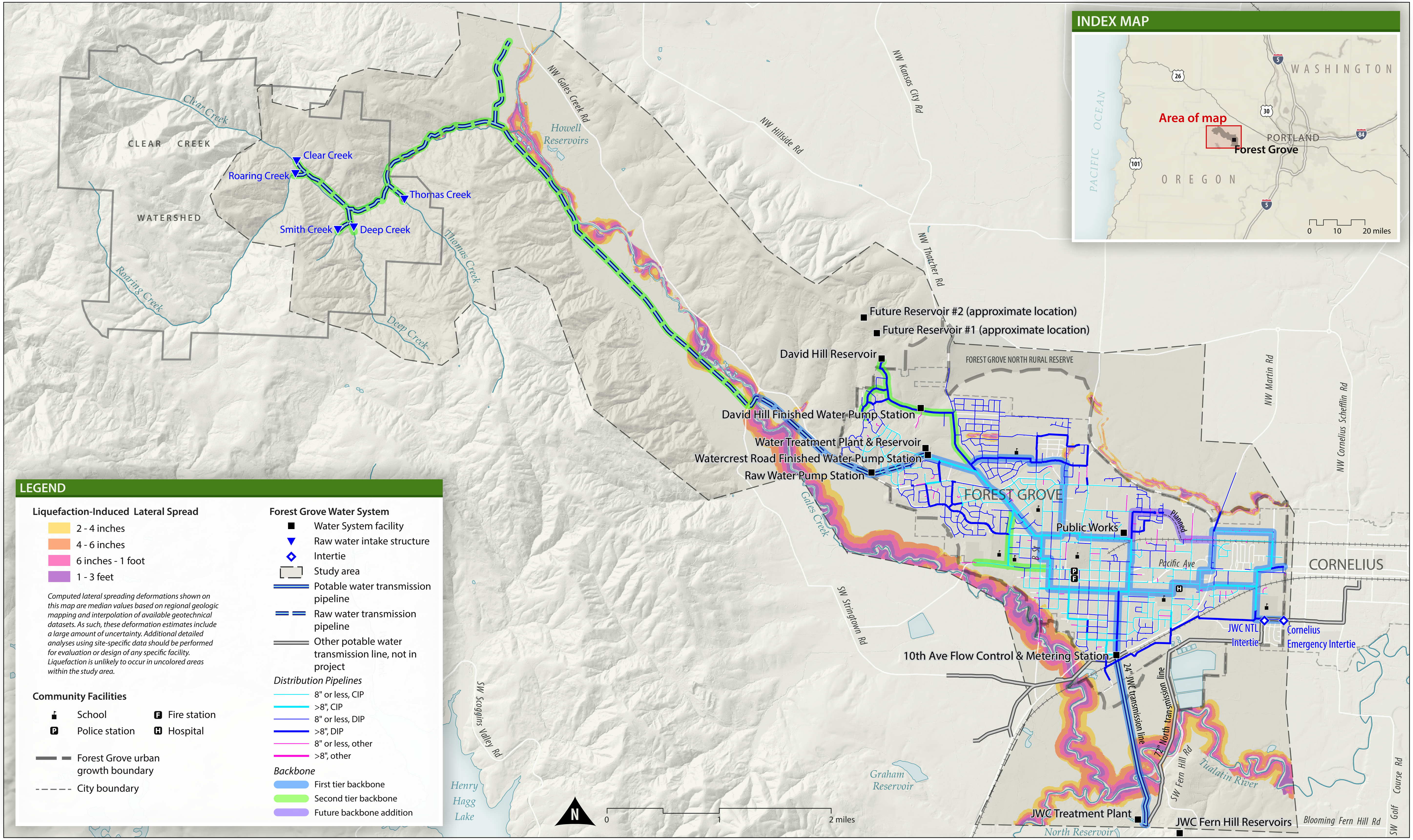
InfraTerra

Liquefaction Susceptibility for Mw 9.0 CSZ Earthquake
Water Distribution System

CITY OF FOREST GROVE WATER SYSTEM SEISMIC RESILIENCY PLAN
Plate 10
OCT 2018



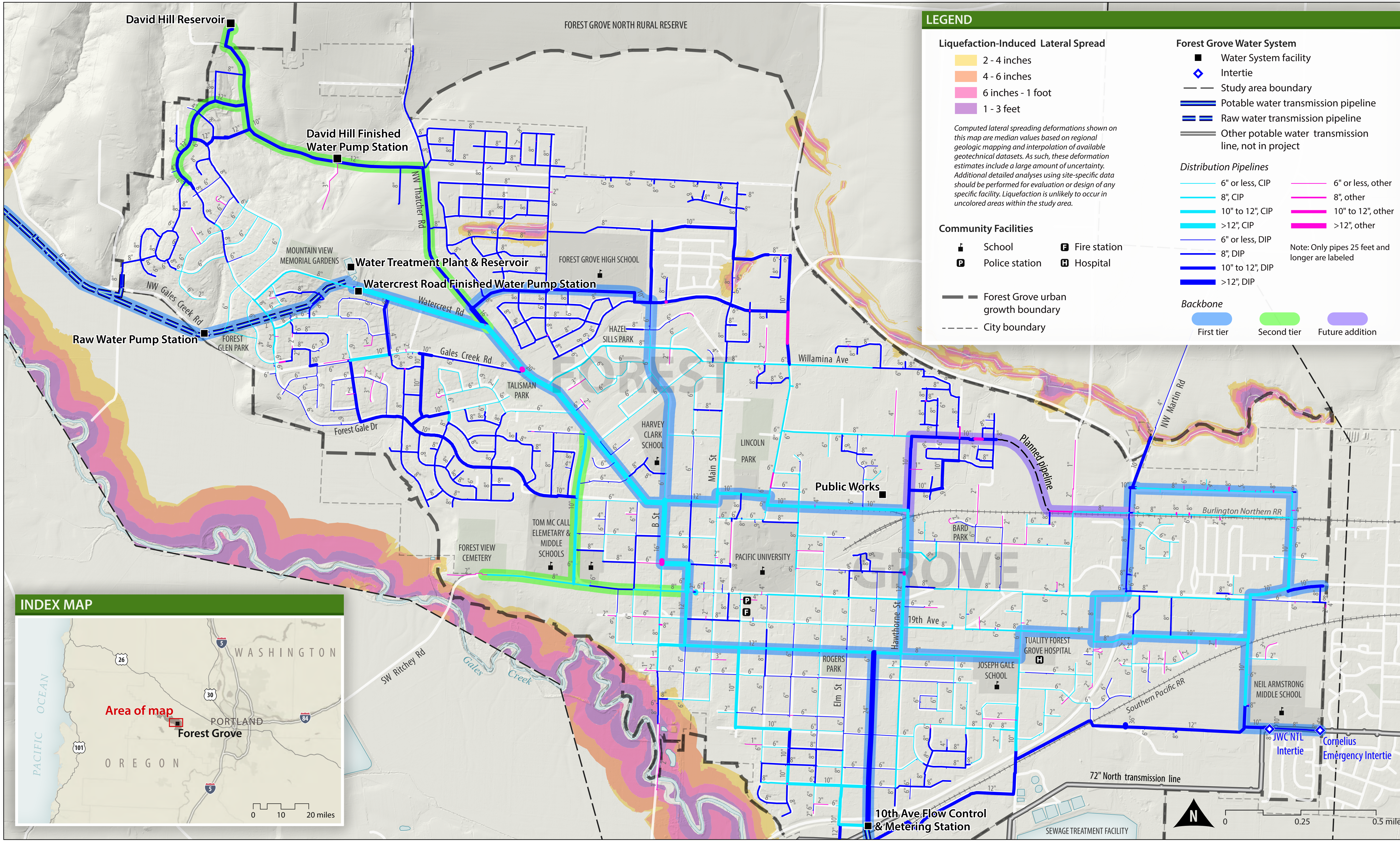
Map projection: NAD 1983 HARN State Plane Oregon North

InfraTerra

Lateral Spread for Mw 9.0 CSZ Earthquake
Water Transmission and Distribution System

CITY OF FOREST GROVE WATER SYSTEM SEISMIC RESILIENCY PLAN
Plate 11

OCT 2018



Map projection: NAD 1983 HARN State Plane Oregon North

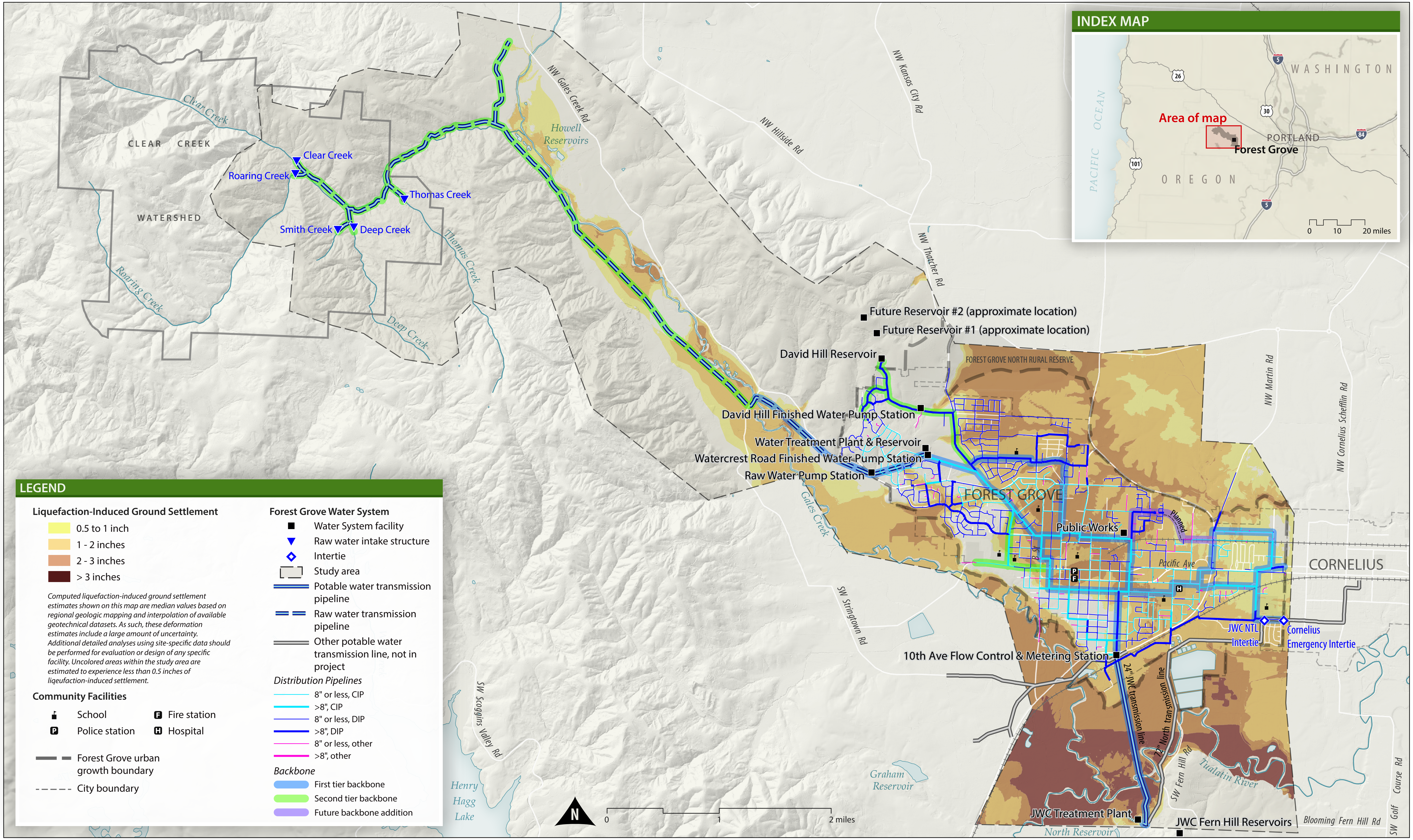
InfraTerra

Lateral Spread for Mw 9.0 CSZ Earthquake
Water Distribution System

CITY OF FOREST GROVE WATER SYSTEM SEISMIC RESILIENCY PLAN

Plate 12

OCT 2018



Map projection: NAD 1983 HARN State Plane Oregon North

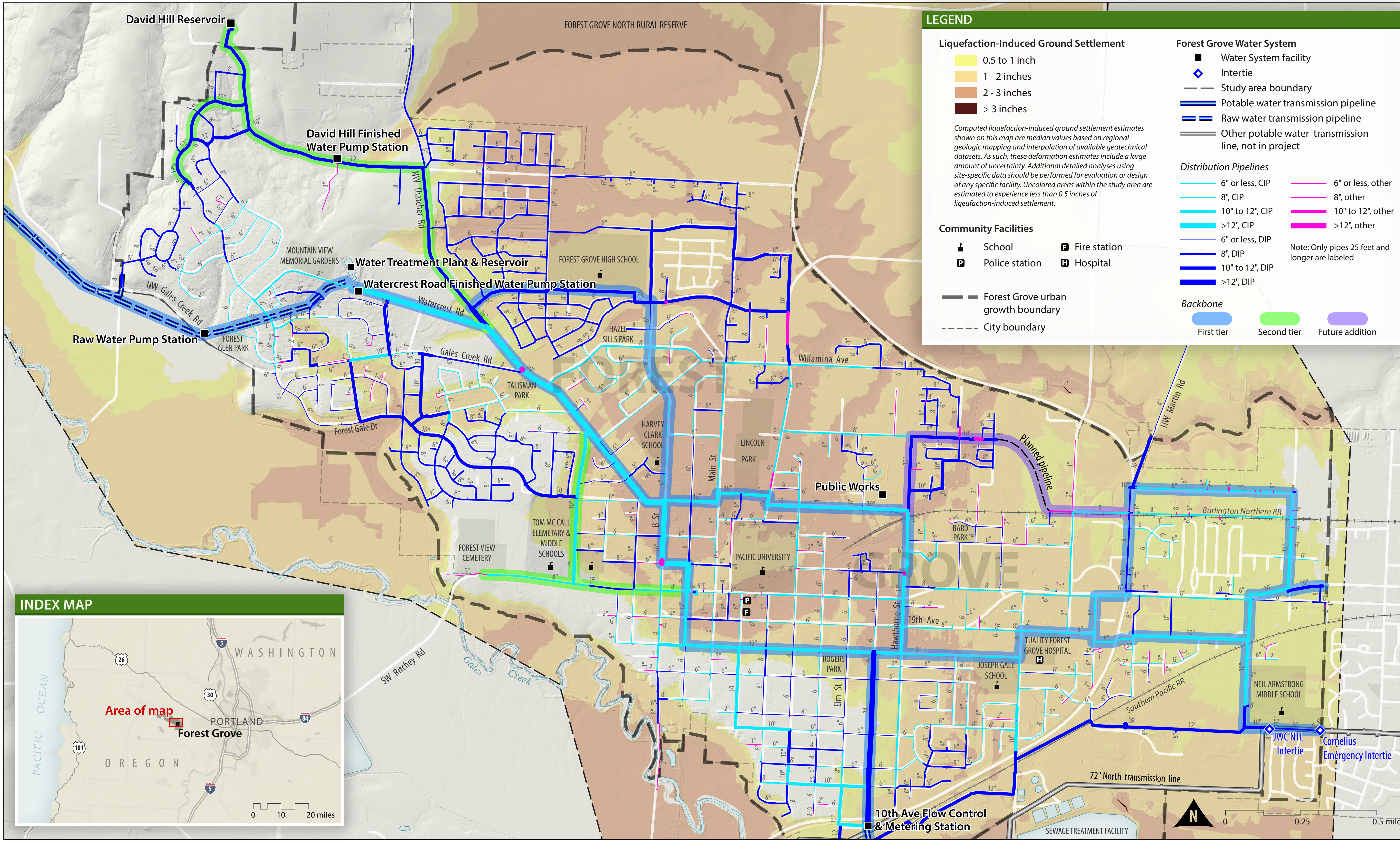
InfraTerra

Ground Settlement for Mw 9.0 CSZ Earthquake
Water Transmission and Distribution System

CITY OF FOREST GROVE WATER SYSTEM SEISMIC RESILIENCY PLAN

Plate 13

OCT 2018



Map projection: NAD 1983 HARN State Plane Oregon North

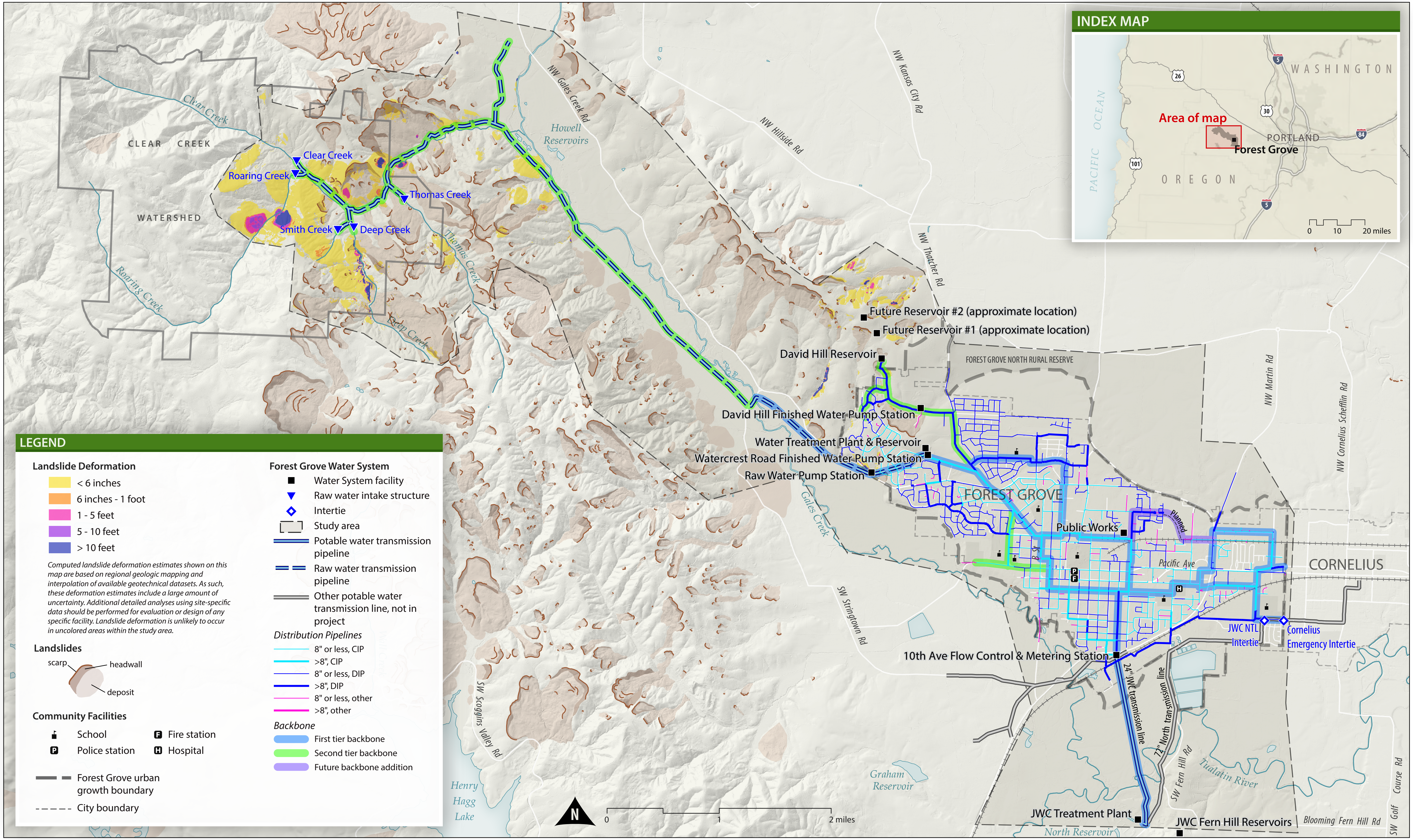
InfraTerra

Ground Settlement for Mw 9.0 CSZ Earthquake
Water Distribution System

CITY OF FOREST GROVE WATER SYSTEM SEISMIC RESILIENCY PLAN

Plate 14

OCT 2018



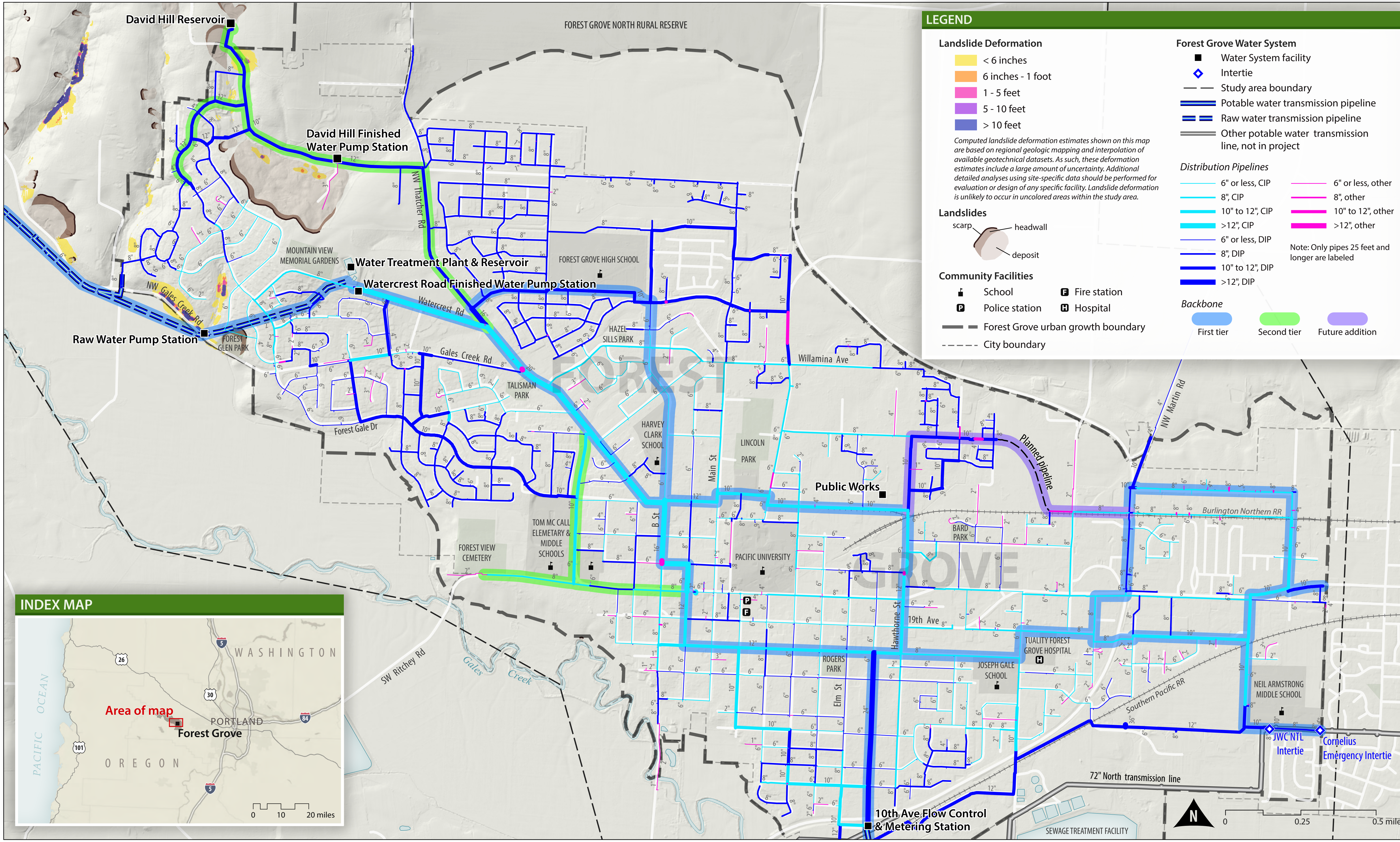
Map projection: NAD 1983 HARN State Plane Oregon North

Landslide Deformation for Mw 9.0 CSZ Earthquake
Water Transmission and Distribution System

CITY OF FOREST GROVE WATER SYSTEM SEISMIC RESILIENCY PLAN

Plate 15

OCT 2018



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InfraTerra

Landslide Deformation for Mw 9.0 CSZ Earthquake
Water Distribution System

CITY OF FOREST GROVE WATER SYSTEM SEISMIC RESILIENCY PLAN

Plate 16

OCT 2018

Appendix A

Fire Following Earthquake

memo SPA Risk

May 2022

Re: Fire Following Earthquake, City of Forest Grove

Table of Contents

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Purpose and organization of this memo

This memo provides estimates of the potential losses to the City of Forest Grove (City) due to fire following earthquake, performed for InfraTerra as part of the City of Forest Grove Water System Seismic Resiliency Plan (Water System SRP) Project. The specific scope of work for this work was stated in the proposal to the City, and consisted of:

> *Task 4*
>
> *"We will meet with the fire department representative to develop an understanding of firefighting resources and capabilities. We will use simplified calculations to estimate post-earthquake fire water demands that can be used for fire department planning. Deliverables Minutes of meeting with the fire department to document firefighting needs including preliminary recommendations for firewater supply following interruption resulting from a major earthquake as discussed during the workshop. Recommended seismic improvement projects (to be included in the draft and final report)*
>
> *Task 6*
>
> *Fire-Flow Meeting will be held with the City and the City's fire department to discuss firefighting resources and information from the fire department that would help us estimate post-earthquake fire water flow requirements*

The organization of this report consists of the following sections: (1) an examination of the City and its exposure to fires following a large earthquake, (2) the specific seismic events considered in this analysis, and (3) the methods employed and results. References, Tables, Figures and Appendices complete this memo.

Forest Grove description, exposure, fire protection and fire history

The City is located in central Washington County and is bordered by Cornelius on the east. It is 25 miles west of Portland, 6 miles west of Hillsboro, 7 miles south of US Highway 26, 30 miles north of McMinnville and 55 miles east of the Oregon coast. The City was incorporated 1872 and is 5.4 sq. miles in area with a population of 23,555 (2017 census) and population growth of 14.1% since 2010. The city is surrounded by rolling hills and evergreen forests with a mild climate (January: Minimum: 32.4 F Max: 51.8 F, July: Minimum: 51.8 F Max: 82.2 F, annual precipitation 44.58 inches). The City has 8,374 housing units and a median single-family home price (2017) of $350,000. Business sectors include high tech-circuit boards, food and beverage processing, wood products, education, healthcare/eldercare and metalworking. There are 22 churches and four elementary, one middle and one high school in the School District (which covers Forest Grove, Cornelius, Gales Creek, Dilley) with a total student enrollment of 6,022. The City is also the home of Pacific University which has a total enrollment of 3,909 students[1].

The City is comprised of 7,862 building of all types (Bauer, Burns and Madin 2018), see Figure 1, totaling 18.8 million sq. ft. in building plan area. Figure 2 shows an aerial view of the city, in which it can be seen that the downtown has a concentration of larger buildings (including Pacific University), Figure 3 and Figure 4, as well as there being several industrial areas (on 23rd Ave to the NE of downtown, and on 19th Ave south of the University, Figure 5 and Figure 6). Another

[1] Paraphrased from https://www.forestgrove-or.gov/community/page/glance.

notable large structure is the high school (226,000 sq. ft. in plan area, Figure 7). Forest Grove Fire & Rescue (FGFR) to date has surveyed about 41% of the City's building inventory, employing an Occupancy Vulnerability Assessment Profile (OVAP) scoring methodology (Forest Grove Fire & Rescue 2016) which categorizes fire risk as Low, Moderate, Significant and Maximum. Of the buildings surveyed, no buildings are in the Maximum category and 28 in the Significant category, shown in Figure 8 and summarized in Table 1. Of these exposures, FGFR has identified 194 target hazards, and completed pre-plans for more than 90% of them (Forest Grove Fire & Rescue 2016).

The Forest Grove Fire and Rescue 2016 Community Risk Analysis and Standards of Cover states, "Forest Grove Fire & Rescue serves a population of approximately 25,000, with just over 22,000 people residing within the boundaries of the City of Forest Grove, with the remainder living in the rural areas that surround the city". The document further states, "The fire department provides fire suppression, rescue, first response emergency medical services, operations level hazardous materials response, fire prevention, and life-safety services from two fire stations, staffed with a combination of career and volunteer responders" (Forest Grove Fire & Rescue 2016).

"Forest Grove Fire & Rescue is staffed with a minimum of four firefighters working a 24-hour shift. Four firefighters are enough to staff one engine company. Our volunteer intern program will occasionally allow us to split our personnel to staff two apparatus daily. Forest Grove Fire & Rescue depends on automatic aid agreements with surrounding departments to assemble an effective response force for all fires and major events. The department does not have on-duty Battalion Chiefs. On-scene supervision is provided by the Fire Chief, two Division Chiefs, and two volunteer Battalion Chiefs on a rotating schedule. The department maintains a force of volunteers who work as suppression firefighters, chaplains and support volunteers. All support volunteers are trained as Community Emergency Response Team (CERT) members. The department responds to approximately 35 structure fires annually. This number has been stable for the last several years." (Forest Grove Fire & Rescue 2016).

FGFR has two fire stations: Station 4 in downtown, and Station 7 in Gales Creek, shown in Figure 9, and Figure 10. The Gales Creek Station 7 is somewhat removed from the City center. The apparatus inventory is summarized in Table 2 for Station 4 and Table 3 for Station 7. The total pumping capacity of all apparatus in Station 4 is 9,623 gpm and 1,323 gpm for apparatus in Station 7; however, it should be noted that the Station 4 total includes 2,000 gpm for WT4 and WT7, which might be used for water shuttling rather than on-scene firefighting in an earthquake.

Figure 11 shows fire stations surrounding the City, such as in Cornelius. These are municipal and/or rural fire district stations, which presumably would be fully committed in the event of an earthquake affecting the City. Cornelius and several other communities have entered into a Cooperative Agreement (Emergency Services Consulting International 2015), but mutual aid for the City from these sources in the event of a large earthquake is probably not likely. No information could be found on Oregon Department of Forestry or federal fire stations, although presumably some exist and would come to the aid of the City and other cities affected by an earthquake. Also, while no specific information is available, it is understood there are substantial private sector wildland firefighting resources in Oregon (contracted annually for wildland firefighting), and these would also presumably come to the aid of the City and other cities affected by an earthquake. In summary, the Gales Creek station resources would probably remain in that vicinity, and the City would have to rely on the resources of Station 4 and perhaps some state and federal wildland and private sector resources which can't be quantified at present. Nevertheless, to have about 10,000 gpm pumping capacity for a community the size of the City is impressive. However, as (Forest Grove Fire & Rescue 2016) concludes:

- "Forest Grove Fire and Rescue is dependent on the surrounding communities to assemble the concentration of an Effective Response Force for most fire suppression and critical EMS events.
- "The current distribution of a single station located in the downtown core has led to significantly extended response times to the Forest Gale Heights area and the northern fire response zones where most future residential development is expected."

Lastly, in a meeting with City officials on 7 December 2017, Dave Nemeyer provided the following information (see Attachment A):

- New construction is not required to be sprinkled
- Fire reporting is via Washington County Consolidated Communications Agency dispatch center.
- Buildings in the Central Business District (CBD) are sprinkled by and large, including older URMs
- The City has a reticulated gas system
- Henningsen's and Cold Foods have anhydrous ammonia stored onsite
- There is a facility that will generate hydrogen peroxide when construction is completed
- Waste Management has an LNG tank, near the school district offices

The fire history of the City is recounted in (Forest Grove Fire & Rescue 2016) and will not be detailed here, except for several noteworthy events:

- "1919: Two city blocks, and sixteen separate buildings, were destroyed by fire. Included in this downtown conflagration were the United Church of Christ and the City Library. (see Attachment B).
- "1933: A fast moving fire develops in a Coast Range Mountains logging operation west of the city, eventually spreading to over 311,000 acres. This fire became known as "The Tillamook Burn". Every six years, until the final fire in 1951, devastating fire would burn in the mountains west of Forest Grove. These Tillamook Burn Fires would destroy nearly 713,700 acres of prime timber land and leave a devastated landscape between Forest Grove and the Oregon Coast.
- 1970: Recently purchased by Pacific University, the former Lincoln Junior High School burns. This begins a dangerous decade of fires on campus. Herrick Hall was destroyed by fire in 1973, and Marsh Hall was gutted by flames in 1975."

From the perspective of fire protection, a number of buildings in the older downtown area are unreinforced masonry (URM) dating from the late 19th or early 20th century, not unlike the buildings that burned in 1919. However, by and large, these buildings may now be sprinklered. Effectiveness of these sprinklers requires adequate water pressure, which may not be available due to main breaks and leaks in a large earthquake.

While Pacific University experienced a number of fires in the 1970s, no major fires appear to have occurred since then. This implies that the fire resistiveness of this concentration of exposures may now be more like other modern construction.

Regarding wildland fires, with the exception of the exceptional Tillamook Burn series (the first of which started in Gales Creek Canyon), a review of historical wildland fire data shows the City area to be virtually an "island" surrounded at some distance by wildland fires, as shown in Figure 12. This may be due in part to the fact that the City is largely directly surrounded by cultivated land, with wildland at some distance. On the other hand, there are a substantial number of trees within the city limits. In summary, based on a limited review, given a large earthquake resulting in wildland fires, the spread to buildings within the limits of the City is difficult to assess.

Seismic hazard and risk

Two scenario events are considered in this analysis: (1) an M_w 6.8 Gales Creek earthquake, and (2) an M_w 9 (M9) Cascadia Subduction Zone (CSZ) earthquake. These are discussed in the Water System SRP report.

It is relevant to consider non-fire damage due to the latter event, as this will impact FGFR resources. Estimates of damage due to the M9 CSZ earthquake are shown in Table 4 as extracted from (Bauer, Burns and Madin 2018) for selected Neighborhood Unit IDs (NUIDs) as shown in Figure 13, for wet and dry conditions. While several of the NUIDs extend beyond the City limits, these are largely rural areas, and the City comprises about 81% of the total building count in the NUIDs. Prorating by this percentage, it can be seen that the City is likely to sustain 240 buildings in the complete damage state under dry conditions, and as many as 900 buildings in the complete damage state under wet conditions, resulting in a significant search and rescue burden on FGFR. Nevertheless, in the analysis of fire following earthquake demands, we assume all FGFR resources are initially committed to firefighting.

Methods and Results

Methods used for estimating fire ignitions and water demands are summarized in this section. For full details, see (Scawthorn 2018; TCLEE 2005). In summary, the steps in the process of fire following earthquake are:

- *Occurrence of the earthquake*—causing damage to buildings and contents, even if the damage is as simple as objects (such as candles or lamps) falling over.
- *Ignition*—whether a structure has been damaged or not, ignitions can occur due to earthquakes. The sources of ignitions are numerous, ranging from overturned heat sources, to abraded and shorted electrical wiring, to spilled chemicals having exothermic reactions, to friction from objects rubbing together.
- *Discovery*—at some point, the fire resulting from the ignition will be discovered, if it has not self-extinguished (this aspect is discussed further, below). In the confusion following an earthquake, the discovery may take longer than it might otherwise.
- *Report*—if it is not possible for people discovering the fire to immediately extinguish it, fire department response will be required. For the fire department to respond, a report has to be made to the fire department. Communications system malfunction and congestion may delay many reports.

- *Response*—the fire department then has to respond, but may be delayed by responding to non-fire emergencies (for example, building collapse) and by transportation disruptions.
- *Suppression*—the fire department then has to suppress the fire. If the fire department is successful, they move on to the next incident. If the fire department is not successful, they continue to attempt to control the fire, but it can spread, and become a conflagration. Success or failure hinges on numerous factors including the functionality of the water supply system, building construction and density, and weather conditions including wind and humidity. If they are unable to contain the fire, the process ends when the fuel is exhausted or when the fire reaches a firebreak.

Ignitions were modeling using the relations employed in HAZUS (SPA Risk 2009):

$$\text{(ignitions/million sq. ft. of building floor area)} = -0.029444\,PGA + 0.581895\,PGA^2$$

which resulted in an estimate of 3 fires on average for the City for the Gales Creek earthquake, and 1 fire on average for the M9 CSZ earthquake. The cause of these ignitions will likely be similar to causes following the 1994 Northridge, California, earthquake, which is the best U.S. dataset for fire following a recent earthquake. About half of all ignitions would be electrical, a quarter gas related, and the remainder due to a variety of causes, including chemical reactions. Also, on the basis of the Northridge experience, nearly half of all ignitions would typically occur in single-family residential dwellings, with another 26 percent in multi-family residential occupancies—that is, about 70 percent of all ignitions would occur in residential occupancies. Ignitions in educational facilities would be a small percentage of the total (3 percent in Northridge), and most of these would be due to exothermic reactions of spilled chemicals in chemistry laboratories.

Fires are typically reported via Washington County Consolidated Communications Agency (WCCCA) dispatch center. However, in the event of an earthquake, reporting of these ignitions to FGFR is unlikely due to overload of the telephone system and dispatchers at WCCCA. Rather, FGFR will probably learn of the fires by their own observations, citizen reports to Stations 4 and 7, and/or the engine companies during their post-earthquake survey. Delay in response is thus likely. We estimate this delay will result in three incidents, each with about 4,000 sq. ft. of building floor area being totally involved upon first arrival of emergency services for the Gales Creek earthquake, and one incident with about 4,000 sq. ft. for the M9 CSZ earthquake. Under these circumstances, FGFR tactics will be defensive, serving only to protect surrounding exposures. These tactics will require at a minimum one to two engines (or the aerial, which also has equivalent pumping capacity) at each incident, meaning a total water demand of about 6,000 gpm for the Gales Creek earthquake, and about 2,000 gpm for the CSZ earthquake. If water hydrants are dry, the two water tenders may be able to provide sufficient supply for the CSZ earthquake but are unlikely to provide sufficient supply for the Gales Creek earthquake. Known alternative sources of water supply in City are shown in Figure 14 with 2000 ft. buffers (the probable maximum relay distance for FGFR), from which it can be seen that perhaps half of the City might be supplied with alternative water supplies (assuming relay capacity which, in some cases, are the same fire engines required at the fireground).

In summary, it is likely that FGFR will be able to contain the fires resulting from the M9 CSZ earthquake. The Gales Creek earthquake is likely to result in one or two fires growing to large proportions, due as much to the limited resources of FGFR as to the damage and limitations of the water supply. The fires that grow to large proportions may each result in a loss of a city block, or several city blocks under adverse meteorological conditions. At this stage, fire defense would only be feasible at a fire break, such as a large street, and the fires would more than likely cease extension when they encounter an adequately large fire break (i.e., they exhaust available fuel).

Due to the proximity of the Gales Creek fault, ground shaking (and therefore impact) to the water system is greater than that of the CSZ earthquake but has a much lower frequency of occurrence. However, due to the regional nature of the CSZ earthquake, limited resources from other municipalities may be available. In a Gales Creek earthquake, it is possible that resources form other municipalities may be available to FGFR. For planning purposes, water demands are estimated to be about 6,000 gpm for the Gales Creek earthquake, and about 2,000 gpm for the CSZ earthquake.

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Tables

Table 1 Forest Grove fire hazard statistics
Source: (Forest Grove Fire & Rescue 2016)

Hazard Statistics

Risk Level	OVAP Score	# of Occupancies	%
Maximum	60 +	0	0.00%
Significant	40 - 59	28	8.72%
Moderate	15 - 39	278	86.60%
Low	0 - 14	15	4.67%
Average Score	30.90	-	-
	# of complete OVAP scores	321 (41%)	
	# of incomplete OVAP scores	460 (59%)	

Table 2 Forest Grove Station 4 Apparatus Inventory
Source: (Forest Grove Fire & Rescue 2016)

Forest Grove Station 4 Apparatus Inventory							
Apparatus Designation	Type	Year	Make/Model	Condition	Seating Capacity	Pump Capacity	Tank Capacity
E421	Engine (Type 1)	2008	Spartan/BME	Excellent	5	1,500 GPM	750 Gal
E422	Engine (Type 1)	2008	Spartan/BME	Excellent	5	1,500 GPM	750 Gal
E423	Engine (Type 1) (reserve)	2001	HME/Central States	Good	6	1,500 GPM	1,000 Gal
T4	Aerial	2001	HME/Central States	Good	6	2,000 GPM	300 Gal
WT4	Tender	2015	Spartan	Excellent	2	1,000 GPM	3,000 Gal
WT7	Tender	1991	Int./Western States	Good	2	1,000 GPM	3,000 Gal
MED4	Medic	2004	Int./Horton	Good	3	N/A	N/A
HB4	Brush (Type 3)	2015	HME	Excellent	4	1000 GPM	500 Gal
BR418	Brush (Type 6)	2011	Dodge/Local	Excellent	4	123 GPM	400 Gal
TR4	Tech. Rescue	2010	Millennium Trailer	Excellent	N/A	N/A	N/A
EOC4	Command EOC	2010	Trailer	Excellent	N/A	N/A	N/A
B4	Rescue Boat	2008	Boat	Very Good	4	N/A	N/A

Table 3 Forest Grove Station 7 Apparatus Inventory
Source: (Forest Grove Fire & Rescue 2016)

Forest Grove Station 7 Apparatus Inventory							
Apparatus Designation	**Type**	**Year**	**Make/Model**	**Condition**	**Seating Capacity**	**Pump Capacity**	**Tank Capacity**
E427	Engine (Type I)	2005	HME/BME	Good	4	1,200 GPM	875 Gal
BR417	Brush (Type VI)	2011	Dodge	Excellent	4	123 GPM	400 Gal

Table 4 Damage estimates for selected Neighborhood Unit IDs for CSZ M9 event
Source: (Bauer, Burns and Madin 2018)

DRY						Casualty Day					Casualty Night					Buildings in Damage State				
NUID	BldgLoss	Bldg Loss Ratio	Content Loss	Debris (MM tons)	Displaced Pop	Total	Level 1	2	3	4	Total	Level 1	2	3	4	None	Slight	Mod	Extens	Complete
853	44,174,960	0.16	18,785,999	29,112	251	64.8	46.0	13.0	2.0	3.8	24.5	19.3	4.4	0.3	0.5	438	218	115	94	83
860	63,710,304	0.16	27,798,813	37,875	23	39.1	27.9	7.9	1.1	2.2	6.8	5.4	1.1	0.1	0.2	655	380	209	72	40
861	33,997,644	0.15	12,362,036	18,011	44	37.8	27.7	7.2	1.0	1.9	6.5	5.2	1.0	0.1	0.2	317	179	96	31	18
862	16,526,085	0.11	6,509,858	4,865	16	11.0	7.8	2.2	0.4	0.7	5.3	4.0	0.9	0.1	0.3	193	106	54	12	4
863	33,425,368	0.15	15,664,171	19,583	85	25.7	20.0	4.6	0.4	0.7	12.9	10.6	2.0	0.1	0.2	82	88	153	113	31
864	42,820,368	0.10	21,962,874	20,050	5	27.8	21.8	4.8	0.4	0.8	3.4	2.8	0.5	0.0	0.1	498	260	103	27	12
865	17,326,432	0.08	4,854,003	6,889	43	8.8	6.4	1.7	0.2	0.5	6.4	4.9	1.1	0.1	0.2	175	97	52	16	7
866	31,638,798	0.11	10,126,246	17,645	26	91.2	63.1	18.8	3.1	6.2	5.6	4.6	0.8	0.1	0.1	624	301	141	58	14
867	20,346,348	0.11	6,845,731	10,257	23	22.7	16.4	4.5	0.6	1.2	4.7	3.7	0.7	0.1	0.2	393	222	111	30	12
868	23,000,552	0.10	8,842,085	11,125	3	63.4	43.4	13.4	2.2	4.4	1.6	1.3	0.2	0.0	0.1	437	212	68	10	4
869	48,907,948	0.08	19,555,780	24,410	24	7.6	5.7	1.4	0.2	0.4	3.8	3.2	0.5	0.0	0.1	1,044	551	279	117	97
	$ 375,874,807		**$ 153,307,596**	**199,822**	**542**	**399.8**	**286.1**	**79.3**	**11.6**	**22.8**	**81.4**	**64.9**	**13.3**	**1.1**	**2.0**	**4,856**	**2,614**	**1,381**	**580**	**322**
WET						**Casualty Day**					**Casualty Night**									
NUID	BldgLoss	Bldg_LR	ContentLoss	Debris (MM tons)	Displaced Pop	Total	Level 1	2	3	4	Total	Level 1	2	3	4	None	Slight	Mod	Extens	Complete
853	65,110,800.00	0.23	27,935,891	37,440	503	94.8	66.5	19.6	2.9	5.8	43.9	34.0	8.4	0.6	0.9	398	197	104	86	163
860	96,112,792.00	0.24	40,151,001	47,362	276	55.1	39.2	11.3	1.6	3.0	27.0	20.7	5.2	0.4	0.7	597	345	190	66	158
861	50,693,668.00	0.23	18,969,321	23,484	203	62.1	44.1	12.6	1.8	3.5	18.4	14.2	3.5	0.3	0.5	289	163	87	28	74
862	28,411,918.00	0.19	11,344,965	7,801	140	19.1	13.6	3.9	0.6	1.1	16.0	12.0	3.1	0.3	0.6	177	97	49	11	35
863	49,629,928.00	0.23	25,120,584	26,228	208	44.2	32.8	8.6	1.0	1.8	23.4	18.4	4.1	0.3	0.5	74	80	140	104	69
864	77,949,032.00	0.18	37,101,543	32,434	249	83.1	58.5	17.2	2.5	4.9	25.2	18.6	5.0	0.5	1.0	454	236	93	25	92
865	34,964,464.00	0.16	9,895,081	11,146	233	22.3	15.7	4.6	0.7	1.3	23.4	17.1	4.7	0.6	1.1	158	89	48	15	37
866	53,819,580.00	0.19	17,348,285	26,174	280	128.2	87.7	27.2	4.5	8.9	25.1	19.5	4.8	0.3	0.6	571	274	129	53	111
867	35,080,200.00	0.18	11,248,264	14,607	234	33.7	24.3	6.8	0.9	1.7	20.5	15.8	3.9	0.3	0.5	360	202	101	27	78
868	44,857,964.00	0.20	16,265,161	18,565	149	77.8	53.3	16.6	2.7	5.3	12.6	9.7	2.4	0.2	0.3	393	191	62	10	75
869	87,470,424.00	0.14	33,720,292	37,755	205	17.2	12.7	3.4	0.4	0.7	17.7	13.8	3.3	0.2	0.4	980	509	255	107	237
	$ 624,100,770		**$ 249,100,388**	**282,996**	**2,680**	**637.6**	**448.3**	**131.9**	**19.5**	**38.0**	**253.3**	**####**	**48.4**	**4.0**	**7.1**	**4,451**	**2,383**	**1,258**	**532**	**1,129**

Figures

Figure 1 Forest Grove building footprints, with downtown detail
Data source: (Bauer, Burns and Madin 2018)

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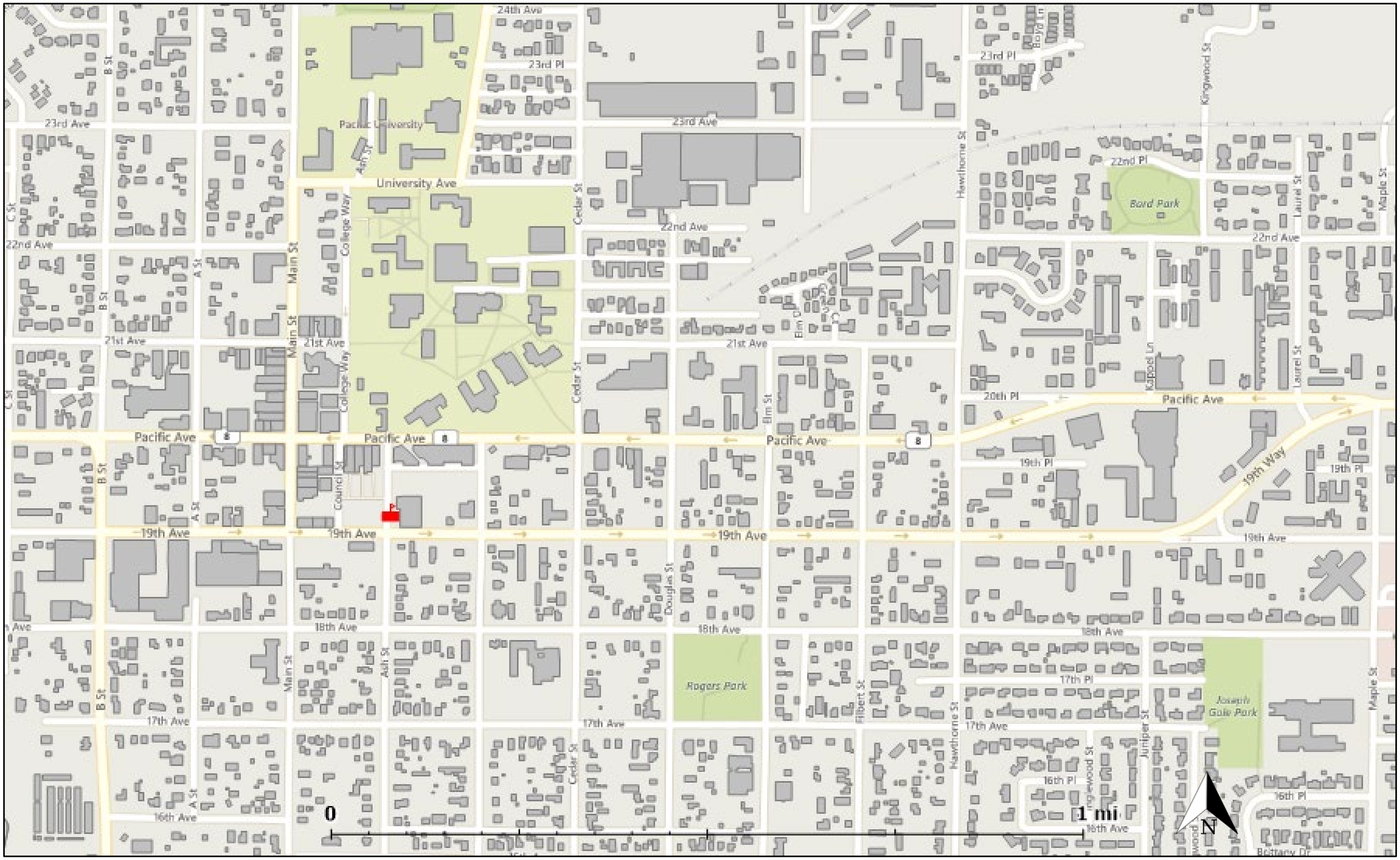

Figure 2 Forest Grove building footprints, with downtown detail
Data source: (Bauer, Burns and Madin 2018)

Figure 3 Aerial view Forest Grove and Cornelius
Source: Google Earth

Figure 4 Aerial view of Forest Grove downtown
Source: Google Earth

Figure 5 Downtown oblique view looking NW, showing predominantly one story buildings, with a few two and three story older brick masonry buildings
Source: Google Earth

Figure 6 Central Pacific University campus, showing some four story buildings
Source: Google Earth

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Figure 7 23rd Ave Industrial complex
Source: Google Earth

Figure 8 19th Ave Industrial complex
Source: Google Earth

Figure 9 Forest Grove High School
Source: Google Earth

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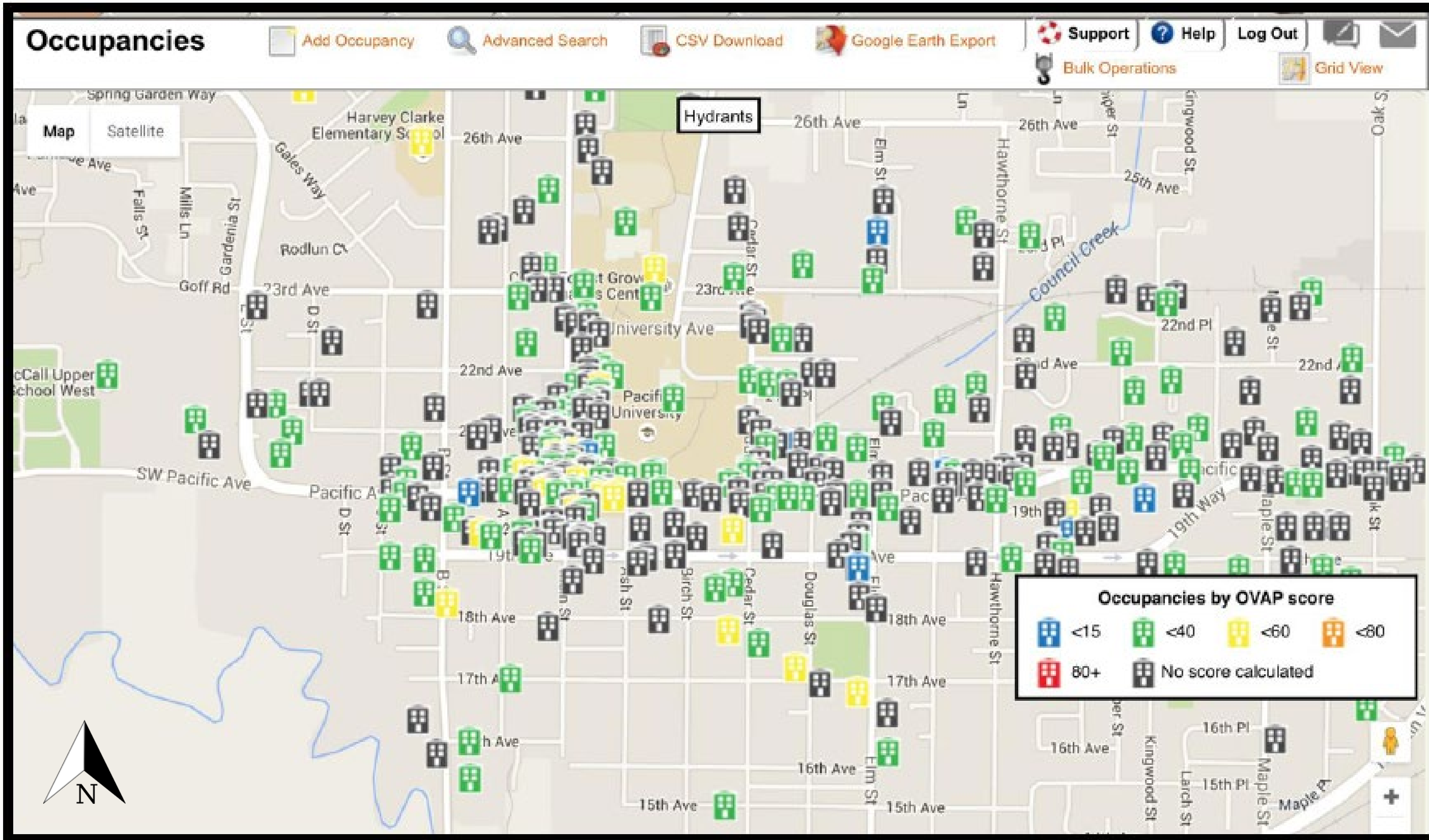

Figure 10 Forest Grove OVAP scores
Source: (Forest Grove Fire & Rescue 2016)

Forest Grove Fire Station 4

1919 Main Street

Forest Grove

Built in 1995, this station serves as Forest Grove's main fire station and includes their administrative offices. The facility consists of five apparatus bays of a drive-through configuration, housing three engines, two water tenders, one ladder truck, one medic unit, two brush vehicles, technical rescue trailer, EOC trailer, boat and 2 staff vehicles.

Station 4 includes the fire department's administrative offices, consisting of six individual offices and one shared office with four work areas. The facility is modern, well designed, and will serve the fire department adequately for the foreseeable future.

Structure	
Construction type	Wood frame and masonry
Date Built	1995
Seismic protection/energy audits	Completed in 2011
Auxiliary power	Automatic start generator is in place
Special considerations (American with Disabilities Act of 1990 (ADA), mixed gender appropriate, storage, etc.)	Station is ADA compliant, storage is reaching capacity
Square Footage	18,000
Training/meetings	A large training room is present as well as a conference room and Emergency Operations Center
Sprinkler system	Building is fully protected by a fire sprinkler system
Smoke detection	Building is fully protected by a smoke detection system
Security	Electronic key pad

Figure 11 FGFR Station 4
Source: (Forest Grove Fire & Rescue 2016)

FOREST GROVE FIRE STATION 7

GALES CREEK SUBSTATION

The Gales Creek Station is a six-bay sub-station, housing one engine and one brush truck. The facility is configured for volunteer use only and does not include residential quarters. However, a small kitchen is present along with a bed in an office area in the front of the station.

Construction type	Steel clad, steel frame
Date Built	1982
Seismic protection/energy audits	None other than when originally designed
Auxiliary power	Automatic start generator is in place
Square Footage	1,800
Sprinkler system	Station is not protected by a fire sprinkler system; residential house is protected by sprinkler system
Smoke detection	Smoke and heat detection system is in place and monitored off-site
Security	Electronic key pad, monitored alarm, video surveillance.

Figure 12 FGFR Station 7
Source: (Forest Grove Fire & Rescue 2016)

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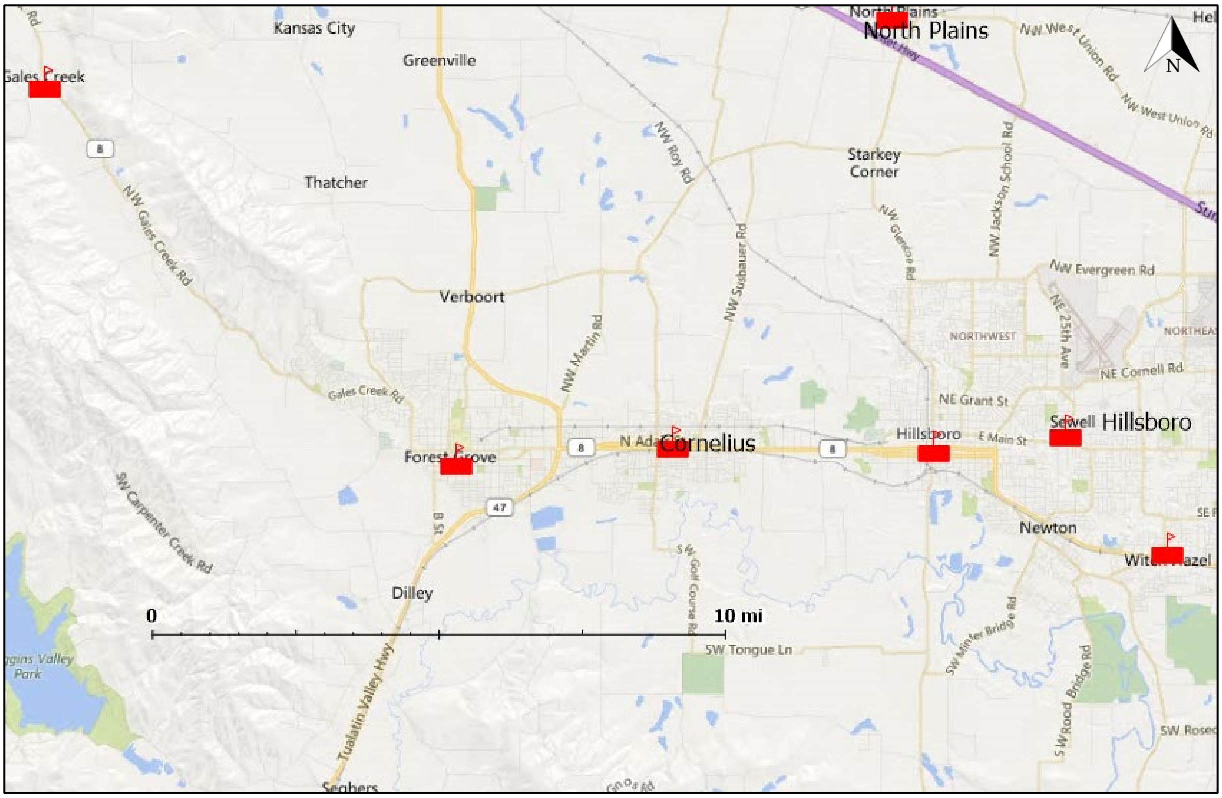


Figure 13 Fire stations in and around Forest Grove
Source: (SPA Risk)

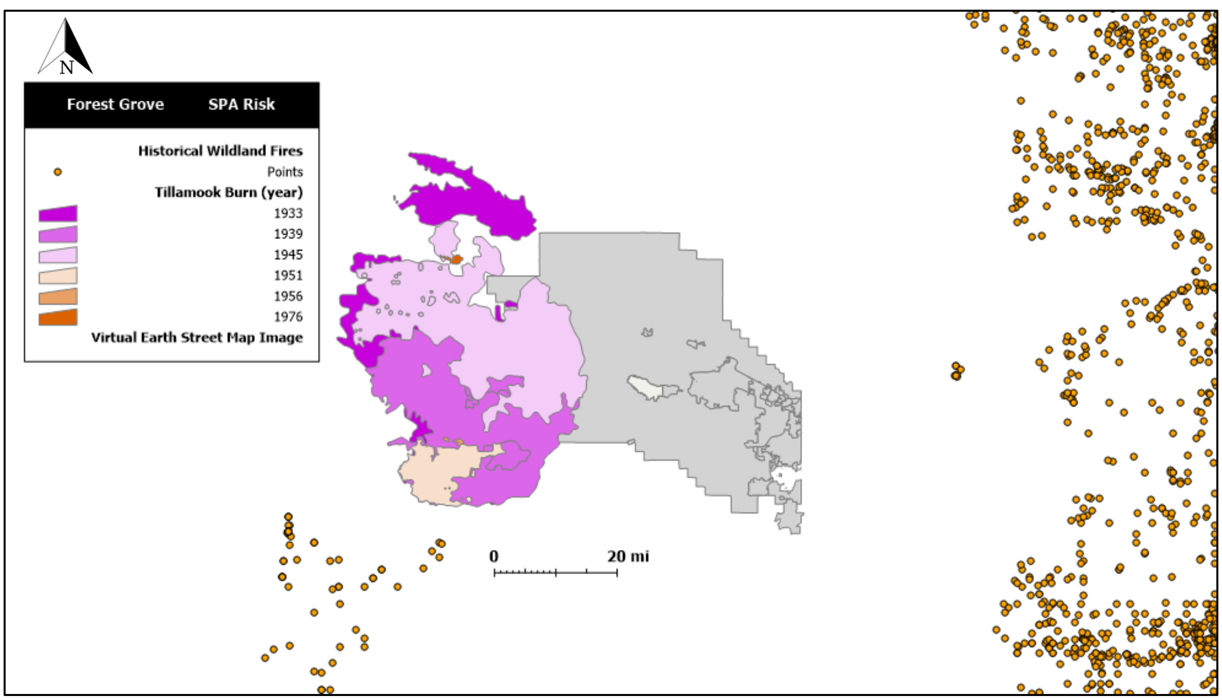


Figure 14 Washington County and municipalities, wildland fires (1900-2004) shown as point sources and Tillamook Burn perimeter(s)
Source: (SPA Risk)

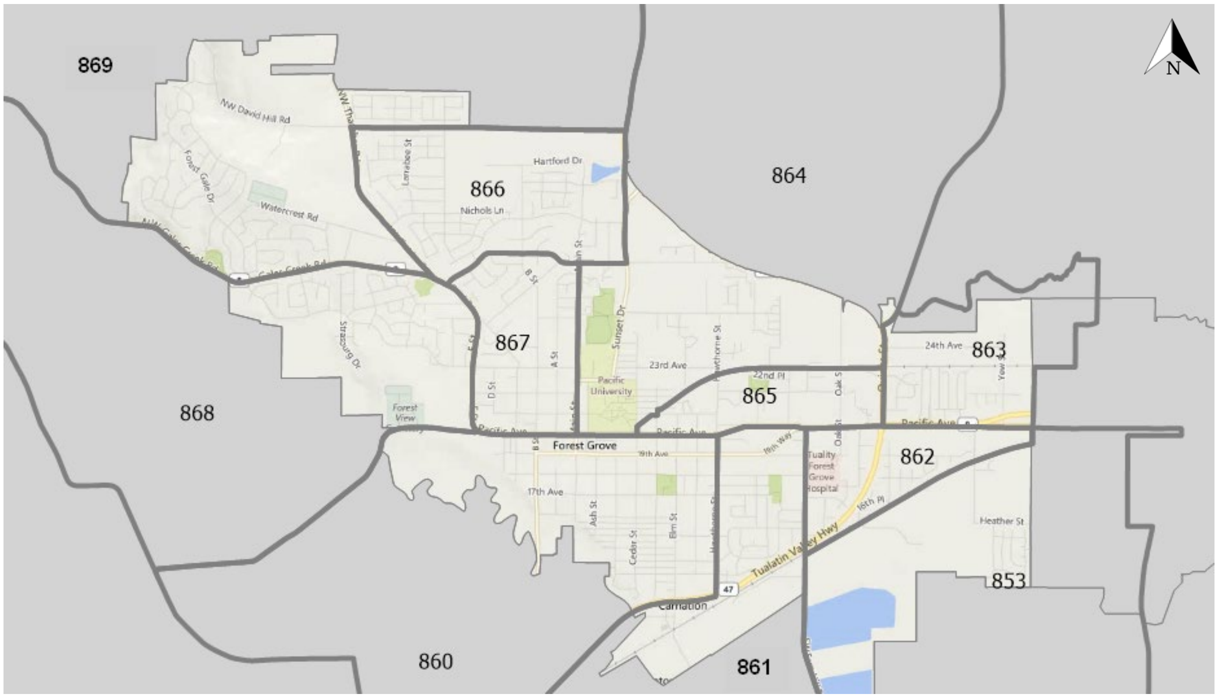


Figure 15 Neighborhood Unit IDs
Source: (Bauer, Burns and Madin 2018)

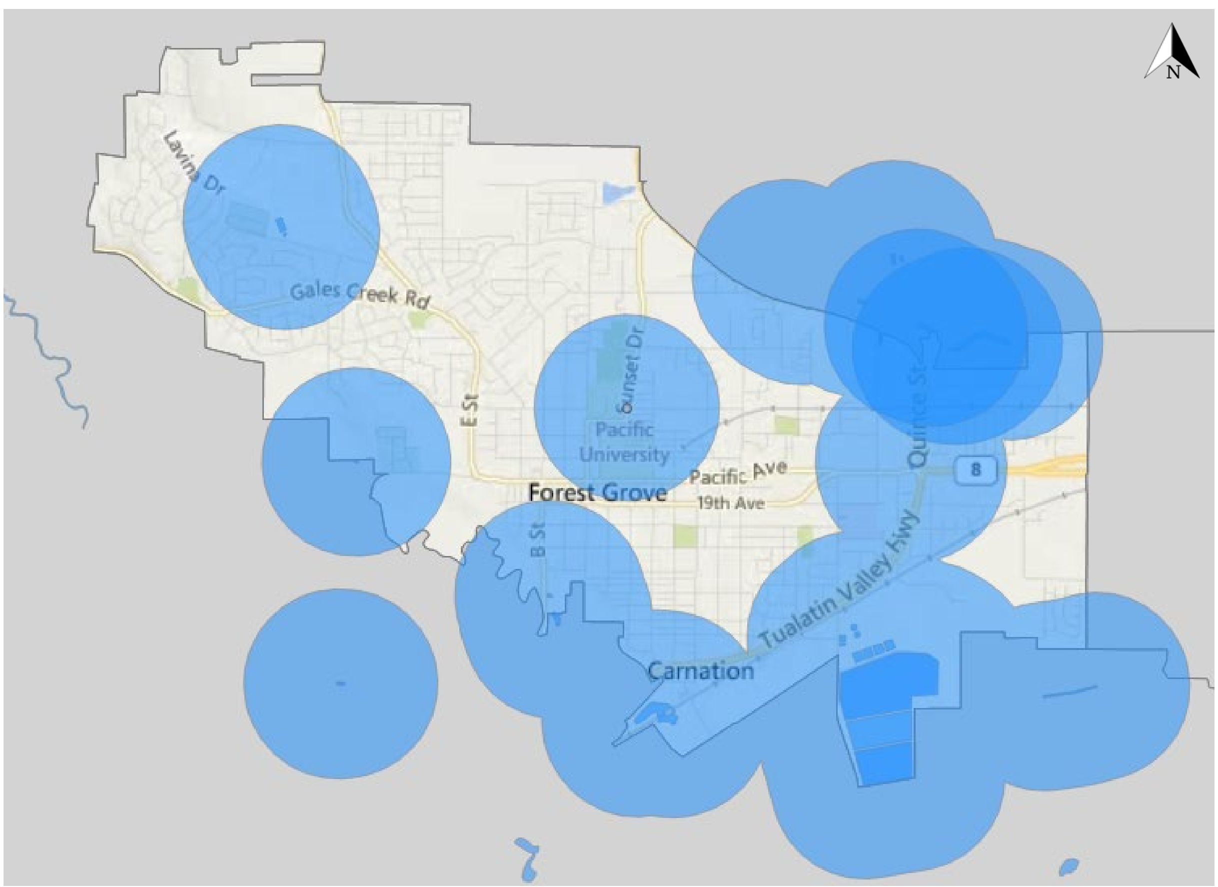


Figure 16 Alternative water supply sources with 2000 ft. buffer
Source: (SPA Risk)

Attachment A: Record of Meeting, 7 December 2017

Record of Meeting SPA Risk

Date of Meeting	7 December 2017
Location	Forest Grove Engg Office
Client	Forest Grove WD
Purpose	Review geotech, det fire following earthquake needs, id backbone
Attendees	Forest Grove: • Rob Foster – Public Works Director • Rich Blackmun - Engineering • Derek Robbins - Engineering • Rick Vanderkin – Public Works Division • Brian Dixon - Water Treatment Plant • Dave Nemeyer - Fire Department Infraterra: Ahmed Nisar, Mike Greenfield (indep. Consultant) SPA: Charles Scawthorn

Actions resulting:

1. David Nemeyer to furnish CRS matls as defined below.

Record:

The meeting covered three topics:

1. Geohazards – Ahmed and Mike covered the geo hazards mapping to date. Maps were shown and discussed.
2. Fire following earthquake: Charles Scawthorn discussed with David Nemeyer the City's needs and capacities. Discussion in summary:
   - New construction is not required to be sprinkled
   - Fire reporting is via Washing County Consolidated Communications (WCCCA) dispatch center.
   - Bldgs. in CBD are sprinkled by and large, including older URMs
   - FG has a reticulated gas system
   - Henningsens and Cold Foods have anhydrous ammonia stored onsite
   - There is a facility that will generate hydrogen peroxide when construction is completed
   - Waste Mgmt has an LNG tank, near the school district

- Engines carry 1000' 4" hose, 900' 2.5" hose
- 5 water tenders 3000 gallons
- FGF&R apparatus:
    - 3 type 1 engines
    - 1 T 3
    - 1 T 6 (pickup)
    - 1 ladder truck (quint)
- Fires stations:
    - The City has one station (nearby, looked modern RM construction, raised seam roof
    - Gales Creek has a station (seen, light metal)
    - Gaston – older wood frame
    - Cornelius ?
- Water supply: Tualatin Valley Irrig District has a 54" diam CCP running through town, otherwise no ponds or alternative supplies

3. Materials requested which Nemeyer is to furnish are:
    a. Annual Report or summary of FGF&R staffing, apparatus and equipment, ISO rating, area protected
    b. Summary of special concerns
    c. Summary of Alternative water supply planning, sources
    d. Summary of critical water needs as identified – for example, how many hospital beds, dialysis and other needs are in FGF&R response area
    e. Pdf of Comprehensive Plan map

Attachment B: 1919 Forest Grove fire

Reproduction of "Holocaust of flame sears Forest Grove", by Ken and Kris Bilderback, Wednesday, April 09, 2014

https://pamplinmedia.com/fgnt/36-news/216502-75308-holocaust-of-flame-sears-forest-grove

July 20, 1919, was a Sunday, and had the flames started that morning, they might have been spotted and stopped quickly. Unfortunately, the fire started about noon, "an hour when the streets of the city were more nearly deserted than at any other time," lamented the Washington County News-Times in its July 24 edition.

Most churchgoers were home by then, and the Congregational Church's heavy hand in the governing of early Forest Grove made certain that downtown merchants were home as well. Some 70 years before that Sunday's "holocaust of flame," as the News-Times would call it, church founders had deeded land to the city with significant covenants, including enforcement of the "Blue Laws" which kept businesses closed on Sundays.

By noon, only a few stragglers were visible downtown as they finished cleaning up from the morning service and left the church, located on 21st Avenue between College Way and Main Street (current site of its Congregationalist successor, the Forest Grove United Church of Christ).

One straggler, Mrs. Ernest Brown, thought she saw wisps of smoke emanating from the back of O.M. Sanford's secondhand store across the street from her home near A Street and 21st (then known as First Ave.), but dismissed it.

"Imagine her surprise," the News-Times story continued, "when H.W. Danielson knocked at the door and informed the family that the Sanford building was on fire ..."

Ernest Brown and H.W. Danielson leapt into action, breaking down the door of the Sanford building and lugging out the roll-top desk. Mrs. Brown ordered her small son, Wendall, to mount his bicycle and spread the news to neighbors that a holocaust of flames was threatening their neighborhood.

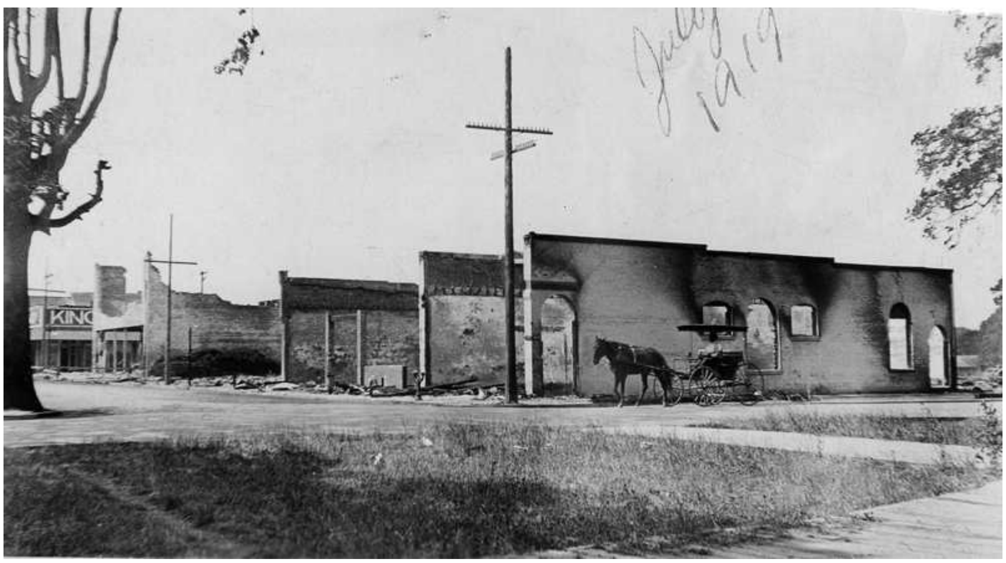
Little Wendall Brown pedaled furiously about the town of 1,900, and soon caught the eye of Dr. S.E. Todd, who listened to the boy's harrowing tale and hastened to the fire bell several blocks away to summon the town's gallant volunteer firefighters.

A few neighbors with telephones (then a rarity) had heard little Wendall's cries for help and called operators at the Forest Grove Telephone Company on the corner of Ash Street and 19th Avenue.

A young T.M. VanDyke was at the telephone exchange, stopping on his way home from church to flirt with his girlfriend, one of two teenage operators manning the switchboard that sleepy Sunday afternoon. They'd taken a couple calls about the fire, but had no training on what to do in such an emergency.

VanDyke lived on a farm and was unfamiliar with city customs, but raced to the fire scene. He wrote about that day 55 years later in a history story for the News-Times: "I went back to the telephone office and told them what I saw, then went back to the fire."

As he ran back to the fire the second time, VanDyke heard Dr. Todd frantically ringing the fire bell — which stood next to the telephone office. "Had I known," he recalled years later, "I could have rung that bell at least 15 minutes sooner."


July 1919

Before and after photos, downtown area

By the time VanDyke saw the galloping horses pulling the fire cart toward the scene from their stables on Council Street, the flames were 30 feet high, he said.

A brisk, dry wind was hurling embers toward the new downtown commercial buildings on Main, Pacific and College streets.

Several of the older wooden buildings were already “goners,” so the volunteers decided to stop the holocaust’s advance by turning their hoses on the Caples Building, which was built to fireproof standards and would be a certain firewall against further damage.

The windows of the Caples Building exploded in the intense heat, but the structure held its ground. The light-green building still stands on Main Street, adjacent to the south side of Valley Art Gallery.

Unfortunately, while the small volunteer fire department assigned all its resources to defend the Caples Building, embers ignited a different Main Street building, Miss Belle Darling's photography studio. Even worse, the yard of the Copeland-McCready Lumber Company (now Parr Lumber) was also ablaze.

The young telephone operators were in tears as their boss rushed up and told them to call the Cornelius Fire Department, the Hillsboro Fire Department and every other department east for 30 miles, all the way to Portland.

All the neighboring firefighters rushed to Forest Grove, even distant Portland's department — though not before its chief totaled his car along the way.

But their efforts weren't enough to keep building after building from erupting in flame, including Forest Grove's library on the corner of College and 21st.

Across from the library, crews poured every ounce of water they could muster on the beloved Congregational Church, but swirling embers soon entered the exploding windows of that structure as well. As crews watched helplessly, the church burst into flames for the second time in 20 years.

"When the fire burned the rope on the faithful old bell of the Congregational Church Sunday, it rang its own funeral knell," the News-Times reported.

The next morning, former Forest Grove Mayor George Paterson opened his mail. One envelope contained a letter written two days earlier from an anonymous writer, seething with anger over the treatment of German-Americans during the recently concluded World War I. "Your business and all the rest will go up in smoke," the letter warned.

The day after those words were written, Forest Grove lost most of its downtown in what appeared to be the latest in a long line of politically motivated arson fires that marked the city's early history.

Ken and Kris Bilderback write a history column for the News-Times every other week.

Appendix B

Regional Geohazard Assessment

Regional Geohazard Assessment

City of Forest Grove

Water System Seismic Resiliency Plan

Prepared by:
InfraTerra, Inc.
Date: May 2022

TABLE OF CONTENTS

1.0 PROJECT DESCRIPTION

This document presents the methodology used to perform regional seismic hazard mapping for the City of Forest Grove's (City) water system seismic resiliency study. An overview of the study area is shown in Figure 1. The information provided in this document is based on regional-scale analyses to provide information for planning purposes and is not appropriate for site-specific interpretation, analyses, or design.

The primary seismic hazard assessed for this project was based on a Moment Magnitude (M_w) 9.0 (M9) Cascadia Subduction Zone (CSZ) earthquake scenario. Other earthquake scenario including a possible Gales Creek Fault rupture, was evaluated relative to the CSZ scenario. The following seismic hazard maps were developed for the study area:

- site-amplified peak ground acceleration (PGA) and velocity (PGV),
- the probability of liquefaction-induced ground damage,
- liquefaction lateral spreading and reconsolidation settlement deformations, and
- seismically triggered landslide deformation.

Regional-scale geologic information that was necessary to develop these seismic hazard maps was based on published data by the United States Geological Survey (USGS) and the Oregon Department of Geology and Mineral Industries (DOGAMI). The City also provided supplemental subsurface data, which was used in the liquefaction and landslide hazard analyses.

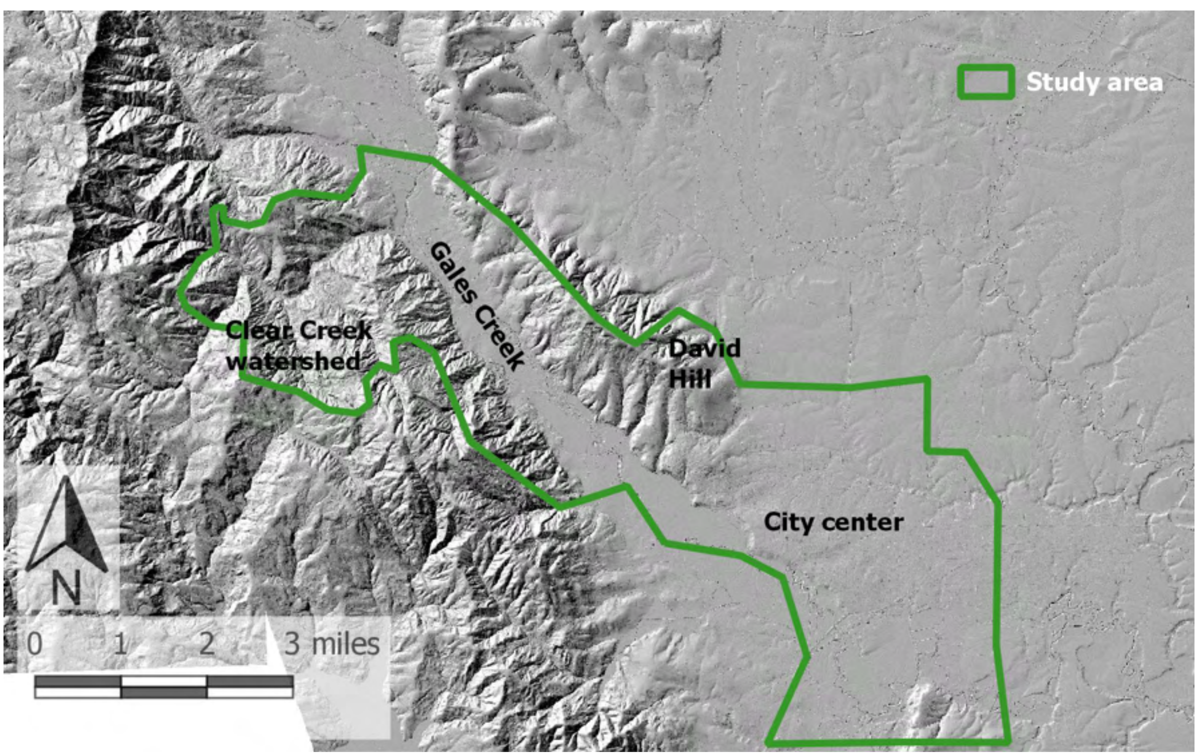


Figure 1: Study Area

2.0 REGIONAL GEOLOGY AND ENGINEERING PROPERTIES

DOGAMI has mapped surficial geology (Smith and Roe, 2015) and landslides (Burns and Watzig, 2014) on a state-wide basis. This information provides general descriptions of the extent and location of geologic units within the study area. However, the state-wide descriptions of geologic units are insufficient for engineering analysis. To support the surficial geologic data, a significant number of geotechnical boring and well logs from publicly available sources including the Oregon Department of Transportation (ODOT), DOGAMI, and the Oregon Water Resources Department were reviewed. In addition, the City provided reports with geotechnical boring data and subsurface descriptions, including borings in the Clear Creek watershed, the David Hill Reservoir, and near the City center. Table 1 shows a summary of the 107 borings from the City provided reports that were reviewed for this study. Well log data from Washington County for 18 wells installed within the study area was reviewed to obtain information about the subsurface and groundwater conditions at the time of the well installation. The well log data was used to estimate the piezometric groundwater elevation within the study area.

In addition to the data review, a preliminary geology reconnaissance of the study areas was performed on July 27 and 28, 2017. The site reconnaissance focused on observing and documenting the presence of liquefaction-susceptible soils and potential landslides within the study area. Lidar data was used to identify topographic features from recent landslides such as hummocks and debris fans. The data collected during field reconnaissance, Lidar data and data from sources listed above was used to refine the surficial geologic maps. On the basis of this work, we have grouped the surficial geologic units within the study area into five distinct units:

1. Eocene-age volcanics consisting primarily of marine basalt and volcanic breccia (Ttv)
2. Oligocene-age marine siltstone (Ts)
3. Colluvium landslide debris (Qls)
4. Willamette Silt (Qs)
5. Recent alluvium (Qal)

Figure 2 shows the extent of these five geologic units. Each of the geologic units is discussed subsequently in terms of its engineering significance.

Table 1: Boring Summary

Source	Date	Number of borings	Depth of borings
Seismic Hazard Mitigation Study, Joint Water Commission	October 2008	12	51.5 to 118 ft
Gales Creek Bridge, Tualatin Valley Highway, ODOT	August 1968	2	101.5 ft
Carpenter Creek Bridge, Tualatin Valley Highway, ODOT	August 1968	2	98 to 102 ft
2 Overflow Structures, Forest Grove Section, Tualatin Valley Highway, ODOT	September 1973	4	90 to 95 ft
Stringtown Road Bridge, Washington County, Oregon	May 1997	1	96.5 ft
Susbauer Bridge, 19th Avenue, City of Cornelius, Washington County, Oregon	June 2005	3	121.5 to 151.5 ft
Tualatin River Bridge, Fern Hill Road, ODOT	July 1982	2	82 to 86 ft
Gales Creek Bridge, Ritchey Road, ODOT	April 1984	2	66 to 75 ft
New Pacific University Library, Forest Grove, Oregon	May 2002	4	26.5 to 31.5 ft
Proposed Upper System Reservoir, City of Forest Grove, Oregon	August 1981	2	29 to 49 ft
Former Cain Petroleum Bulk Plan, Forest Grove, Oregon	December 2004	16	20 ft
David Hill & Gales Creek Road, Purdin Road UGB, and Elm Street UGB, Westside Planning Project	February 2015	3	21.5 to 31.5 ft
Landslide and Diversion Structure and Repairs, Forest Grove, Oregon	July 1997	4	24 to 56 ft
Clear Creek Pipe Bridge, Forest Grove, Oregon	July 2013	2	15 to 25 ft
Residence Hall, Pacific University	July 2013	7	26.5 to 36.5 ft
Silverstone Subdivision, City of Forest Grove, Oregon	November 2015	11	8 to 14 ft
The Parks at Forest Grove, David Hill Road and Thatcher Road, Forest Grove, Oregon	August 2005	22	10 ft
Mixed Use Development, Pacific Avenue to 21st Avenue between A Street and B Street, Forest Grove, Oregon	June 2016	8	3.5 to 51.5 ft

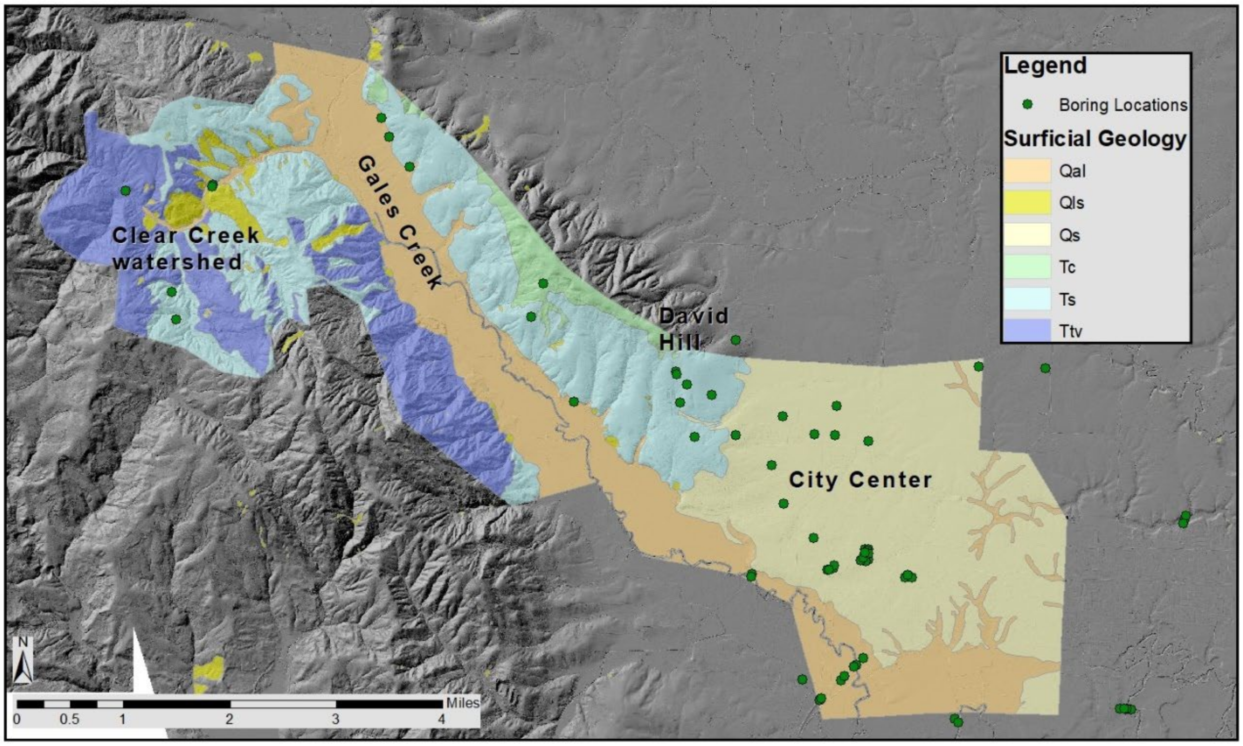


Figure 2: Study Area Geologic Map and Boring/Well Locations

Eocene-age volcanics (Ttv). Blackwood (1994) described the geology near the diversion structures in the Clear Creek watershed as almost entirely composed of Tillamook Volcanics (Ttv). Geologic reconnaissance performed as part of this study observed basalt rock outcrops in the upper sections of Clear Creek, consistent with the findings from Blackwood. Rock in these outcrops ranged from moderately to slightly weathered with joints spacing between about 1 ft to over 10 ft. Basalt was quarried about ½ mile northwest of the Clear Creek diversion structure, indicating that rock within the Ttv unit has been used for rockfill purposes. A subsurface investigation for the Clear Creek diversion structure by Dames & Moore (1997) encountered gravel and sand composed of residual basalt near the ground surface. Dames & Moore (1997) report described encountering closely to moderately fractured and moderately to slightly weathered basalt at a depth of about 12 ft.

Downstream of the diversion structures, Jacobs Associates (2013) performed an investigation for the raw water transmission pipe bridge over Clear Creek. During the subsurface investigation, Jacobs Associates (2013) encountered basalt at depths between 14 to 18 ft below the ground surface. They described the basalt as hard, highly fractured and moderately weathered.

Oligocene-age marine siltstone (Ts). Blackwood (1994) also described an outcrop of marine siltstone Yamhill Formation (Ts) near the Roaring Creek diversion structure. The geologic reconnaissance performed as part of this study also observed the presence of siltstone rock outcrops near Roaring Creek. The reconnaissance also observed siltstone outcrops and residual siltstone near Thomas Creek and at the eastern extent of the Clear Creek watershed. Previous subsurface investigations for landslide repairs upstream of the Deep Creek diversion structure described residual siltstone near the ground surface. Dames & Moore (1997) performed a subsurface investigation and described the residual soil from the Ts unit as medium stiff to stiff silt with fine sand and gravel. Dames & Moore (1997) indicated that the residual soil extended from the ground surface to depths of up to 30 ft. Below the residual soil, they encountered completely to highly weathered siltstone with some clay seams.

Squire Associates (1981) also described encountering Oligocene-age siltstone in borings for the David Hill Reservoir, approximately 6 miles southeast of the Clear Creek watershed. According to Squire Associates (1981) report, residual clayey silt from the Ts unit mantled the ground surface. The residual soil transitioning to weathered tuffaceous siltstone and sandstone below depths of 18 to 28 ft.

The available subsurface information reviewed for this study included 33 soil samples within the Ts unit. These samples were from the upper 15 ft of the deposit and primarily consisted or residual soil that was described as soft to stiff silt and clay with medium to high plasticity. The average depth and energy-corrected penetration resistances, $(N_1)_{60}$, of soils within the Ts unit were about 13 blows/ft.

Colluvium landslide debris (Qls). DOGAMI has mapped several large historic and pre-historic landslides within the Clear Creek watershed as part of the Statewide Landslide Information Database for Oregon (SLIDO) database. Information provided by the City also shows evidence of several recent landslides in the Clear Creek watershed. Dames & Moore (1997) performed a geotechnical investigation and landslide repair at two locations along an access road near the Deep Creek diversion structure. Dames & Moore (1997) indicated that the landslide debris consisted of weathered soils from the Ts unit.

Photographs provided by the City also indicated that small landslides have occurred near the David Hill Reservoir. These landslides appear to be in man-made cuts and oversteeped slopes constructed as part of the road bench above David Hill Reservoir. The reconnaissance observed surficial raveling and erosion near the David Hill Reservoir.

Willamette Silt (Qs). At the end of the Pleistocene epoch, catastrophic flows from ice dam bursts in the pre-historic Glacial Lake Missoula deposited glaciofluvial clays, silts, and sands within the Willamette Valley. At the western edge of these deposits, near Forest Grove, these soils tended to be primarily composed of clay and silt with minor sand constituents. The USGS has mapped most of the low-lying areas of Forest Grove near the City Center as Willamette Silt.

The available subsurface information reviewed for this study included 173 sample within the Willamette Silt unit. Most borings near the City Center of Forest Grove encountered Willamette Silt near the ground surface. These borings were terminated in Willamette Silt soils at depths of up to 35 ft. Farther to the east, boring logs for a bridge over Council Creek indicated that the Willamette Silt unit extended to depths of up to 77 ft.

Samples within the Willamette Silt unit were generally described as silt with trace to some clay and trace to some sand. The samples tended to exhibit low to moderate plasticity with PI values ranging from 3 to 19. The average depth and energy-corrected penetration resistances, $(N_1)_{60}$, of samples within the Qs unit were about 9 blows/ft.

Recent alluvium (Qal). Creeks and streams within the study area have deposited recent alluvial soils in low-lying areas. Most of these deposits were along the banks of Gales Creek and Council Creek. Boring logs in recent alluvial soils within the study area indicated the Qal unit tended to be composed of varying thicknesses of silt, sand, and gravel with minor constituents of clay.

The recent alluvium tended to be relatively thin along Gales Creek at the northwest extent of the study area. The recent alluvium became thicker as Gales Creek meandered towards the City Center. At several locations, the creek had incised the alluvium to expose bedrock, and thickness of the recent alluvium could be observed during the site reconnaissance. The alluvium ranged in thickness from about 8 ft at the Northwest Soda Springs Road bridge, to about 15 ft at the Northwest Cox Road bridge, to about 33 ft at the confluence of Gales Creek with Kelly Creek. Borings logs provided by ODOT indicated that the alluvium was about 30 ft thick at the Southwest Ritchey Road bridge over Gales Creek, and up to 55 ft-thick along Southwest Highway 47. Borings for the Susbaurer bridge over Council Creek indicated the alluvium was up to 50 ft thick.

Very limited boring information was available in the recent alluvium soils near Gales Creek. However, clayey silt, silty sand, fine sand, and fine sandy gravel were all observed along the banks of Gales Creek during the site reconnaissance. The available subsurface information from borings elsewhere in the study area included 178 samples from the Qal unit. These samples were described as a range of soils including clay with moderate plasticity, silty clay, sandy silt, fine sand with silt, and fine sandy gravel. The samples ranged in plasticity from nonplastic to moderate plasticity. Atterberg limit PI values ranged from 9 to 48, but these tests were primarily performed on clay or silty clay samples. Many samples from granular soils in the Qal unit were described as nonplastic. The average depth and energy-corrected penetration resistances, $(N_1)_{60}$, of samples from the Qal unit were about 8 blows/ft.

2.1 THICKNESS OF GEOLOGIC UNITS

The approximate thickness of geologic units is important for liquefaction analysis. The two units of significance for liquefaction analysis, Qal and Qs, vary in thickness throughout the study area. Borings and field observations provided measurements of the unit thicknesses at specific point locations. These point observations were used to interpolate a raster of the layer thickness in GIS. This raster was then used for regional-scale liquefaction analysis. Figure 3 shows the estimated thicknesses of Qal and Qs within the study area.

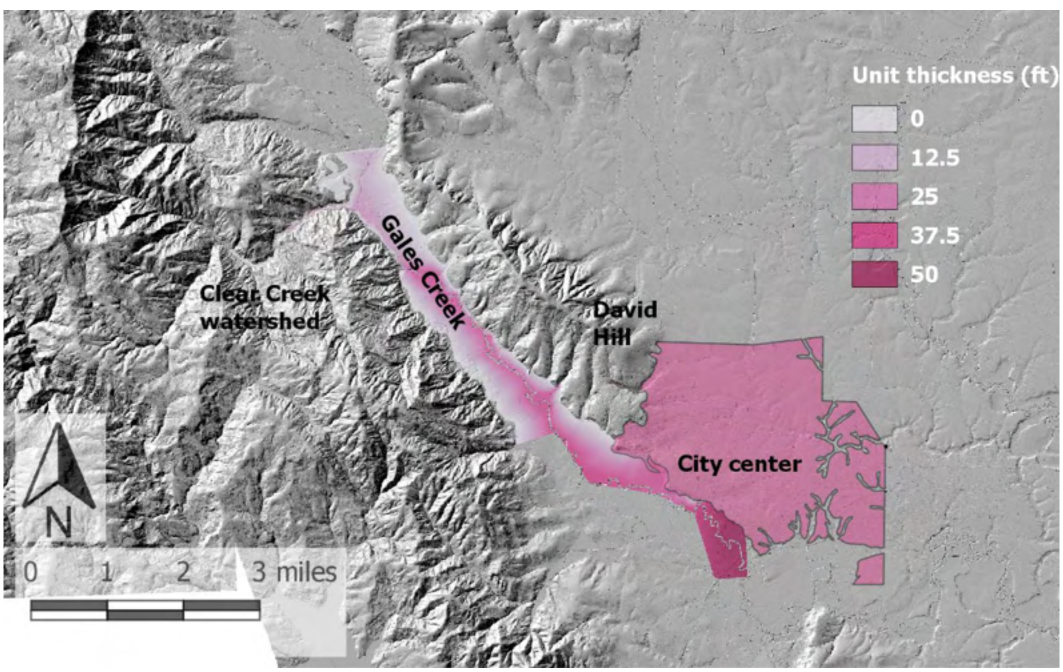


Figure 3: Thickness of Qal or Qs Geologic Unit at Ground Surface

2.2 GROUNDWATER

The depth of groundwater varied with topography and geology throughout the study area. Based on the boring and well logs, groundwater was relatively consistent with the elevation of surface water including streams and creeks in the Clear Creek watershed, Gales Creek, Council Creek, as well as wetlands and ponds near the City center. However, fluctuations may occur seasonally during wet and dry seasons. Groundwater may also become perched near the ground surface in areas of poorly drained soils.

Groundwater was relatively shallow within the valley near Gales Creek. Ponded water was observed in the valley during the site reconnaissance. Groundwater becomes deeper near the City Center and boring and well logs indicate that the groundwater ranges from about 5 to 20 ft below the ground surface. Groundwater approaches the ground surface at the northern side of the City Center, where ponded water and evidence of shallow groundwater were observed during the site reconnaissance. Geotechnical borings for the Joint Water Commission's Fern Hill Road Water Treatment Plant (Shannon & Wilson, 2008) indicate that groundwater was encountered at depths of about to 45 to 48 ft below the ground surface, which is consistent with the elevation of the Tualatin River.

In addition to the presence of surface water, boring and well log data provided individual point locations of the groundwater elevation within the study area. The data points for groundwater elevation were interpolated as a raster of groundwater elevation in GIS. At locations where the interpolated GIS layer of groundwater elevation daylighted above the ground surface, additional points were added to constrain the layer at or below the ground surface. The resulting GIS layer provides a simple estimate of the piezometric groundwater elevation across the study area. Figure 4 shows the estimated piezometric groundwater elevation within the study area. The USGS (Snyder, 2008) performed a similar procedure to estimate groundwater elevation within the Portland metro region. However, the USGS's map did not extend to the study area.

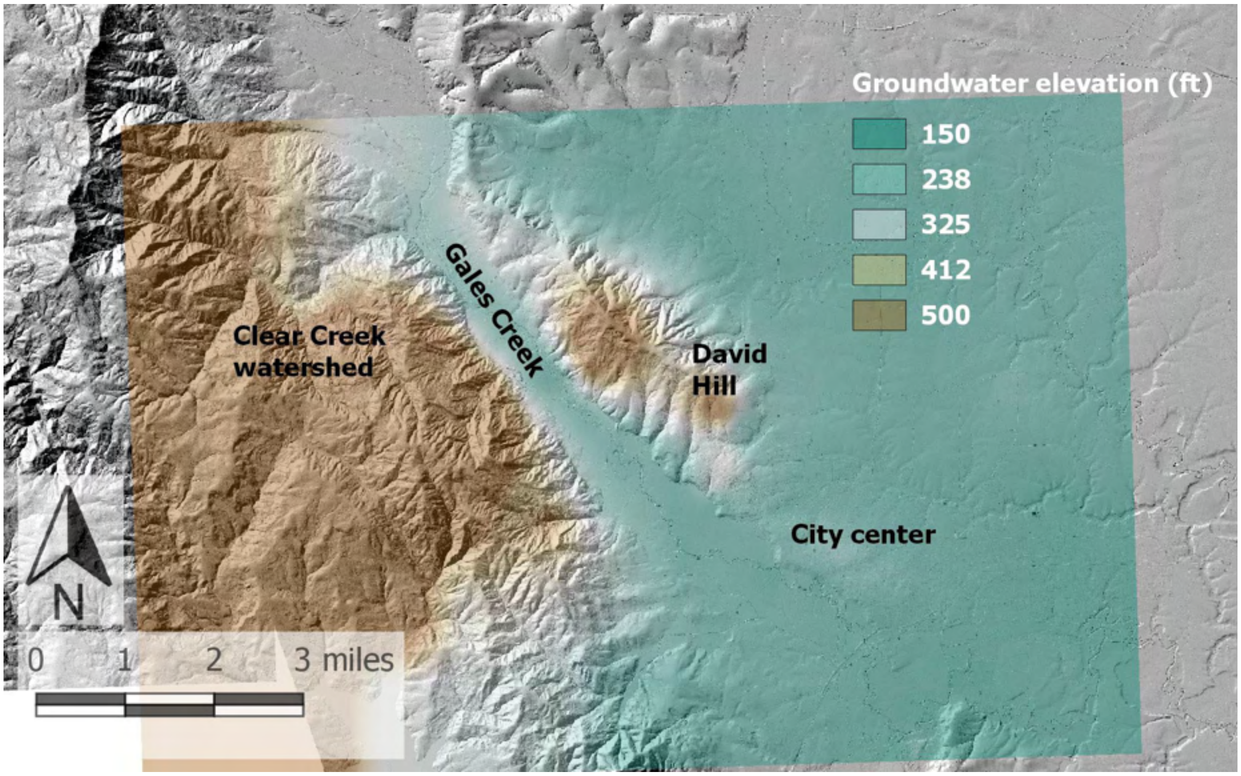


Figure 4: Piezometric Groundwater Elevation (NAD83)

3.0 SEISMIC HAZARD

The primary hazard considered for this project was associated with median ground motions from an M9 CSZ earthquake. Paleoseismic studies using seafloor sediment records indicate that there have been numerous large-magnitude earthquakes along the CSZ within the Holocene epoch (Goldfinger et al. 2012). The data indicate that great earthquakes (Magnitudes greater than 8.0) have occurred, on average, about every 500 to 530 years off the coasts of Oregon and Washington. Evidence of ruptures from these large earthquakes extends from Cape Mendocino in California to Vancouver Island in British Columbia. The geologic record also shows evidence of smaller, but still very powerful earthquakes (Magnitudes 7.0 to 8.0) along the southern margin of the subduction zone. The data indicate that these earthquakes have occurred, on average, about every 240 years. The sediment record correlates well with the most recent M9 earthquake that occurred in January 1700. Studies by the USGS show that the probability of a great earthquake affecting the entire Pacific Northwest is about 7 to 15 percent over the next 50 years (Goldfinger et al., 2016).

The nearest down-dip edge of the CSZ is about 40 km (approximately 25 miles) to the west of the study area, as shown in Figure 5, which presents the locations of the down-dip edge considered in developing the USGS National Seismic Hazard Maps (Petersen et al., 2014). PGA estimates for the M9 CSZ earthquake were estimated by DOGAMI (Madin and Burns, 2013). These estimates included a GIS raster file with PGA data. Ground motion amplification factors were incorporated into the PGA estimates using regional shear-wave velocity data with ground motions prediction equations (Boore and Atkinson, 2008). The results of DOGAMI's study show that PGA from the M9 CSZ scenario ranges from about 0.19g to 0.27g within the study area as shown in Figure 6.

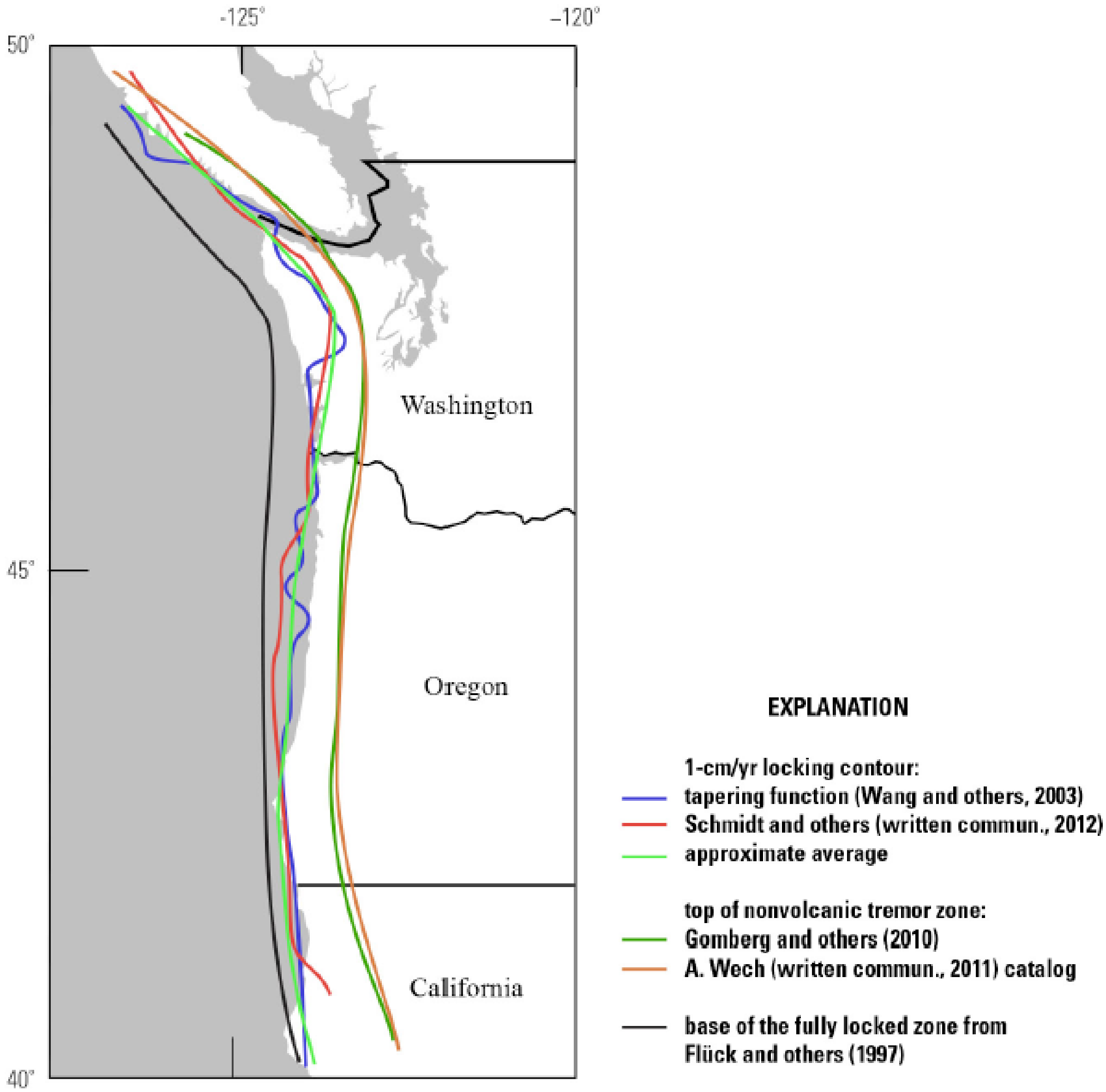


Figure 5: Locations of Down-Dip Edge of Cascadia Rupture (Petersen et al., 2014)

Local crustal faults have formed in the Willamette Valley due to compression and tension in the earth's crust. The Gales Creek fault zone forms the boundary between the Oregon Coast Range and the Willamette Valley. The fault zone has been active at least since the Miocene epoch and fault activity is evident in the displacement of the Miocene Columbia River basalt to the northwest of the study area. No evidence of deformation in Quaternary deposits has been described, but evidence of displacement may be concealed by the thick sedimentary deposits that have buried the fault. The fault zone extends nearly 75 km (approximately 47 miles) and strikes north-northwest parallel to Gales Creek. The USGS (Haller et al., 2002) assigned a characteristic moment magnitude (M_w) of 6.8 (M6.8) with an average recurrence interval of about 64,000 years to the Gales Creek fault. Ground surface PGA map from M6.8

and rupture depth of 9.0 km (approximately 5.5 miles) earthquake on the inferred traces of the Gales Creek fault zone simulated by the USGS is shown in Figure 7. As shown in the figure, the PGA from this scenario ranges from about 0.42 to 0.61 g in the study area.

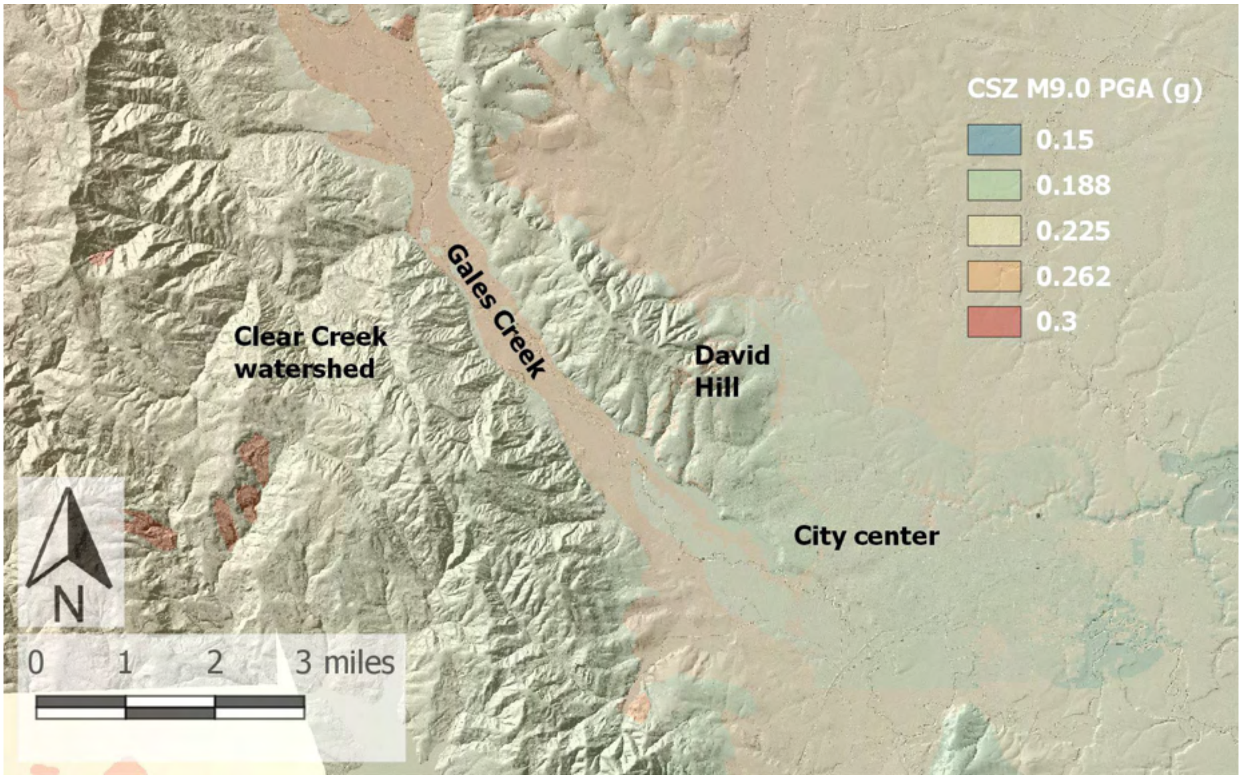


Figure 6: Cascadia Subduction Zone M9 Scenario Earthquake PGA

Although the Gales Creek earthquake scenario produced stronger PGAs than the CSZ earthquake scenario, the CSZ scenario was used as a baseline case for evaluating the liquefaction and landslide hazards for this study. Reasons for doing so include:

- Long duration shaking from a CSZ earthquake will cause more damage compared to the local, crustal faults of the same shaking amplitude.
- While the Gales Creek fault is considered active, the geologic record included no evidence of fault rupture in the past 2 million years.
- A CSZ scenario earthquake has a much higher contribution to the probabilistic seismic hazard than the Gales Creek fault. For 2,475 year return period ground motions (maximum considered earthquake used in the ASCE 7 design code) the CSZ earthquake contributes approximately 60% to the ground shaking, whereas the Gales Creek fault contributes approximately 1.4% to the ground shaking hazard.

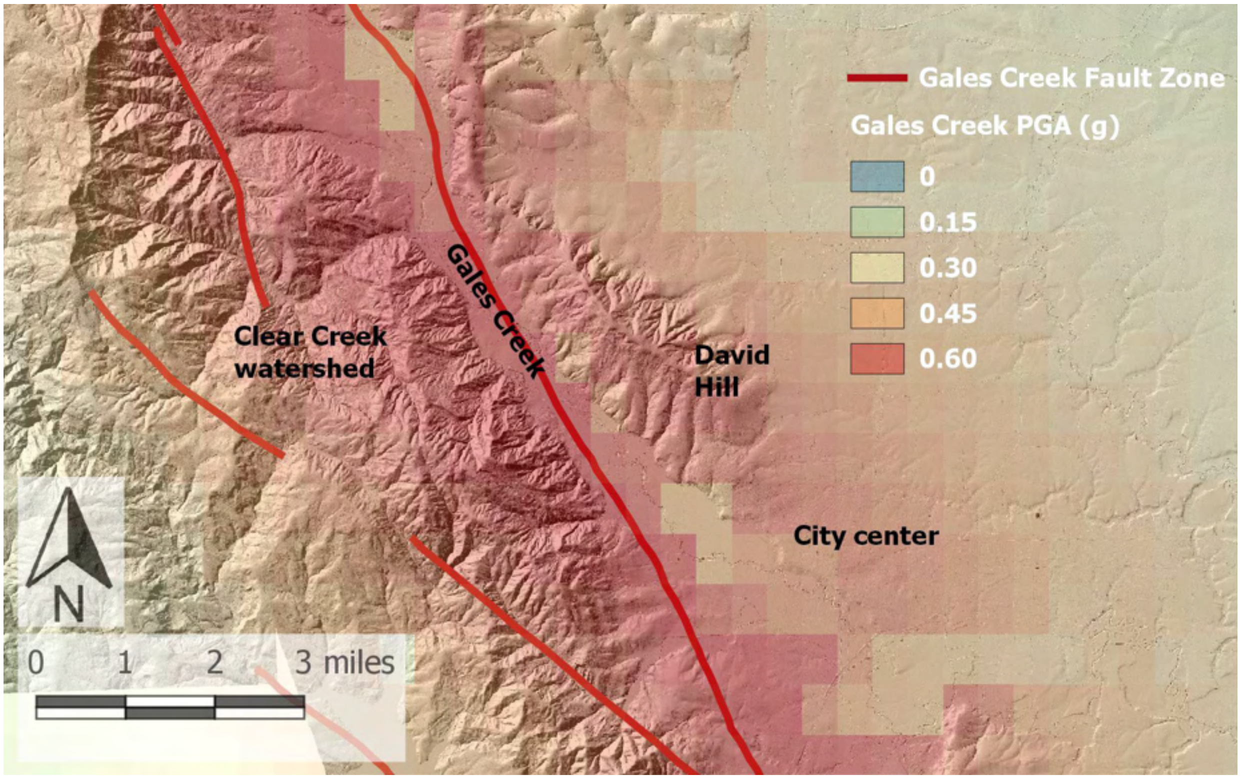


Figure 7: Gales Creek Fault Zone M6.8 Scenario Earthquake PGA

4.0 LIQUEFACTION

The geologic units considered in this study are quite broad, and each individual unit may contain a range of materials that are susceptible to liquefaction and could liquefy during a long-duration CSZ earthquake. Liquefaction hazards are typically evaluated by first assessing if the soil is susceptible to liquefaction, then assessing if liquefaction would be triggered for a specific earthquake scenario followed by assessing the consequences of liquefaction. However, liquefaction assessments at a regional scale includes significant uncertainty because soil conditions are not well-defined at that scale. Many recent studies (e.g. Real and Knudsen, 2010; Holzer and others, 2011; Greenfield and others, 2018) have relied on comprehensive subsurface datasets to approximate the range of possible soil conditions for specific geologic deposits.

For this project, over 100 borings logs from previous studies near Forest Grove were reviewed to develop statistical models of the subsurface data for liquefaction susceptibility, triggering potential, and consequence analyses. Using this information, algorithms that could be implemented in GIS were developed to evaluate liquefaction hazards for this study.

4.1 LIQUEFACTION SUSCEPTIBILITY

Not all soils are susceptible to liquefaction. Soils are only susceptible to liquefaction if they are saturated and have little or no plasticity. Therefore, some fraction of the soils within a geologic unit may not be susceptible to liquefaction. For example, rock and soils above the groundwater elevation are not susceptible to liquefaction. Soils with moderate or higher plasticity, such as clay soils, are also not susceptible to liquefaction.

For this project, we estimated the elevation of the water table in GIS using a raster based on point observations from borings and field reconnaissance. Soils above the estimated groundwater elevation were assumed to be unsaturated and were not susceptible to liquefaction.

The soil's plasticity index is typically used to screen soils for liquefaction susceptibility. Based on the criteria described by Boulanger and Idriss (2006), soils with a plasticity index greater than or equal to 7 are not susceptible to liquefaction. The available boring logs in the project vicinity included 24 Atterberg Limit tests with plasticity index information. In the absence of Atterberg Limit testing, the soil's plasticity characteristics was estimated based on the field descriptions of soil texture and the descriptions from nearby borings (by others) with Atterberg Limit tests. Of the logs reviewed, only data samples from the recent alluvium (Qal) and Willamette Silt (Qs) units were susceptible to liquefaction. Table 2 shows the relative fraction of liquefaction-susceptible samples within the Qal and Qs deposits. Following similar previous studies (e.g. Real and Knudsen, 2010; Holzer and others, 2011; Greenfield and others, 2018) it was assumed that the samples are spatially independent and that the fraction of liquefaction-susceptible samples provides a good approximation of the probability of liquefaction susceptibility, P[sus], within a particular geologic deposit.

Table 2: Liquefaction Susceptibility Based on Soil Plasticity

Unit	Number of sample records	Number of Atterberg Limit tests	Probability of liquefaction susceptibility, P[sus]
Recent alluvium (Qal)	178	12	0.48
Willamette Silt (Qs)	173	11	0.39
Residual siltstone (Ts)	33	1	0.00

4.2 PROBABILITY OF LIQUEFACTION

Soils deemed susceptible to liquefaction will liquefy if subjected to sufficiently strong shaking. The simplified procedure (Seed and Idriss, 1982) considers soil likely to liquefy if the cyclic stress ratio (CSR) exceeds the cyclic resistance ratio (CRR). The CSR is a measure of the ratio of cyclic shear stress to the vertical effective stress. The peak acceleration and earthquake magnitude approximate the cyclic shear stresses during an earthquake since cyclic stresses in the soil cannot be directly measured. The CRR is typically correlated with penetration resistance or shear wave velocity. These correlations include adjustments for several factors such as fines content and overburden pressure. The factor of safety against liquefaction is expressed as the ratio of CRR to the CSR. However, since the soil's susceptibility to liquefaction and the CSR and CRR can be highly uncertain, the liquefaction potential is often expressed as a probability, rather than a binary "yes/no" classification.

To address the uncertainty in liquefaction, each sample record from the dataset was assigned to a geologic unit based on the sample's location and depth. Liquefaction triggering potential for each sample was estimated using the procedure described by Boulanger and Idriss (2014). PGA within the study region ranged from about 0.20g to 0.27g. To account for this variation, the probability of liquefaction triggering was calculated for each sample over the range of possible PGA values. The probability of liquefaction triggering for the geologic deposit was then calculated using the total probability theorem such that:

$$\mathrm{P[L]} = \mathrm{P[sus]} \sum_{i=1}^{n} \mathrm{P[L}_i|\mathrm{PGA]P}[i] \tag{1}$$

where $\mathrm{P[L]}$ is the geologic unit-scale probability of liquefaction triggering, $\mathrm{P[sus]}$ is the probability of selecting a sample that is susceptible to liquefaction, $\mathrm{P[L}_i|\mathrm{PGA]}$ is the probability of sample i liquefying given the PGA, and $\mathrm{P}[i]$ is the probability of selecting sample i. The samples were given equal weight, so $\mathrm{P}[i] = \frac{1}{n}$.

Figure 8 shows the probability of liquefaction triggering within the Qal and Qs geologic units for a range of PGA values. Note that the probability of liquefaction triggering cannot exceed the probability of selecting a sample that was susceptible to liquefaction. Based on the M9 CSZ scenario, and PGA of about 0.21 g would trigger liquefaction in about 38% of the Qal soils and 28% of the Qs soils.

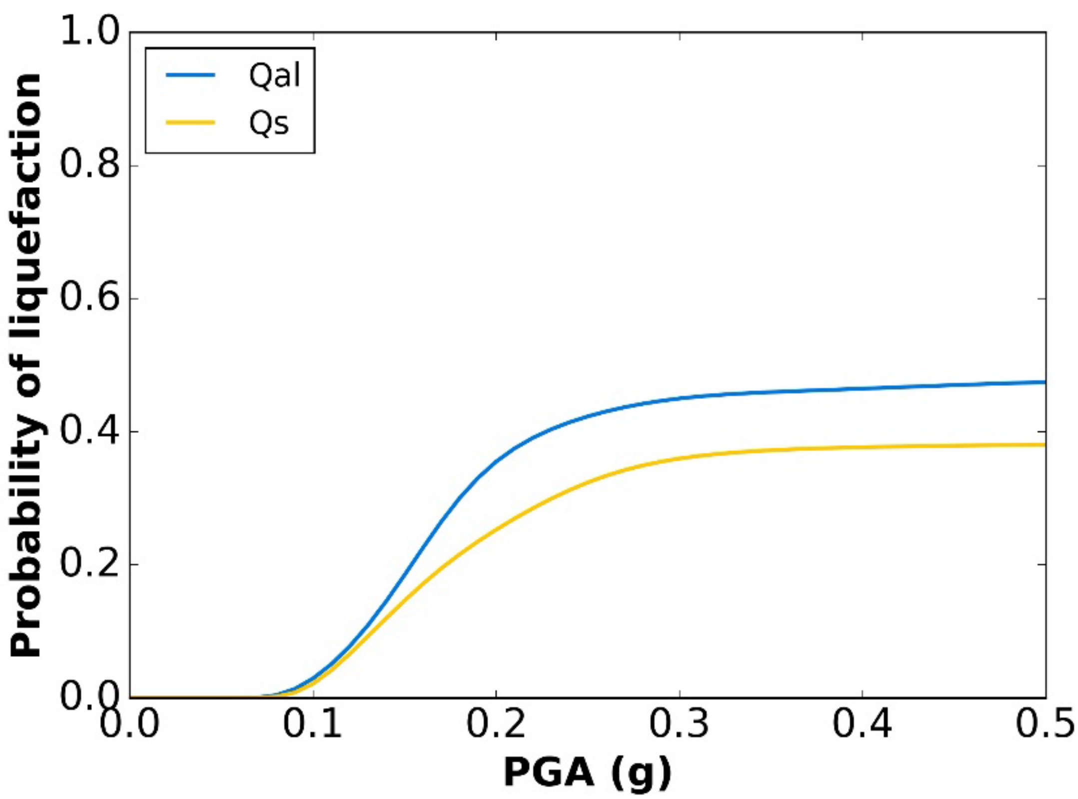


Figure 8: Surficial Geology

For implementation in GIS, general logistic expression was fit to the probability of liquefaction triggering curves in Figure 8. The logistic expression was defined as:

$$\mathrm{P[L]} = \mathrm{P[sus]} \frac{1}{1 + \exp(a[\mathrm{PGA} - b])} \quad (2)$$

where a and b are constants calculated from least squares fitting and PGA is in units of g. We fit the curve to the liquefaction susceptibility and triggering data and Table 3 shows the coefficients for equation (2).

Table 3: Coefficients for Equation (2)

Unit	$\mathrm{P[sus]}$	a	b
Recent alluvium (Qal)	0.48	-30.2	0.169
Willamette Silt (Qs)	0.39	-25.6	0.178

4.3 GROUND DAMAGE DUE TO LIQUEFACTION

Liquefied soils are extremely soft and large deformations and ground failure can occur if soils near the ground surface liquefy. The consequences of liquefaction may be less severe if liquefaction is triggered at great depths. Liquefied soil also continues to soften with additional loading, and the probability of ground damage increases as the intensity of shaking increases. Ishihara (1985) proposed simple curves that separated recorded case histories where ground surface damage was observed from cases where damage was not observed. Figure 9 shows these curves. We generalized mathematical expressions for these curves as

$$H_2 = H_1{}^* \left[1 + \exp\left(\frac{H_1{}^* - 3.33\ \mathrm{m}}{0.515\ \mathrm{m}}\right)\right] \quad (3)$$

$$H_1{}^* = 0.090\, H_1 \left(\frac{\mathrm{PGA}}{1\ \mathrm{g}}\right)^{-1.496} \quad (4)$$

where H_1 is the thickness of the overlying non-liquefied layer in meters (m), H_2 is the minimum thickness of liquefied soil necessary to cause surficial damage in meters (m), and PGA is the peak ground acceleration in units of g. Soils above the groundwater table are not susceptible to liquefaction, so for this regional study, we estimated H_1 as the depth of the groundwater.

Soils are typically sampled at regular or semi-regular intervals during geotechnical investigations. The thickness of a soil layer can, therefore, be described as a function of the sample interval. We estimated the thickness H_2 based on a contiguous layer of liquefied soil. The minimum number of consecutive samples necessary to produce ground damage, n_s, would be:

$$n_s = \max\left\{\frac{H_2}{s}, 1\right\} \quad (5)$$

where s is the sampling interval in the same units as H_2. The average sampling interval of the soil samples reviewed for this study was 5.1 ft or 1.55 m. While P[L] calculated using equation (2) represents the probability of an individual sample liquefying, the binomial distribution describes the probability that n_s consecutive samples would liquefy. The form of the binomial distribution is:

$$\mathrm{P}[\mathrm{D}|n_s, k] = \binom{n_s}{k} \mathrm{P}[\mathrm{L}]^k (1 - \mathrm{P}[\mathrm{L}])^{n_s - k} \tag{6}$$

where $\mathrm{P}[\mathrm{D}|n_s, k]$ is the probability of k consecutive samples liquefying. To cause surficial damage, at least n_s consecutive samples must liquefy, so $n_s = k$. Equation (6) simplifies to:

$$\mathrm{P}[\mathrm{D}] = \mathrm{P}[\mathrm{L}]^{n_s} \tag{7}$$

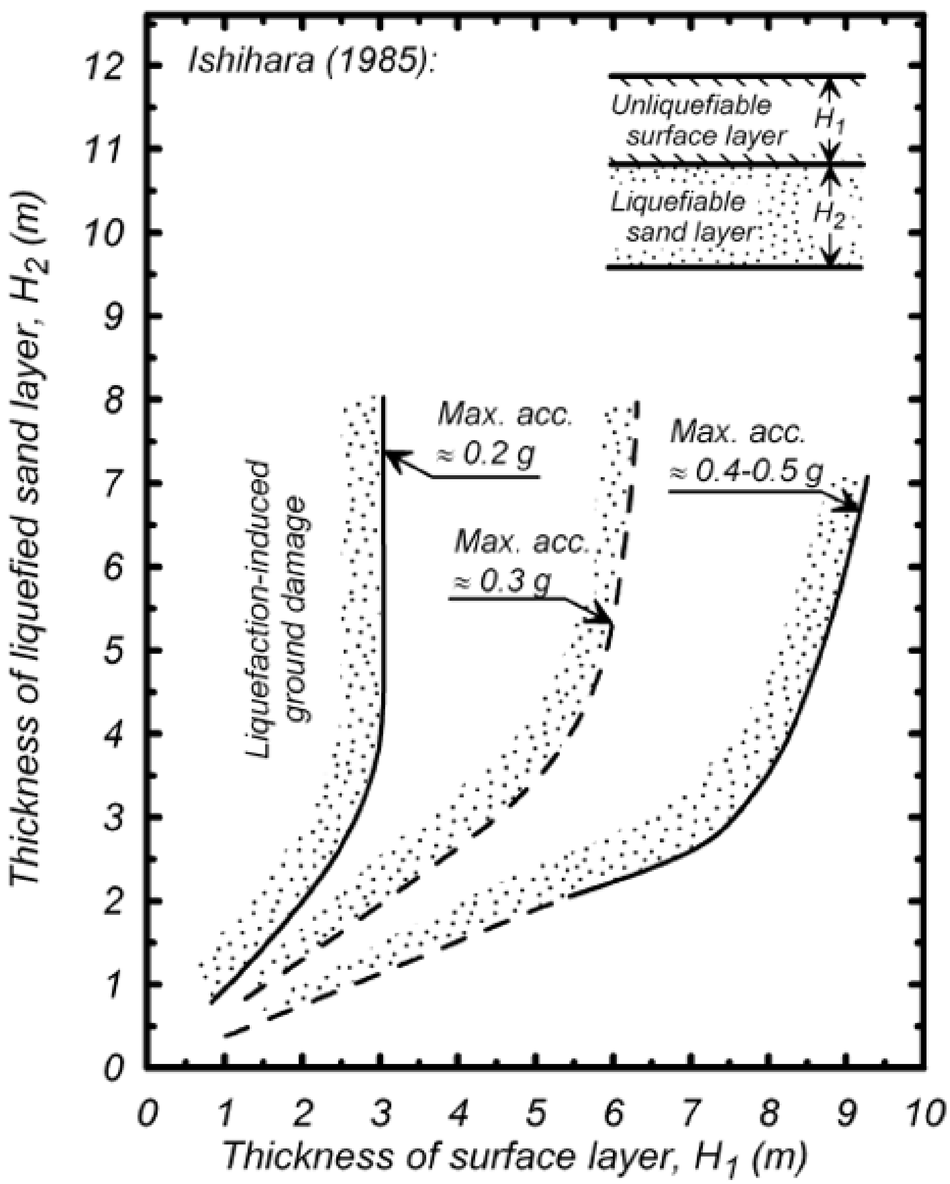


Figure 9: Surficial Geology

Equations (3) through (7) were implemented into GIS to create maps of the probability of ground damage due to liquefaction. The probability of ground damage is appropriate to estimate the potential for damage in free-field conditions where structures, slopes, or nearby changes in topography do not induce static shear stresses in the soil. Under conditions with static shear stresses, lateral spreading may occur.

Maurer and others (2014) associated the probability of liquefaction manifestation and ground damage with qualitative field observations of liquefaction following the 2010 and 2011 Christchurch, New Zealand earthquake sequence. They provide a series of equations and figures that may be used to estimate liquefaction severity classifications based on the probability of ground damage ($\mathrm{P[D]}$). Table 4 provides simple liquefaction severity classifications for a range of $\mathrm{P[D]}$ values.

Table 4: Liquefaction Severity Classification

$\mathrm{P[D]}$	Classification
0 to 0.15	Very little liquefaction
0.15 to 0.30	Marginal liquefaction
0.30 to 0.60	Moderate liquefaction
0.60 to 1.0	Severe liquefaction

4.3.1 Lateral Spreading

Lateral spreading refers to the lateral deformation of blocks of liquefied soil and non-liquefied crust due to shear stresses from topographic features such as riverbanks or slopes. These deformations tend to occur near bodies of water or on gently sloping ground underlain by liquefiable soils. Liquefied soil is very soft, and even relatively small static shear stresses from the topographic features can induce very large shear strains. The accumulation of these shear strains across layers of liquefied soil results in lateral spreading deformation of the ground surface. The aerial extent of lateral spreads can be relatively large and depends on the continuity of liquefied soils, the size of the topographic feature that induces shear stress, and groundwater conditions.

A commonly used approach to estimate lateral spread deformation is based on the concept of a shear strain potential, i.e. a level of shear strain produced by cyclic loading of liquefied soil. Laboratory observations indicate that denser soils exhibit less shear strain than looser soils even after liquefaction has been triggered. These observations also show that the amplitude of shear strain continues to increase with additional loading after liquefaction has been triggered. Ishihara and Yoshimine (1992) developed a figure showing the shear strain potential of liquefied soil as a function of the factor of safety against liquefaction and relative density of the soil. Since the factor of safety against liquefaction is a function of the PGA, shear strain potential is also a function of PGA. The shear strain potential can then be used with semi-empirical observations from case histories (Zhang et al., 2004; Khoshnevisan, 2014) to estimate lateral spreading. At very high levels of shaking and very low factors of safety, investigators (Zhang et al., 2004; Boulanger and Idriss, 2008) have indicated that the shear strain amplitudes reach an upper-bound limit (γ_{lim}) based on the penetration resistance of the soil.

Not all soils within the geologic units are susceptible to liquefaction or have the same relative density. Similar to the process for estimating liquefaction ground damage, the data collected for this study was used to estimate statistics of the shear strain potential for each geologic unit. Figure 10 shows plots of average (median) shear strain potential for Qal and Qs soils. For implementation into GIS, a logistic expression was fit to the median shear strain estimates in Figure 10. The form of the logistic expression is

$$\gamma = \gamma_{\mathrm{lim}} \frac{1}{1 + \exp(a[\mathrm{PGA} - b])} \tag{8}$$

where γ is the peak shear strain amplitude, γ_{lim} is a limiting shear strain amplitude, a and b are curve fitting constants, and PGA is in units of g. Both γ and γ_{lim} are dimensionless.

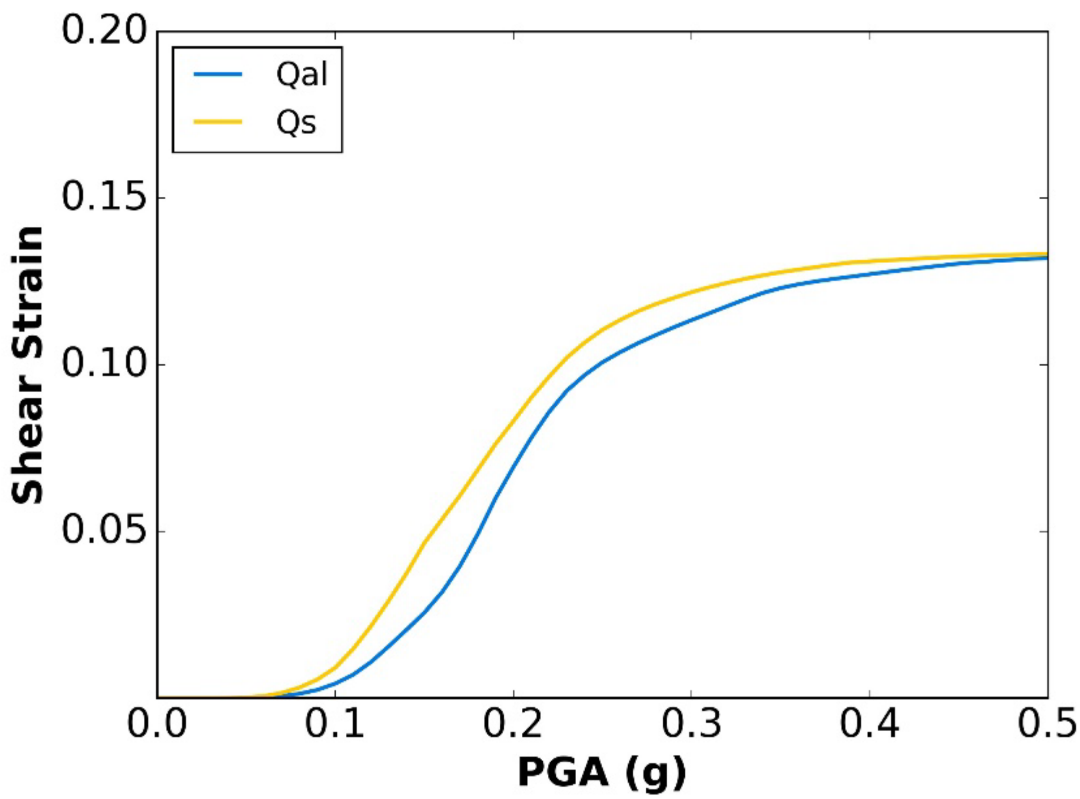


Figure 10: Average Shear Strain of Liquefied Soils

The shear strain potential estimates can exhibit significant uncertainty. While Figure 10 and Equation (8) provide an estimate of the median shear strain potential, the standard deviation of log of the shear strain estimates, $\sigma_{\ln\gamma}$, provides a measure of the uncertainty. Table 5 shows the curve fitting constants for equation (8) as well as the log-normal standard deviation of shear strain.

Table 5: Statistics for shear strain estimates for geologic deposits

Unit	γ_{lim}	a	b	$\sigma_{\ln\gamma}$
Recent alluvium (Qal)	0.127	-26.9	0.199	0.58
Willamette Silt (Qs)	0.130	-26.3	0.179	0.24

The amount of lateral deformation also depends on the thickness of liquefied soil. The lateral deformation index, LDI, is a measure of the potential for lateral spreading deformation based on the shear strain amplitude and thickness of liquefied soil. LDI is calculated as:

$$\text{LDI} = \gamma \text{H}_{\text{liq}} \tag{9}$$

where H_{liq} is the thickness of liquefied soil that contributed to lateral spreading, γ is the dimensionless shear strain amplitude, and LDI and H_{liq} are in consistent units. Chu et al. (2006) found that only liquefied soils up to a depth of two times the height of the free face, H_{ff}, contribute to lateral spreading deformation. The heights of free faces were calculated throughout the study area using Lidar data. Tall free faces, that could potentially cause large lateral spreading deformations, were primarily located along Gales Creek and Council Creek. The height of these free faces extended up to about 30 ft. Figure 11 shows a photo of an approximately 30 ft-tall free face along Gales Creek.

Figure 11: Free Face Along Gales Creek

The deposits of Qal and Qs tended to be very deep, and the heights of the free faces limited the maximum depth of liquefied soils that contributed to lateral spreading. The exception was the northern extent of Gales Creek. In this area, the thickness of alluvium was relatively shallow and the rock below the alluvium was not susceptible to liquefaction. The thickness of the Qal unit was interpolated based on borings and field reconnaissance observations. Figure 3 shows the thickness of Qal or Qs geologic units at the ground surface throughout the study area.

Khoshnevisan et al. (2015) developed equations to estimate lateral spreading deformation with considerations for the probability of liquefaction triggering. For implementation into GIS, the thickness of liquefied soil that contributed to lateral spreading deformation was calculated as:

$$\mathrm{H_{liq}} = \mathrm{P[sus]} \cdot \min \begin{Bmatrix} 2\ \mathrm{H_{ff}} - \mathrm{z_{gw}} \\ \mathrm{z_{geo}} - \mathrm{z_{gw}} \end{Bmatrix} \tag{10}$$

where $\mathrm{H_{ff}}$ is the height of the free face, $\mathrm{z_{gw}}$ is the depth of groundwater, and $\mathrm{z_{geo}}$ is the thickness of the geologic unit, and $\mathrm{H_{ff}}$, $\mathrm{z_{gw}}$, and $\mathrm{z_{geo}}$ are in consistent units.

Lateral spreading deformations are typically greatest immediately adjacent to free faces. Deformations then tend to diminish with distance from the free face. Zhang et al. (2004) provided an equation to estimate lateral spreading deformation based on lateral displacement index, the height of the free face, and the distance from the free face. The form of the equation is:

$$\mathrm{LD} = \mathrm{LDI} \cdot \min \begin{Bmatrix} 6\left(\dfrac{\mathrm{L}}{\mathrm{H_{ff}}}\right)^{-0.8} \\ 2 \end{Bmatrix} \tag{11}$$

where LD is the lateral deformation, L is the distance from the free face, $\mathrm{H_{ff}}$ is the height of the free face, and LD, L, and $\mathrm{H_{ff}}$ are in consistent units. The maximum distance of lateral spreading in Zhang et al.'s database was about 40 $\mathrm{H_{ff}}$, so for this study, lateral spreading deformations at distances farther than 40 $\mathrm{H_{ff}}$ were assumed to be negligible.

The procedure for estimating lateral spreading deformation includes significant uncertainty. Lateral deformations are typically assumed to be log-normally distributed. Based on the data used to develop Zhang et al.'s database, a log-normal standard deviation, $\sigma_{\ln\delta}$, of 0.46 is typically assumed for a specific site. However, at a regional scale, the soil properties are also highly uncertain. Regional-scale assessments must include both the uncertainty in shear strain potential, $\sigma_{\ln\gamma}$, and the uncertainty in lateral spreading deformation given LDI, $\sigma_{\ln\delta}$. Based on these considerations, the estimated deformations for this project have a log-normal standard deviation of about 1.0.

4.3.2 Settlement

Ground surface settlement can occur through multiple mechanisms following liquefaction. Ejecta in the form of sand boils can cause settlement, as can differential shearing due to lateral spreading. Very soft liquefied soil below foundations or embankments can squeeze laterally, also producing ground surface settlement. Settlement can also occur as excess pore pressure dissipates from layers of liquefied soil and the soil densifies. Settlement due to pore pressure dissipation can occur over a period of days after an earthquake.

Permanent shear deformations from lateral spreading can cause a combination of lateral deformations and vertical settlement. The ground surface settlement is often estimated as ½ of the lateral deformation. At locations where the ground surface is flat and lateral deformation is not influenced by nearby topography, the ground surface settlement is often estimated based on the reconsolidation volumetric strain that occurs as excess pore pressure dissipates from the liquefied soil. Ishihara and Yoshimine (1992) indicated that the reconsolidation volumetric strain of liquefied sand corresponds with the factor of safety against liquefaction and the relative density of the soil. Before liquefaction is triggered, volumetric strains are generally less than about 1%. At very high levels of shaking and very low factors of safety, laboratory results indicate that the reconsolidation volumetric strain reaches an upper-bound limit ranging between about 1 to 6%, depending on the relative density of the soil.

Similar to the approach used for estimating shear strain potential, the subsurface dataset collected for this study was used to estimate an average reconsolidation volumetric strain for each geologic unit. These estimates were based on the estimated volumetric strain for each sample, which were then used to calculate an average volumetric stain for an entire geologic unit. Figure 12 shows plots of average volumetric strain for liquefied soils in the Qal and Qs units.

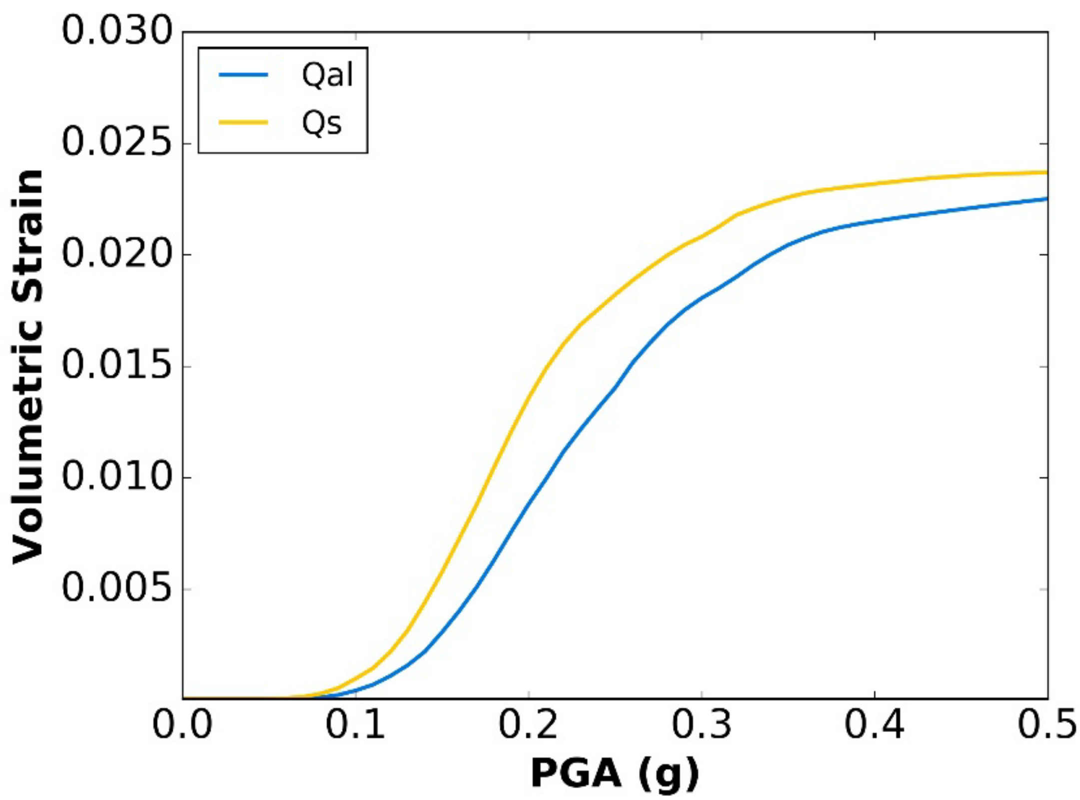


Figure 12: Average Volumetric Strain of Liquefied Soils

For implementation in GIS, a logistic expression was fit to the average reconsolidation volumetric strain, ε_v, in Figure 12. The form of a logistic equation is:

$$\varepsilon_v = \varepsilon_{v\mathrm{lim}} \frac{1}{1 + \exp(a[\mathrm{PGA} - b])} \qquad (12)$$

where $\varepsilon_{v\mathrm{lim}}$ is a limiting volumetric strain, a and b are curve fitting constants, and PGA is in units of g. The standard deviation of logarithm (log) of the volumetric strain estimates, $\sigma_{\ln \varepsilon_v}$, provides a measure of the uncertainty. Table 6 shows the coefficients for equation (12) as well as the log-normal standard deviation of volumetric strain based on the subsurface dataset.

Table 6: Statistics for volumetric strain estimates for geologic deposits

Unit	$\varepsilon_{v\mathrm{lim}}$	a	b	$\sigma_{\ln \varepsilon_v}$
Recent alluvium (Qal)	0.0219	-22.6	0.224	0.71
Willamette Silt (Qs)	0.0231	-26.0	0.193	0.31

The amount of settlement, s, is equal to the cumulative amount of volumetric strain in a layer of liquefied soil. It is calculated as:

$$s = \varepsilon_v \mathrm{H}_{\mathrm{liq,s}} \qquad (13)$$

where $\mathrm{H}_{\mathrm{liq,s}}$ is the thickness of liquefied soil that contributes to the settlement, ε_v is dimensionless volumetric strain, and s and $\mathrm{H}_{\mathrm{liq,s}}$ are in consistent units. Not all soil layers within either the Qal or Qs units are susceptible to liquefaction, therefore, for implementation in GIS, the thickness of liquefied soil that contributes to lateral spreading deformation was calculated as follows:

$$\mathrm{H}_{\mathrm{liq}} = \mathrm{P[sus]} \cdot \left(\mathrm{z}_{geo} - \mathrm{z}_{gw}\right) \qquad (14)$$

where $\mathrm{z}_{geo}$is the thickness of the geologic unit, z_{gw} is the depth to groundwater, and $\mathrm{H}_{\mathrm{liq}}$, z_{geo}, and z_{gw} are in consistent units.

The procedure for estimating reconsolidation settlement may not fully capture all phenomenon associated with ground surface damage due to liquefaction. The occurrence of sand-boils, bearing failure, etc. is best assessed using the probability of surficial damage due to liquefaction. Estimates of reconsolidation settlement also include significant uncertainty. Juang et al. (2013) indicated that log-normal standard deviation of settlements estimated from volumetric strain calculations, $\sigma_{\ln s}$, is about 0.31. At a regional-scale, the soil properties are also highly uncertain, and regional-scale assessments must include both the uncertainty in shear strain potential, $\sigma_{\ln \varepsilon_v}$, and the uncertainty in settlement given volumetric strain, $\sigma_{\ln s}$. Based on these considerations, the estimated deformations for this project have a log-normal standard deviation of about 1.0.

5.0 COSEISMIC LANDSLIDES

Strong shaking from a CSZ rupture could also trigger landslides within the study area. Landslides triggered by earthquakes are most likely to occur in areas where landslides have occurred previously. DOGAMI's SLIDO project mapped many historic and pre-historic landslides within the project extent, some of which are extremely large and are near the elements of the City's water system. Most existing landslides within the project extent are in the Clear Creek watershed or near David Hill.

5.1 SLOPE STABILITY METHODOLOGY

Slope stability depends on the balance between driving forces (gravity and seismic shaking) and resisting forces (soil strength and passive pressure). The factor of safety is the ratio of the shear strength of the soil to the shear stress along the sliding interface. A factor of safety less than 1.0 indicates that the slope is unstable. Permanent slopes are typically designed with a static factor of safety (i.e. no horizontal acceleration from earthquake shaking) of at least 1.5. Slopes exhibiting marginal static stability or slopes that have failed in the past are usually the most susceptible to earthquake-induced failure. These types of slopes commonly include head scarps from previous landslides, slopes that have been incised by rivers, and man-made slopes. Natural slopes composed of loose soil or decomposed rock are also susceptible to earthquake-induced landslides.

Coseismic slope stability is typically evaluated based on the horizontal acceleration necessary to destabilize the slope, also known as the yield acceleration, k_y. Accelerations greater than the yield acceleration can cause the slope to deform, since the driving forces are greater than the resisting forces. Slopes that are only marginally stable before shaking have lower yield accelerations than slopes that are statically stable. Chien and Tsai (2017) developed equations to calculate the yield acceleration of slopes based on the static factor of safety.

$$\mathrm{k}_y = \frac{(\mathrm{FS} - 1)g}{\tan\phi + 1/\tan\alpha} \tag{15}$$

where FS is the static factor of safety, g is the acceleration of gravity, ϕ is the friction angle in degrees along the sliding mass, and α is the ground slope in degrees.

Landslides triggered by earthquake shaking tend to be shallower and have different failure surfaces compared to static, groundwater-driven landslides. Wartman et al. (2013) evaluated landslide datasets following the 2011 Tohoku earthquake in Japan and concluded that most seismically-triggered landslides were composed of shallow, disrupted masses. Shallow, disrupted slides are typically associated with failure of steep slopes composed of loose soil or oversteepened head scarps from previous landslides. These types of slopes are both common in the Clear Creek watershed. However, deep, coherent slides can also be triggered by earthquake ground shaking (Grant et al., 2016). The triggering of deep, coherent slides are strongly influenced by the presence of deep, weak layers of soil, pore pressure at the sliding surface, and the resonance of ground motions within the landslide mass. The low-frequency, long-duration ground motions from a CSZ earthquake could potentially trigger larger coherent slides and produce more deformation than a shallow crustal earthquake with a same shaking amplitude.

Limit equilibrium analyses can assess the factor of safety for both shallow, disrupted landslides and deep, coherent landslides. For this study, the static factor of safety (before shaking) was calculated using the 3D limit equilibrium slope stability program published by the USGS called Scoops3D (Reid et al., 2015). The inputs required for Scoops3D included GIS-based rasters of ground surface elevation, piezometric groundwater elevation, and the elevation of different soil layers. Scoops3D calculated static factors of safety for many potential failure surfaces within the study area. The output from Scoops3D was used to calculate the yield acceleration using equation (15). Chien and Tsai (2017) have proposed correction factors to adjust equation (15) for very deep, coherent landslides. These correction factors accounted for passive resistance at the toe of the landslides and tended to increase the yield acceleration, and were calculated at several key locations within the Clear Creek watershed and near David Hill. Since the depth of the critical sliding surfaces calculated using Scoops3D tended to be shallow relative to the height of the slope, the increased yield accelerations using Chien and Tsai's correction factors were generally less than 10%.

Coseismic landslide deformations are typically estimated on a regional basis using empirical correlations to rigid-block deformation analyses. The rigid-sliding block assumption have been validated for many earthquakes, and regression to the sliding block deformation can be predicted using seismic loading intensity measures. Saygili and Rathje (2009) developed equations to estimate coseismic landslide deformation, D, with consideration for the peak ground acceleration, PGA, and the earthquake magnitude, M. These equations have the form:

$$\mathrm{D} = \exp\left(4.89 - 4.85\left(\frac{k_y}{\mathrm{PGA}}\right) - 19.64\left(\frac{k_y}{\mathrm{PGA}}\right)^2 + 42.49\left(\frac{k_y}{\mathrm{PGA}}\right)^3 - 29.06\left(\frac{k_y}{\mathrm{PGA}}\right)^4 + 0.72\ln(\mathrm{PGA}) + 0.89(\mathrm{M} - 6)\right) \quad (16)$$

where k_y is the yield acceleration in units of g and PGA is the peak ground acceleration in units of g. Equation (16) predicts coseismic deformation, D, in units of centimeters. Saygili and Rathje indicated that the uncertainty in deformation estimates is log-normally distributed with a standard deviation, $\sigma_{\ln\delta}$, that depends on the level of shaking, the steepness of the slope, and the strength of the geologic material. For the estimated level of shaking and geologic strength of slopes in the Clear Creek watershed and near David Hill, the standard deviation of slope deformation was estimated to be about 0.9. Cascade GIS, Inc. implemented equations (15) and (16) into GIS within the Clear Creek watershed and near David Hill.

5.2 CLEAR CREEK

Landslides in the Clear Creek study area have been previously mapped by DOGAMI and incorporated in DOGAMI's SLIDO project (Burns and Watzip, 2014). The SLIDO maps indicate that recent, historic, and pre-historic landslides are all present within the Clear Creek watershed. Figure 13 shows these mapped landslides.

In addition to the SLIDO data, information about landslides within the Clear Creek watershed was obtained for this study from geotechnical reports provided by the City. The reports indicate several landslides have occurred in the past 25+ years. These landslides required repairs to maintain road access into the watershed. Figure 14(a) shows a photograph of a landslide that occurred in 1996. Details of this landslide and repair designs are included in Dames & Moore's 1997 report. Figure 14(b) shows a photograph of an active landslide in the Clear Creek watershed that we encountered during the reconnaissance.

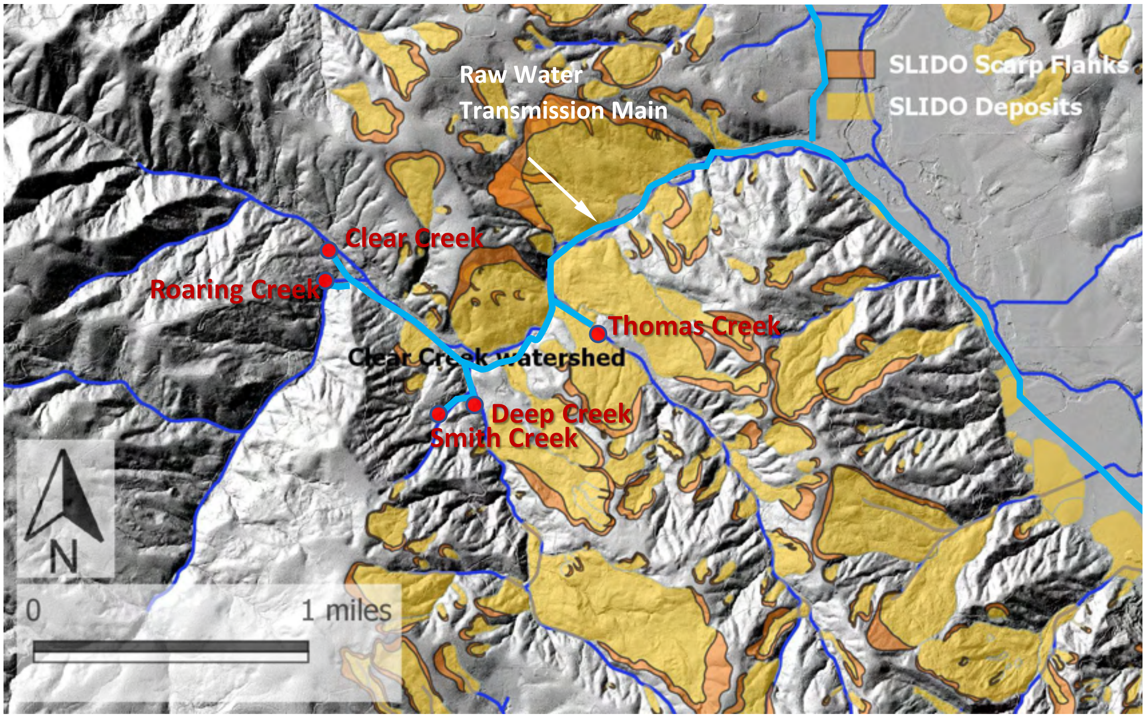


Figure 13: Mapped Landslides in SLIDO Database within the Clear Creek Watershed

Estimates of soil strength are necessary to calculate the static factor of safety and yield acceleration of slopes. Many sources (Keefer 2000, Burns et al. 2013, Dreyfus et al. 2013) have estimated and back-calculated the approximate strengths of surficial geologic units based on previous case histories. These estimates were combined with available subsurface data to estimate the strength and thickness of the geologic materials within the study area, which was used to calculate the factor of safety and yield acceleration using Scoops3D. Using the regionally-averaged values, locations where static stability or instability was falsely predicted were identified and the geologic strength values were adjusted to match the current observations, which was used to perform an updated slope stability analysis. Table 7 shows the estimated soil properties that resulted from this updated analysis. Figure 15 shows a map of the resulting static factor of safety estimates from Scoops3D.

Figure 14: Photographs of Landslides in Clear Creek Watershed

Table 7: Estimated Geologic Strength Values in Clear Creek Watershed

Surficial Unit	Soil	Depth range (ft)	Unit weight, γ (lbs/ft^3)	Friction angle, ϕ	Cohesion, c (lbs/ft^2)
Eocene-age volcanics (Ttv)	SILT; some clay	0 to 12	120	30°	500
	Clayey GRAVEL	12 to 30	125	36°	500
	Moderately weathered BASALT	Below 30	130	38°	1,500
Oligocene-age marine siltstone (Ts)	SILT; some clay	0 to 12	120	30°	500
	Clayey GRAVEL	12 to 30	125	36°	500
	Moderately weathered SILTSTONE	Below 30	130	38°	1,500
Colluvium landslide debris (Qls)	Clayey SILT	0 to 30	120	32°	0
	Weathered SILTSTONE	Below 30	130	38°	1,500
Recent alluvium (Qal)	Sandy SILT	0 to 12 ft	120	34°	0
	Slightly weathered BASALT	Below 12 ft	130	38°	1,500

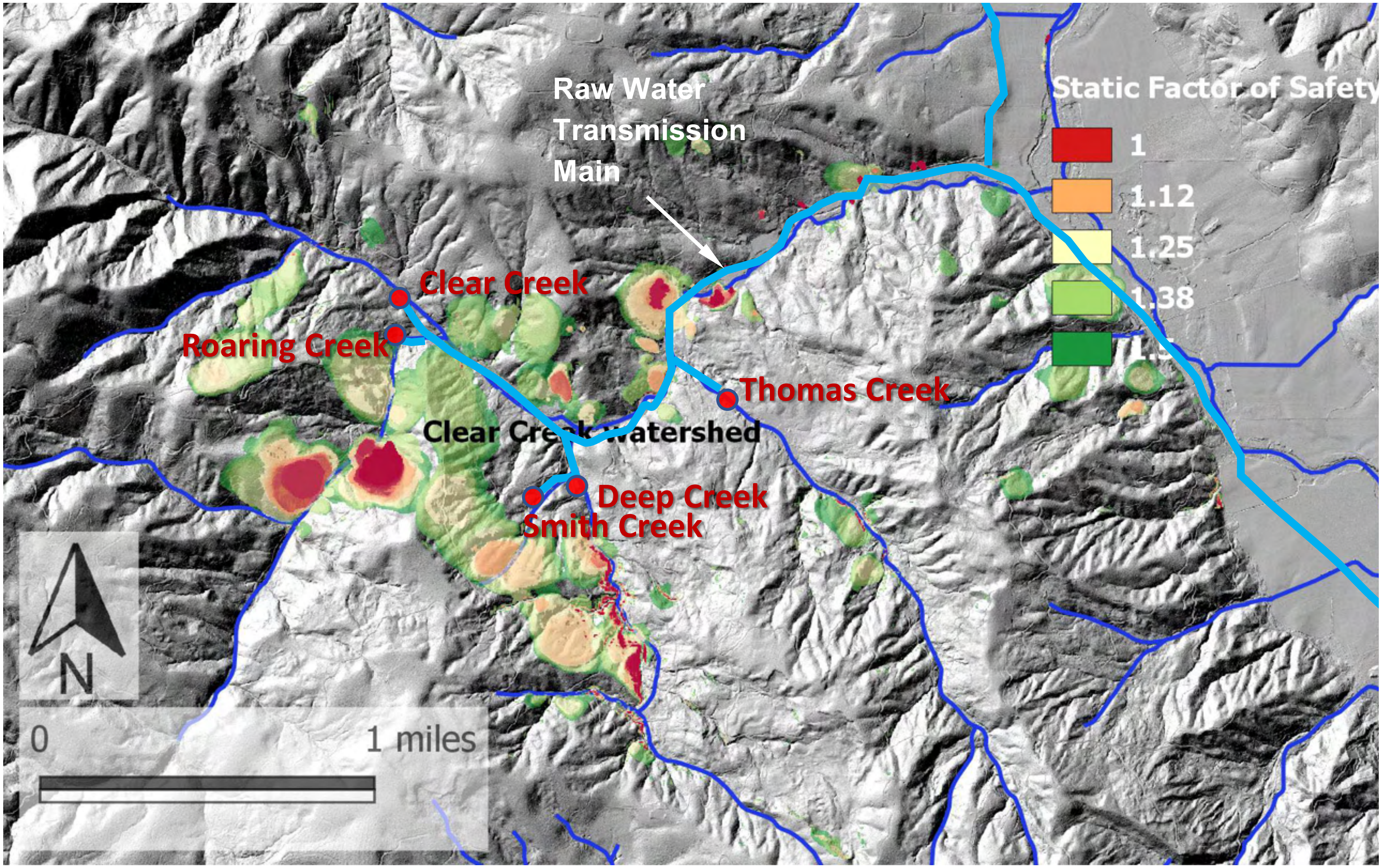


Figure 15. Clear Creek Static Factor of Safety

Many locations along Soda Springs Road are immediately below large slopes with numerous historic and pre-historic landslides. The limit equilibrium results indicate that the toe of these historic landslides ranges from marginally stable to unstable. In many locations, the static factors of safety approaches 1.0, indicating ongoing landslide activity. Forest Grove maintenance staff have indicated that the transmission line has been repaired several times near these locations, possibly indicating active landslide movements. These marginally stable slopes could potentially become unstable and fail catastrophically during an earthquake. The raw water transmission line follows the alignment of Soda Springs Road at this location and could be impacted if these landslides were retriggered. The limit equilibrium results also indicated that the steep slopes along Deep Creek and Roaring Creek are also potentially statically unstable with factors of safety approaching 1.0.

We used Equation (16) to estimate coseismic deformations for an M9 CSZ scenario. Figure 16 shows the resulting estimates. The analyses indicated that large deformations could occur at isolated locations near Soda Springs Road, and some of these coseismic landslides could impact the access road and raw water transmission line. The results also indicated that many coseismic landslides of varying extent could be triggered upstream of the diversion structures. Landslides upstream of the diversion structures could cause increased turbidity and introduce debris into the diversion structure pools. Following the 2001 M_w 6.8 Nisqually earthquake, the City of Olympia, WA reported increased turbidity in their water supply. After the very powerful 1964 M_w 9.2 Alaska earthquake, sediment load in rivers and streams was greatly increased during the spring runoff. A similar increase in turbidity could occur in the Clear Creek watershed after a large earthquake. The level of turbidity may remain high for a period of weeks or months after the main shock, especially if powerful aftershocks disturb failed landslide masses.

5.3 DAVID HILL

Landslides near David Hill have been previously mapped by DOGAMI and incorporated in DOGAMI's SLIDO project (Burns and Watzip, 2014). The SLIDO maps show locations of recent, historic, and pre-historic landslides all near David Hill. Figure 17 shows the mapped landslides near David Hill. The raw water transmission line crosses several of these landslides as it rises from Gales Creek to the Water Treatment Plant, including a historic landslide in Forest Glen Park. Distribution lines also cross landslides within the study area.

The City has provided photographic evidence of recent landslides near the David Hill Reservoir. These landslides appear to be relatively shallow and originated due to roadway cuts and fills in the hillside. Figure 18 shows two photographs of small landslides near the David Hill Reservoir. Severe erosion along the road and nearby slopes was observed during the reconnaissance.

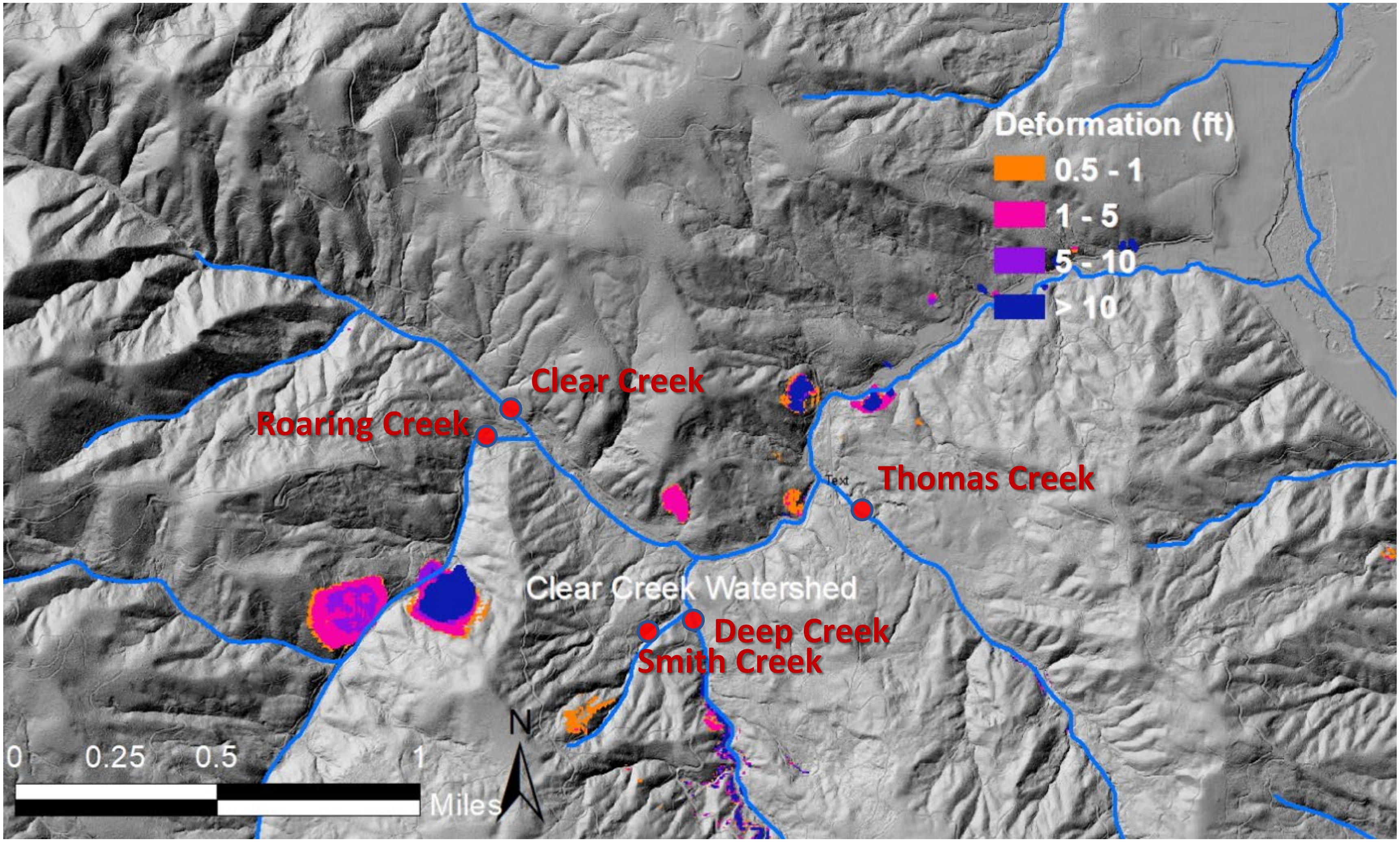


Figure 16: Clear Creek Estimated Deformation

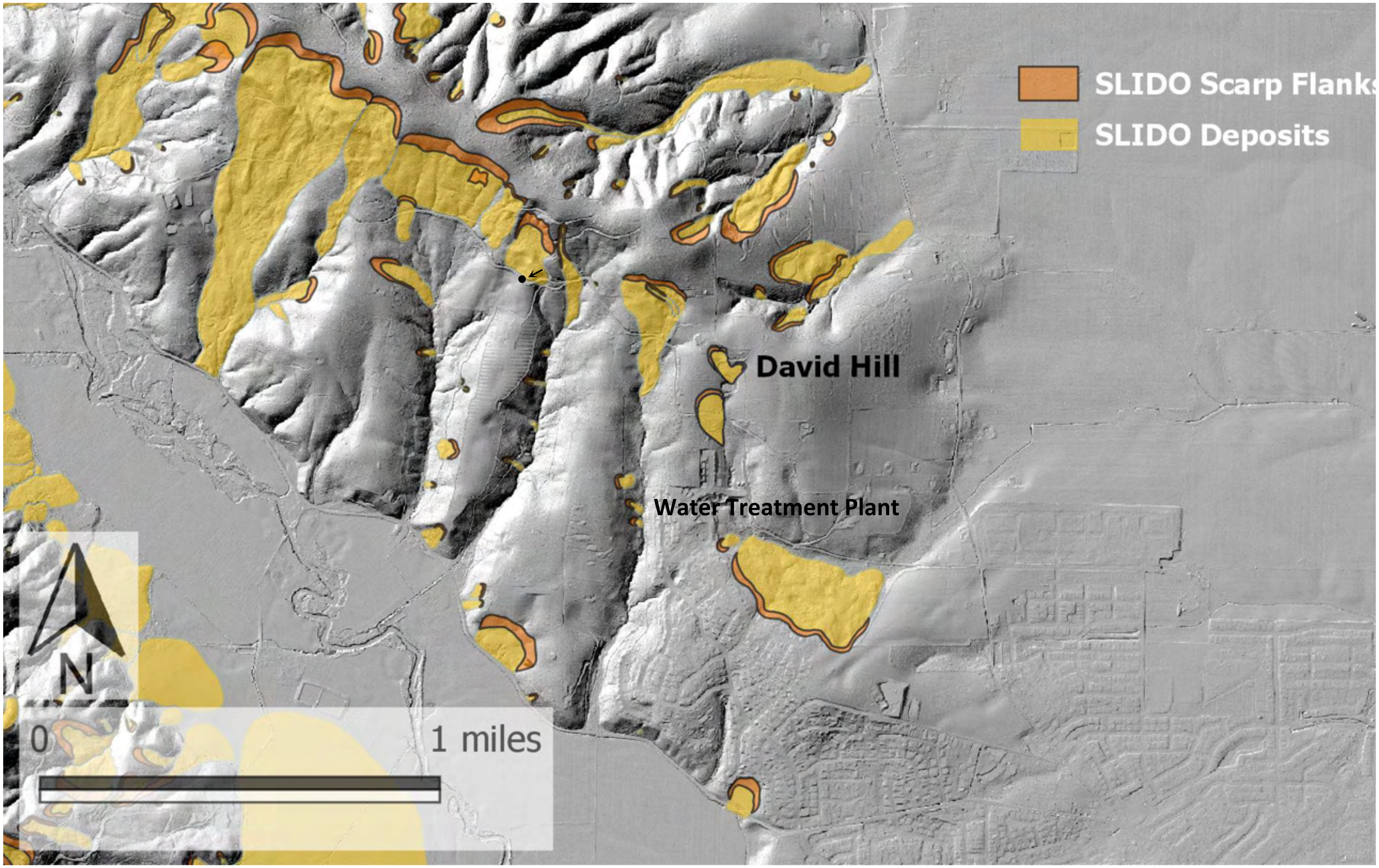


Figure 17: Clear Creek Mapped Landslides in SLIDO Database

Figure 18: Landslides Near David Hill Reservoir

For this study, geologic strength values near David Hill were estimated as described previously. Many authors have provided back-calculated estimates of soil strength for regional studies. When available, data from available boring logs was used to estimate subsurface properties. Following an initial analysis using Scoops3D, locations where static stability or instability was falsely predicted were identified using average, regional engineering properties. Based on this information, the geologic strength values were adjusted to match current conditions. Table 8 shows the resulting soil properties corresponding to each of the geologic units. Figure 19 shows the resulting static factor of safety estimates.

Table 8: Estimated Geologic Strength Values Near David Hill

Surficial Unit	Soil	Depth range (ft)	Unit weight, γ (lbs/ft^3)	Friction angle, ϕ	Cohesion, c (lbs/ft^2)
Oligocene-age marine siltstone (Ts)	Clayey SILT	0 to 17.5	110	30°	100
	Clayey SILT; decomposed SILTSTONE	17.5 to 30	120	32°	400
	Moderately weathered SILTSTONE	Below 30	120	38°	1,500
Colluvium landslide debris (Qls)	Clayey SILT	0 to 30	110	30°	100
	Weathered SILTSTONE	Below 30	130	38°	1,500
Willamette Silt (Qs)	Sandy SILT	0 to 60	120	34°	100
	Slightly weathered SILTSTONE	Below 60	130	38°	1,500

Slopes near David Hill have been incised by Gales Creek and other, smaller tributaries. The limit equilibrium results indicate that the stability of these slopes ranges from marginally stable to unstable with factors of safety approaching 1.0. Relatively small, active landslides have been reported near these locations, namely near Forest Glen Park. Forest Grove maintenance staff have indicated that the transmission line has been repaired near Forest Glen Park, possibly indicating ongoing landslide activity. The limit equilibrium results also indicate that the steep slopes north of the David Hill Reservoir range from marginally stable or potentially unstable with factors of safety approaching 1.0.

Coseismic deformations were estimated based on the limit equilibrium results using Equation (16). Figure 20 shows the resulting estimates of coseismic landslide deformation. The results indicate that very large deformations could occur near Forest Glen Park that could impact the raw water transmission line. Large deformations could also occur near the road accessing the David Hill Reservoir, potentially damaging distribution lines from the reservoir or inhibiting access to the reservoir.

The regional-scale analyses do not capture the increased cyclic stresses caused by the foundation pressure and lateral acceleration of the David Hill Reservoir. To evaluate the interaction between the reservoir and the slope, a site-specific analysis is necessary.

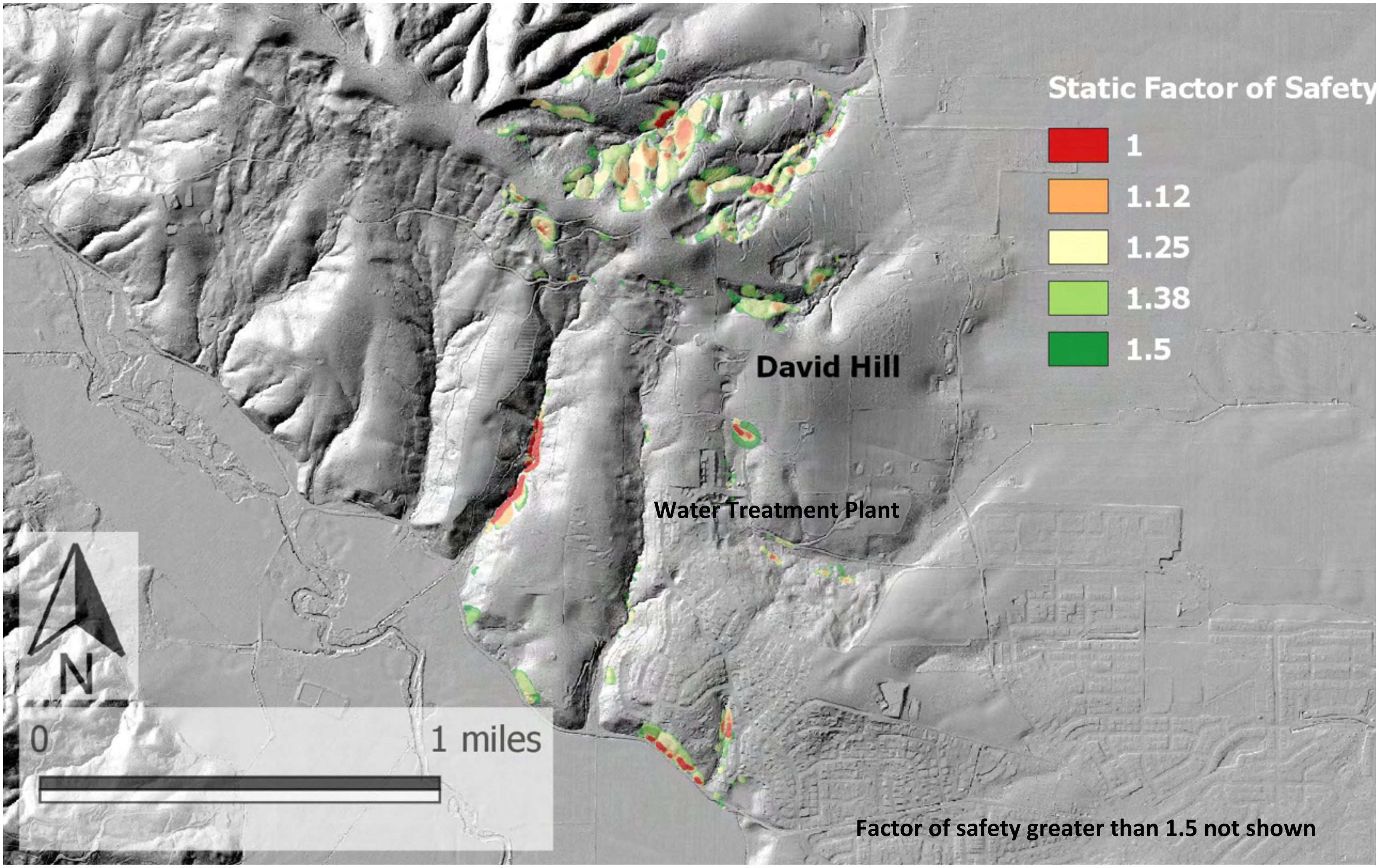


Figure 19: David Hill Static Factor of Safety

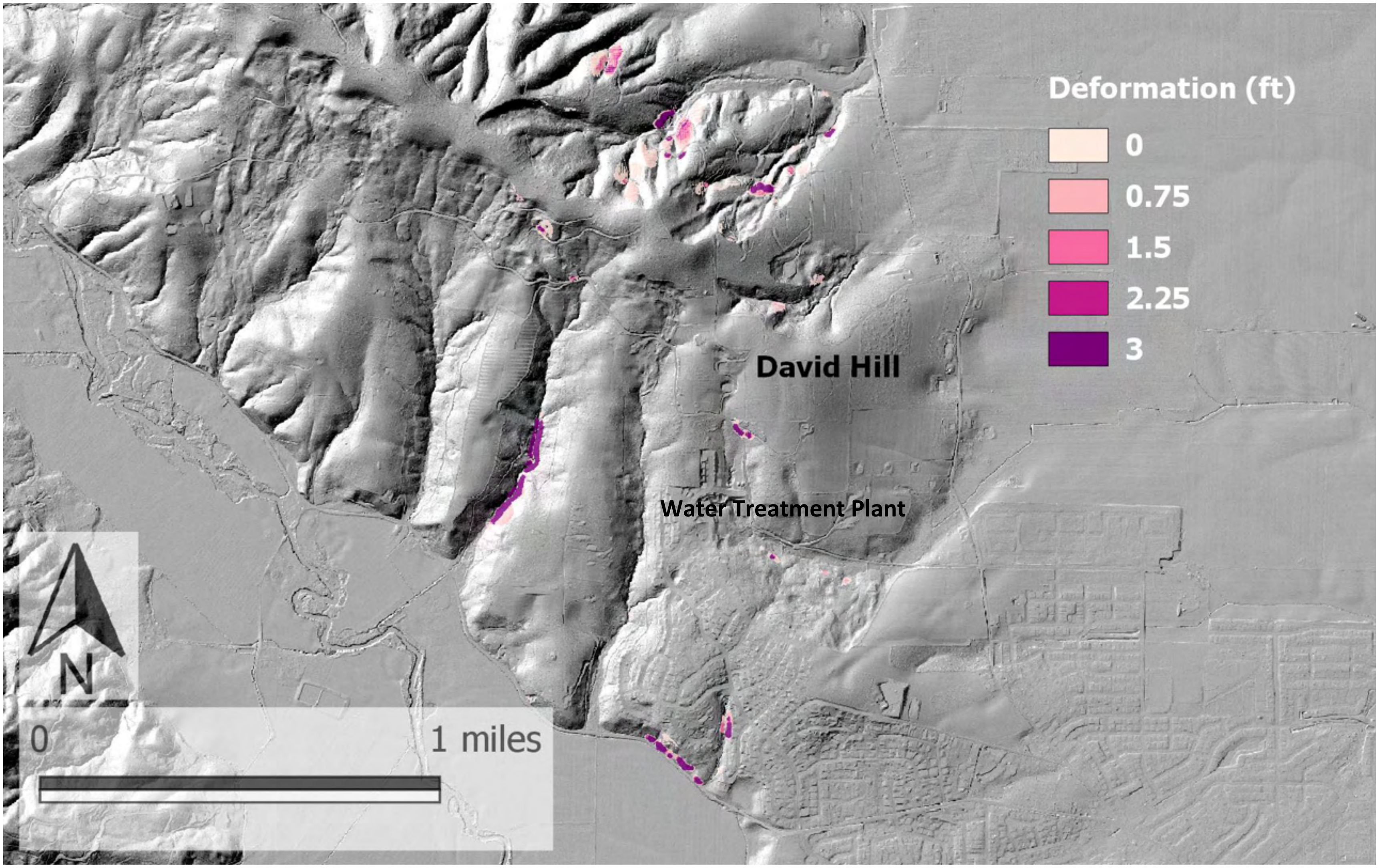


Figure 20: David Hill Estimated Deformation

6.0 FAULT RUPTURE

The Gales Creek Fault traverses parallel to Gales Creek. The fault displaces as a right-lateral reverse fault. The USGS has approximated the slip rate at about 0.016 mm/year. As such, we estimate offset from the fault rupture would be on the order of about 3 ft if a characteristic magnitude earthquake occurs. However, the trace of the fault has been concealed by recent alluvium, and the exact location of the fault is uncertain. Studies show that recurrence intervals associated with Gales Creek Fault rupture are significantly higher than the CSZ event considered for this study.

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Appendix C

Reservoir Seismic/Geologic Hazards Assessment

Reservoir Seismic/Geologic Hazard Assessment

City of Forest Grove

Water System Seismic Resiliency Plan

InfraTerra

Prepared by:
InfraTerra, Inc.
Date: May 2022

TABLE OF CONTENTS

1.0 INTRODUCTION

The City of Forest Grove (City) is developing a resiliency plan for their drinking water system. The City's two reservoirs, the 5 million-gallon (MG) Water Treatment Plant (WTP) reservoir and the 1 MG David Hill reservoir, are located on or near slopes that could potentially become unstable and deform during an earthquake. Deformation of these slopes could damage the reservoirs. The purpose of this assessment is to perform a preliminary evaluation of the stability of the adjacent slopes and estimate coseismic deformations using available subsurface information.

This document describes and presents the results of our slope stability analyses for the WTP reservoir and the David Hill reservoir in support of the City's water system seismic resiliency plan. Slope stability assessment is performed for scenario earthquakes on the Cascadia Subduction Zone (CSZ) and the Gales Creek fault.

This document presents preliminary analyses to support the system-wide hazard screening study. The subsurface data described in this document is based on readily available information for the purposes of this assessment only and should not be used for design.

2.0 WATER TREATMENT PLANT RESERVOIR

2.1 GENERAL DESCRIPTION

The 5 MG WTP reservoir was originally constructed circa 1948. It is approximately 150 ft long by 300 ft wide and is embedded about 19 ft deep. When full, the reservoir applies a bearing pressure of about 1,200 pounds per square foot (psf). A 20 inch-diameter supply line extends from the southeast corner of the reservoir and connects the reservoir to the water distribution system.

2.2 SITE DESCRIPTION

The eastern side of the facility has been filled such that the entire reservoir is embedded. The filled slope of the reservoir is about 37 ft-high at its tallest and slopes down at a grade of about 2.3H:1V (horizontal to vertical) to meet the original ground surface. The 20 inch-diameter supply line connecting the reservoir to the water distribution system is about 5 feet from the edge of the fill slope and is embedded about 20 feet deep.

The plan set shows that the fill slope to the east of the facility was originally designed at a grade of about 2H:1V. Reports from the WTP operator indicate that uncontrolled fill has been added to the slope over time. Lidar data for the area shows that the slope is currently graded at about 2.3H:1V. Minor cracking was observed at the crest of the slope during a site reconnaissance performed as part of this study.

2.3 SUBSURFACE CONDITIONS

The evaluation of the subsurface conditions at the WTP Reservoir is based on regional mapping (Smith and Roe, 2015); geotechnical boring well logs from publicly available sources including Oregon Department of Transportation (ODOT), Oregon Department of Geology and Mineral Industries (DOGAMI), and the Oregon Water Resources Department; reports with geotechnical boring data and subsurface descriptions provided by the City; and geological reconnaissance performed as part of this study.

The WTP Reservoir has been mapped by DOGAMI (Smith and Roe, 2015) as Oligocene-age marine siltstone (Ts). The available subsurface information reviewed for the SRP study included 33 soil samples within the Ts unit. These samples were from the upper 15 ft of the deposit and primarily consisted of residual soil that was described as soft to stiff silt and clay with medium to high plasticity. The average depth and energy-corrected penetration resistances, ($N_{1,60}$), of soils within the Ts unit were about 13 blows/ft. This blow count average is typically associated with medium dense coarse-grained soils or stiff fine-grained soils.

The original plan set for the WTP Reservoir drawings includes a table that lists four borings that were advanced to depths of up to 26 ft below the ground surface. The table describes the soils encountered in these borings as stiff clay and sandy clay. Groundwater was encountered in the borings at depths between 16 and 24 ft deep. Geotechnical data near the reservoir also includes three borings by Foundation Engineering, Inc. (FEI) drilled on May 14 and 15, 2018 (OBEC, 2018). The borings encountered about 15 to 20 ft of low to medium plasticity silty clay fill surrounding the reservoir. The consistency of the fill ranged from soft to stiff. Stiff to very stiff medium plasticity silty clay was encountered below the fill.

2.4 SITE OBSERVATIONS

A geological reconnaissance was performed by Christopher Hitchcock, PG, CEG and Mike Greenfield, PhD, PE on July 27 and 28, 2017. The reconnaissance observed the presence of soils that are susceptible to liquefaction as well as potential landslides within the study area for the Water System SRP project. At the reservoir location, longitudinal cracks were observed at the top of the slope outside of the wire-fence surrounding the reservoir. The toe of the slope appeared to be in good condition and no signs of movement was observed.

A site visit to observe the current conditions of the WTP Reservoir was also performed by Vladimir Calugaru, PhD, PE and Jenny Taing, PE of InfraTerra on March 20, 2018 as part of this project. The WTP Reservoir was observed to generally be in fair condition.

Minor cracks were observed on the roof slab. Concrete spalling, water damage, and exposed rebar were observed in one location within the valve chamber.

2.5 GROUND SHAKING

The seismic hazards considered for this project are based on median ground motions from either an M_W 9.0 (M9) CSZ earthquake at a distance of about 40 km (approximately 25 miles) or an M_W 6.8 (M6.8) Gales Creek fault earthquake at a distance of about 3 km (approximately 1.9 miles). The ground motions from a CSZ earthquake were based on DOGAMI's CSZ scenario (Madin and Burns 2013), and ground motions from a Gales Creek fault earthquake were based on a USGS Scenario Shakemap. Table 1 shows the spectral accelerations for each of these scenarios at the WTP.

Table 1: Spectral Acceleration Ordinates for Earthquake Scenarios at the WTP

Scenario	Period		
	PGA	0.2 sec	1.0 sec
Cascadia Subduction Zone	0.21 g	0.52 g	0.24 g
Gales Creek	0.54 g	1.34 g	0.63 g

The present assessment, initiated in 2017, is based on the 2013 DOGAMI estimate of median surface peak ground acceleration (PGA) in an M9 CSZ scenario earthquake. In 2018, DOGAMI updated the surface ground shaking maps for the M9 CSZ earthquake in the Open File Report O-18-02 (Bauer et al., 2018). Although these revisions resulted in significant changes from the 2013 maps in some areas, however, they are generally similar near the WTP and David Hill reservoirs. For example, at the WTP reservoir site, the 2013 maps show a PGA of approximately 0.21g for the M9 earthquake whereas the 2018 maps show a PGA of 0.22g. Therefore, the present assessment was not updated for the 2018 DOGAMI ground shaking estimates.

2.6 LIQUEFACTION ASSESSMENT

The WTP Reservoir is underlain by stiff clean to sandy clays which are unlikely to experience earthquake-induced liquefaction. Therefore, liquefaction-induced lateral spread and settlement are also unlikely to occur.

2.7 SLOPE STABILITY ASSESSMENT

Ground shaking from either earthquake scenario (M9 CSZ or M6.8 Gales Creek) could temporarily destabilize the slopes and cause large deformations around WTP. We analyzed the stability of the slopes using limit equilibrium analyses by the finite element method (Griffiths and Lane, 1999). The finite element method is preferred over the conventional method of slices, especially when the interaction of structures, like the reservoir, impact the stability of the slope. Figure 1 shows a profile of the reservoir and fill slope. Since very limited subsurface information was available to define the subsurface conditions, we estimated soil properties based on regional average values (Burns et al. 2013). Table 2 shows the estimated soil properties used for the limit equilibrium analyses. We assumed the groundwater elevation to be at the bottom of the reservoir for this preliminary assessment. This groundwater level represents our estimate of an annual average elevation. It should be acknowledged that groundwater could approach the ground surface during periods of wet weather.

Table 2: Subsurface Properties of the WTP reservoir

Soil	Depth range (ft)	Unit weight, γ (pcf)	Shear wave velocity (ft/s)	Friction angle, ϕ	Cohesion, c (psf)
Medium stiff clayey SILT	0 to 17.5	110	380	30°	100
Fill	0 to 30	110	380	30°	100
Stiff SILT	Below 17.5	120	600	36°	400

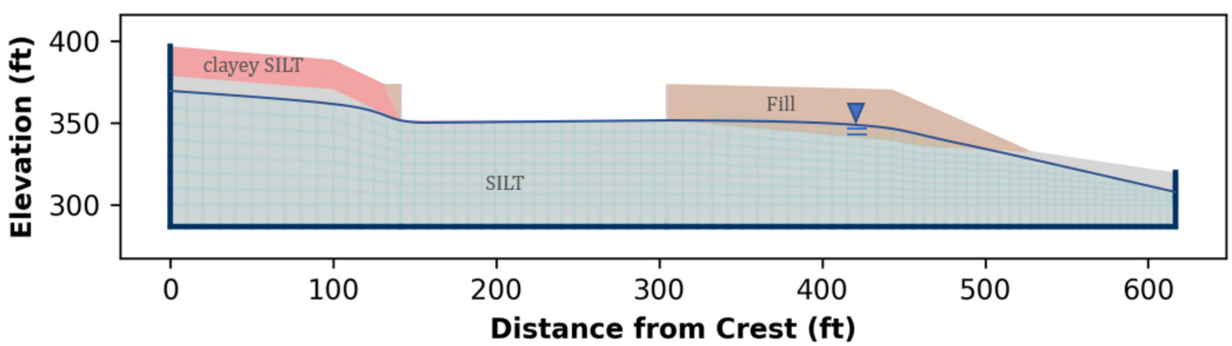

Figure 1: WTP subsurface profile

Slope stability depends on the balance between driving forces (gravity and seismic shaking) and resisting forces (soil strength and passive pressure). The factor of safety, FS, is the ratio of the shear strength of the soil to the shear stress along the sliding interface. An FS less than 1.0 indicates that the slope is unstable. Permanent slopes are typically designed with a static FS (no horizontal acceleration) of at least 1.5. Based on the assumed, average regional soil properties, the static FS of the fill slope is about 1.7. However, during periods of high groundwater, the strength of the soil is reduced, and the FS approaches 1.0. Therefore, during periods of high groundwater, the fill slope may become unstable.

The horizontal acceleration necessary to destabilize the slope and cause an FS = 1.0 is referred to as the yield acceleration. Figure 2 shows a profile of the yield acceleration through a section of the WTP slope. The yield acceleration at the top of the fill slope is about 0.23g. At the depth and offset of the 20-inch supply line, the yield acceleration is about 0.27g. Under the reservoir, the yield acceleration is about 0.33g. These values are based on the assumed seasonally average groundwater conditions.

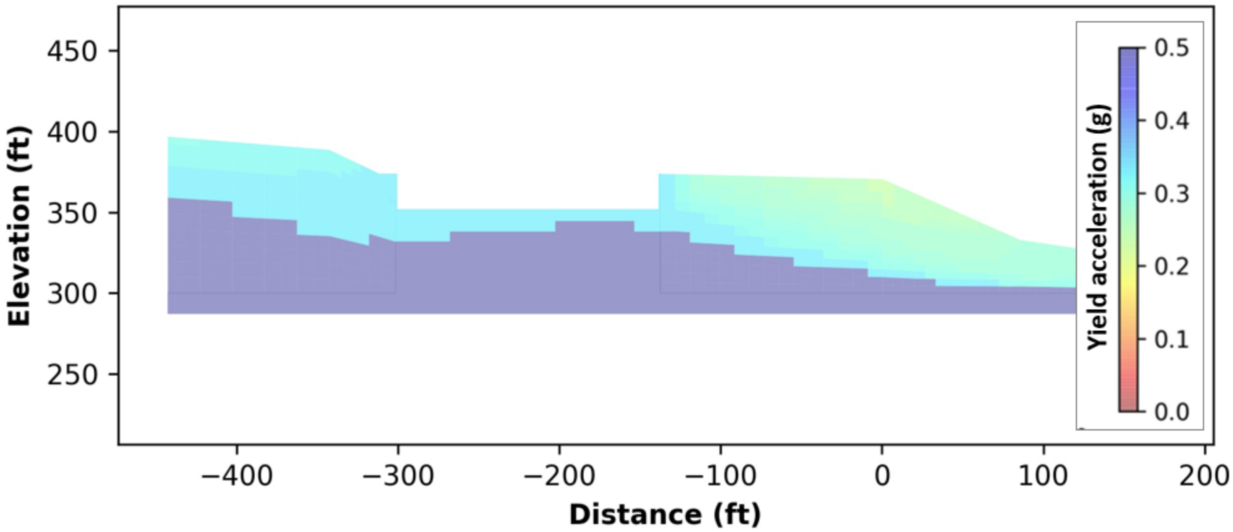

Figure 2: Yield Acceleration at the WTP

Deformable slopes oscillate at a spectral period equal to $4H/v_s$, where H is the thickness of the sliding mass and v_s is the shear wave velocity of the soil. Horizontal accelerations that are greater than the yield acceleration temporarily destabilize the slope and cause permanent deformation. The slope deformation model by Bray and Travasarou (2009) considers the spectral acceleration of deformable slopes and the earthquake magnitude as a proxy for the duration of shaking. The model also accounts for high-frequency waves scattering in large deformable masses.

Our analyses indicate that the crest of the fill slope could deform about 2 inches during a CSZ earthquake and about 1/2-inch during a Gales Creek earthquake. These deformations would likely extend to the depth and offset of the 20-inch supply line. Our analyses also show that the deformations of the reservoir would be less than 1/2-inch during either a CSZ or Gales Creek earthquake. These values represent median estimates of deformation for the two earthquake scenarios investigated for this study. The uncertainty in coseismic landslide deformations is relatively large and there is a possibility of damage to the 20-inch line at the pipe penetration into the reservoir wall. It is recommended that flexibility be added to this connection.

Our assessment did not show significant deformation of the cut slope above the reservoir. Assessment of the stability of the cut slope by FEI showed similar results.

3.0 DAVID HILL RESERVOIR

3.1 GENERAL DESCRIPTION

The David Hill reservoir was constructed in 1985 and consists of an approximately 96 ft-wide square concrete vault that is embedded between 13 and 16 ft deep. The reservoir has a capacity of 1 MG. When full, the reservoir applies a bearing pressure of about 1,400 psf.

L. R. Squire Associate documented subsurface conditions for the design of the David Hill reservoir in their 1981 report. They indicated clayey silt mantled the ground surface and extended to depths between 18 and 28 ft. The clayey silt was soft to very stiff with field standard penetration test N-values ranging from 4 to 18 blows/ft. The soil transitioned to weathered tuffaceous siltstone and sandstone below depths of 18 to 28 ft. Groundwater was encountered about 27 ft below the ground surface.

3.2 SITE DESCRIPTION

The natural grade of the hillside is about 2.2H:1V and the reservoir has been cut into the hillside such that the slope above the reservoir rises at a grade of about 1.5H:1V.

Photographs provided by the City show evidence of small, relatively shallow landslides in the slope above the David Hill reservoir. These landslides appear to be in man-made cuts and oversteepened slopes constructed as part of the road bench above David Hill reservoir. Surficial raveling and erosion were near the David Hill reservoir during a field reconnaissance performed by InfraTerra.

3.3 SUBSURFACE CONDITIONS

The evaluation of the subsurface conditions at the David Hill Reservoir is based on regional mapping (Smith and Roe, 2015); geotechnical boring well logs from publicly available sources including ODOT, DOGAMI, and the Oregon Water Resources Department; reports with geotechnical boring data and subsurface descriptions provided by the City; and geological reconnaissance performed by InfraTerra.

The David Hill Reservoir has been mapped by DOGAMI (Smith and Roe, 2015) as Oligocene-age marine siltstone (Ts). The subsurface conditions at the site was documented in the design report for the David Hill Reservoir by L. R. Squire Associates, Inc. (1981) and indicates that clayey silt mantled the ground surface and extended to depths between 18 and 28 feet. The clayey silt was soft to very stiff with field standard penetration test N-values ranging from 4 to 18 blows/foot. The soil transitioned to weathered tuffaceous siltstone and sandstone below depths of 18 to 28 feet. Groundwater was encountered about 27 feet below the ground surface.

3.4 SITE OBSERVATIONS

A geological reconnaissance was performed by Christopher Hitchcock, PG, CEG and Mike Greenfield, PhD, PE, of InfraTerra on July 27 and 28, 2017. The reconnaissance observed the presence of soils that were susceptible to liquefaction and potential landslides within the study area for the SRP Project. Additionally, the head scarp from the previous landslide described above was observed above the reservoir.

A site visit to observe the as-built condition of the David Hill Reservoir was performed by Vladimir Calugaru, PhD, PE and Jenny Taing, PE of InfraTerra on March 20, 2018 as part of this project. The David Hill Reservoir was observed to be in generally good condition. No significant cracks in the reinforced concrete walls or roof slab were observed.

3.5 GROUND SHAKING

The seismic hazards considered for this project are based on median ground motions from either an M9 CSZ earthquake at a distance of about 40 km (24.9 miles) or an M6.8 Gales Creek fault earthquake at a distance of about 3 km (1.9 miles). The ground motions from a CSZ earthquake were based on DOGAMI's CSZ scenario (Madin and Burns, 2013). Ground motions from a Gales Creek fault rupture were based on a USGS Scenario Shakemap scenario. Table 3 shows the spectral accelerations at the David Hill Reservoir from these sources.

Table 3: Spectral Acceleration Ordinates for Earthquake Scenarios at the David Hill Reservoir

Scenario	Period		
	PGA	0.2 sec	1.0 sec
Cascadia Subduction Zone	0.21 g	0.52 g	0.24 g
Gales Creek	0.56 g	1.40 g	0.56 g

3.6 LIQUEFACTION ASSESSMENT

Ground shaking, liquefaction-induced lateral spreading and settlement, and landslide hazards were assessed based on published data and liquefaction and deformation mapping performed for this project. As described above, the David Hill Reservoir is underlain by stiff stilt over siltstone which are unlikely to experience liquefaction in the event of a CSZ earthquake. Therefore, liquefaction-induced lateral spread and settlement are also unlikely to occur.

3.7 LANDSLIDE ASSESSMENT

Landslides near David Hill have been previously mapped by DOGAMI and incorporated in DOGAMI's SLIDO project (Burns and Watzip, 2014). The SLIDO maps show locations of recent, historic, and pre-historic landslides near David Hill. Figure 3 shows the mapped landslides near David Hill.

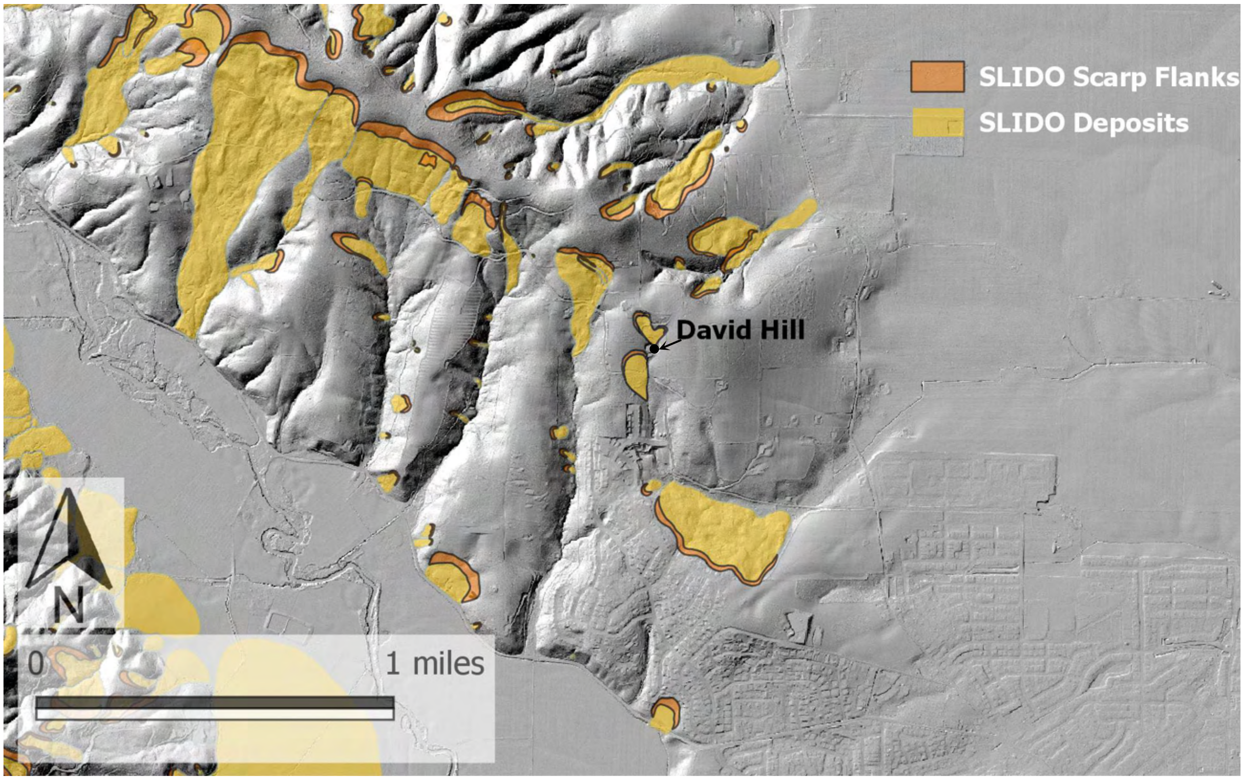

Figure 3: Mapped Landslides in SLIDO Database

Photographs provided by the City show evidence of small, relatively shallow landslides in the slope above the David Hill Reservoir during the 1996 flood (Figure 4 and Figure 5). These landslides appear to be in man-made cuts and oversteepened slopes constructed as part of the road bench above David Hill Reservoir. Surficial raveling and severe erosion were observed along the road and at nearby slopes reservoir during the geology field reconnaissance performed by InfraTerra. Relatively small, active landslides have been reported near these locations, namely near Forest Glen Park. Forest Grove maintenance staff have indicated that the raw water transmission main has been repaired near Forest Glen Park, possibly indicating ongoing landslide activity.

Figure 4: Historical Landslide behind David Hill Reservoir during 1996 Flood

Figure 5: Historical Landslide near David Hill Reservoir during 1996 Flood

3.8 SLOPE STABILITY ASSESSMENT

We analyzed the stability of the David Hill reservoir using limit equilibrium analyses by the finite element method. The soil properties for the analyses were estimated based on subsurface information described in L. R. Squire's report. Table 4 shows the input properties for the limit equilibrium analysis. For this preliminary seismic hazard analysis, the groundwater elevation was assumed to be at the bottom of the reservoir. However, groundwater levels fluctuate seasonally and can approach the ground surface during periods of wet weather. We also evaluated the stability of the reservoir and slope during high groundwater conditions. Figure 6 shows the profile for the limit equilibrium analyses with both seasonal average and high groundwater elevations.

Table 4: Subsurface Properties for David Hill Reservoir

Soil	Depth range (ft)	Unit weight, γ (pcf)	Shear wave velocity (ft/s)	Friction angle, ϕ	Cohesion, c (psf)
Medium stiff clayey SILT	0 to 18	110	450	30°	50
Stiff SILT (residual soil)	8 to 40	120	525	32°	400
Weathered SILTSTONE	Below 28 to 40	125	825	38°	1,600

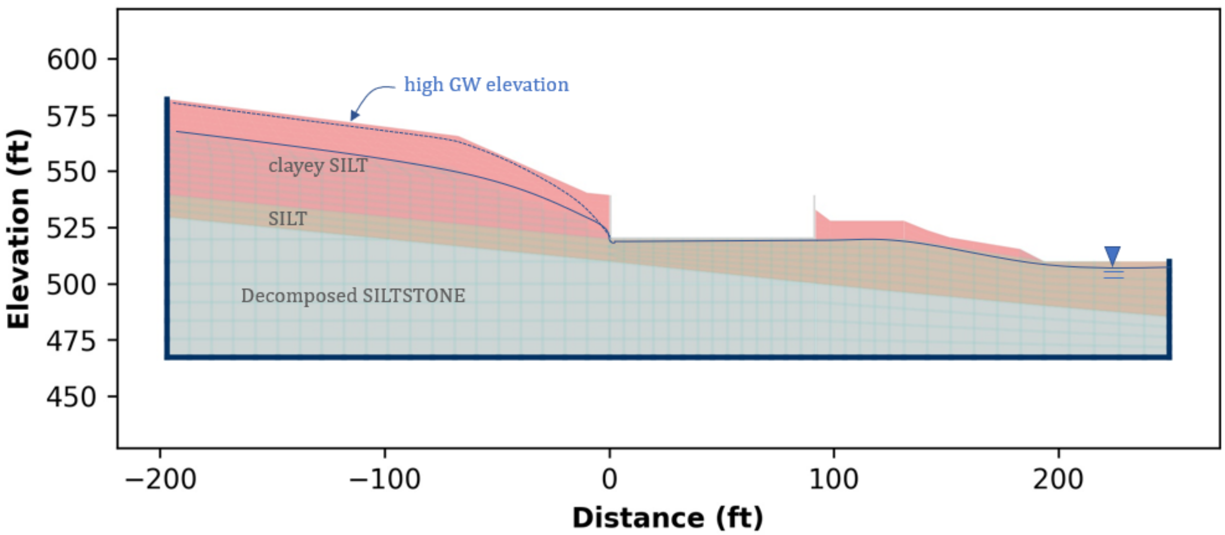

Figure 6: David Hill reservoir subsurface profile

We first analyzed the static factor of safety using the high groundwater conditions. Since the slope above the reservoir has failed during past periods of very wet weather, the slope stability model should predict low factors of safety during high groundwater conditions. Figure 7 shows the estimated factors of safety at the David Hill reservoir during high groundwater conditions. Indeed, the model shows that the factor of safety of the slope above the reservoir approaches 1.0 during high groundwater conditions, and the assumed soil strengths appropriately match the observed conditions. During the seasonal average groundwater conditions, the model indicates that the static factor of safety is about 1.4.

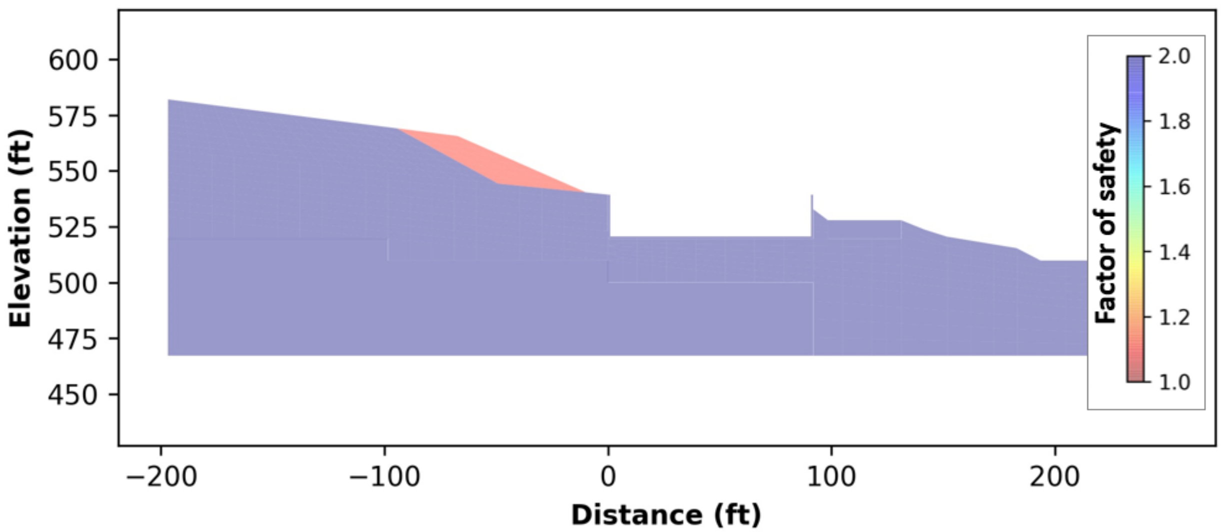

Figure 7: David Hill Factor of Safety during High Groundwater Conditions

Ground shaking from an earthquake could temporarily destabilize the slope and cause deformations. Figure 8 shows a profile of the yield acceleration through a section of the David Hill reservoir and slope. The yield acceleration of the slope above the reservoir is about 0.19g and the yield acceleration of the slope and reservoir is about 0.24g.

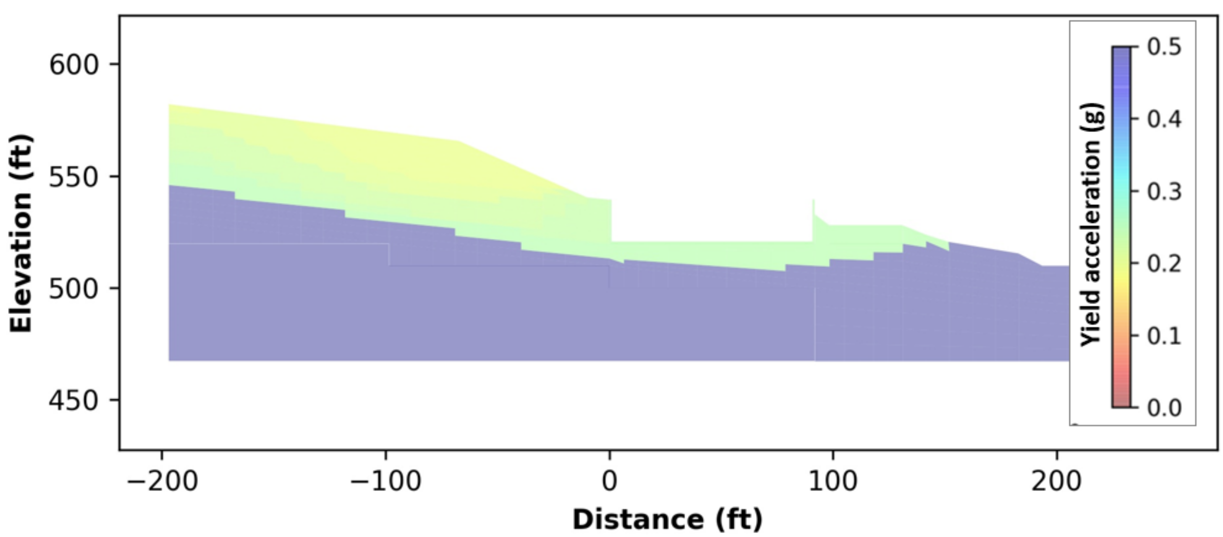

Figure 8: David Hill Yield Acceleration during Average Groundwater Conditions

Deformable slopes oscillate at a spectral period equal to about $4H/v_s$. Spectral accelerations greater than the yield acceleration temporarily destabilize the slopes and cause the slope to deform. We estimated slope deformations using the model by Bray and Travasarou (2009), which considers the spectral acceleration of deformable slopes and the earthquake magnitude as a proxy for the duration of shaking. This model indicates that the slope above the reservoir could deform about 4 inches during a CSZ earthquake and about 1.5-inch during a Gales Creek Fault scenario. The critical condition for deformations of the reservoir occurs when the reservoir is nearly empty. In this condition, deformations of the reservoir vault would be about 1.5-inch during a CSZ scenario and 1-inch during a Gales Creek Fault scenario. These values represent median estimates of deformation for the two earthquake scenarios investigated for this study and the uncertainty in coseismic landslide deformations may be relatively large.

4.0 REFERENCES

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Appendix D

Pipeline Repair Assessment Methodology

Pipeline Repair Assessment Methodology

City of Forest Grove

Water System Seismic Resiliency Plan

Prepared by:
InfraTerra, Inc.
Date: May 2022

InfraTerra

TABLE OF CONTENTS

Page

TABLES

FIGURES

1.0 INTRODUCTION

This appendix provides supplementary information for the Water System Seismic Resiliency Plan (SRP), and includes additional details describing the methodology and sensitivity studies for seismic assessment of pipelines. The objective of the appendix is to serve as a practical guide for engineers with background in earthquake engineering to understand the technical basis and approach used in this study.

2.0 PIPELINE ASSESSMENT METHODOLOGY

The seismic response of buried pipelines depends on their complex interaction with the adjacent soil. Pipeline seismic response is a function of both the imposed ground deformation and the type of pipeline construction, especially joints. The imposed ground deformation include two components as follows:

- Permanent Ground Deformation (PGD): Ground failure from liquefaction, landslide, or fault rupture results in PGD. Such ground deformations are not recovered after the earthquake shaking stops.
- Transient Ground Deformation (TGD): Seismic shaking introduces strains in the ground from the propagation of seismic wave propagation, and the ground returns to its original position at the end of shaking. TGD is a function of peak ground velocity (PGV).

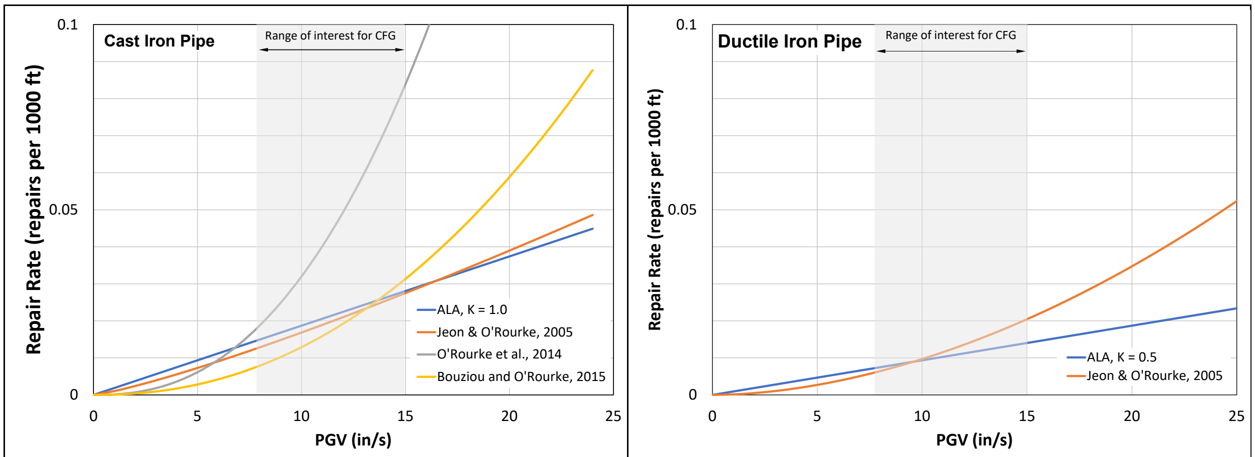
Seismic damage to a pipeline network is typically described in terms of estimated number of repairs. These repair estimates include both leaks and breaks. A leak occurs due to joint pullout, a round or longitudinal crack, a local loss of pipe wall, or a local tear in the pipe wall, which results in a loss of a pipeline's pressure boundary (Shi, 2006). A break is defined as a complete disengagement of pipe with water flowing out to the atmosphere from the full cross-section of the pipe. Observations from past earthquakes suggest that leaks are more common and generally constitute 80 percent to 90 percent of total repairs (Ballantyne 2008).

Pipeline repairs are generally estimated using repair data from past earthquakes expressed as a function of PGV and PGD in the form of empirically derived pipeline fragility relationships. These relationships are developed using statistical analysis of pipe repair data from past earthquakes. The fragility functions provide pipeline repair rates as a function of pipeline type and PGD or TGD. Distribution of PGV and PGD for the Moment Magnitude 9.0 (M9) Cascadia Subduction Zone (CSZ) earthquake in the City's service area is shown in Plates 5 through 6 and 9 through 16 of the Water System SRP report, respectively.

Some of the commonly available empirical fragility functions for buried pipelines include the American Lifelines Alliance (ALA, 2001), Jeon and O'Rourke (2005); O'Rourke et al. (2014); and Bouziou and O'Rourke (2015). The ALA (2001) relationships provide guidance for a range of pipeline and joint types for both PGD and TGD, the Jeon and O'Rourke (2005) relationship applies only to TGD for cast iron, ductile iron and asbestos cement pipelines, and the O'Rourke et al. (2014) and Bouziou and O'Rourke (2015) relationships address PGD and TGD but apply only to cast iron, asbestos cement, and PVC pipelines.

A comparison of repair rates for cast iron and ductile iron pipelines computed using different fragility relationships for TGD is shown in Figure 1. The figure shows that for cast iron pipelines with cement or lead-caulked joints, the ALA (2001) and Jeon and O'Rourke (2005) relationships give similar results. Repair rates from the O'Rourke et al. (2014) and the Bouziou and O'Rourke (2015) relationships are substantially higher. The higher repair rates from these two relationships are likely due to their use of the data from the New Zealand's Canterbury Earthquake Sequence (CES) of 2010 – 2011. The CES consisted of three successive earthquakes within the span of a few months. It is likely that the use of data from successive earthquake in the same region include the disturbance and residual pipeline deformation caused by the earlier earthquakes in the sequence.

The results from all four relationships are generally similar for PGV in the 8 in/sec to 14 in/sec range, which is the range of interest for this study (Figure 1). For this reason, the ALA (2001) relationships, although not as rigorous as the other relationships, were used for the Water System SRP because of its simplicity.



(a) Cast Iron Pipeline Fragilities for TGD

(b) Ductile Iron Pipeline Fragilities for TGD

Figure 1: Comparison of TGD Fragilities for Cast Iron and Ductile Iron Pipelines

Table 1 shows the ALA (2001) relationship for both TGD and PGD. The coefficients K_1 and K_2 in these relationships are a function of pipeline material type, joint type, and soil conditions. ALA used mostly engineering judgment as a basis for recommending different K_1 and K_2 coefficients as a function of joint type and pipe size. The recommended coefficients range from 1.0 for cast iron pipelines with cement or lead-caulked joints to 0.15 for arc-welded steel pipelines (lap welded) located in non-corrosive soils.

The ALA-recommended coefficients used for this study are shown in Table 2. For pipeline types where a range of K_1 and K_2 coefficients were provided for different joint types (cast iron, concrete cylinder, and welded steel pipes), conservative interpretation of joint type was used for this study because of uncertainty in the actual as-built condition of the pipelines.

For the City's pipeline network, repair estimates were developed using PGD and PGV values from the GIS maps developed for this project. For areas subjected to PGD, the largest deformation resulting from lateral spreading, settlement, or landslides was used and the final repair rate estimates used the highest calculated repair rate resulting from either PGD or TGD.

Table 1: Pipeline Repair Rates (ALA, 2005)

Ground Deformation	Repair Rate[1]	Lognormal Standard Deviation	
Transient Ground Deformations (TGD)	$RR = K_1 \cdot 0.00187 \cdot PGV$	1.15	(1)
Permanent Ground Deformation (PGD)	$RR = K_2 \cdot 1.06 \cdot PGD^{0.319}$	0.74	(2)

Note:

1. Units: Repair Rates are Number of Repairs in 1000 feet of pipeline; PGV is in inches/second, and PGD is in inches

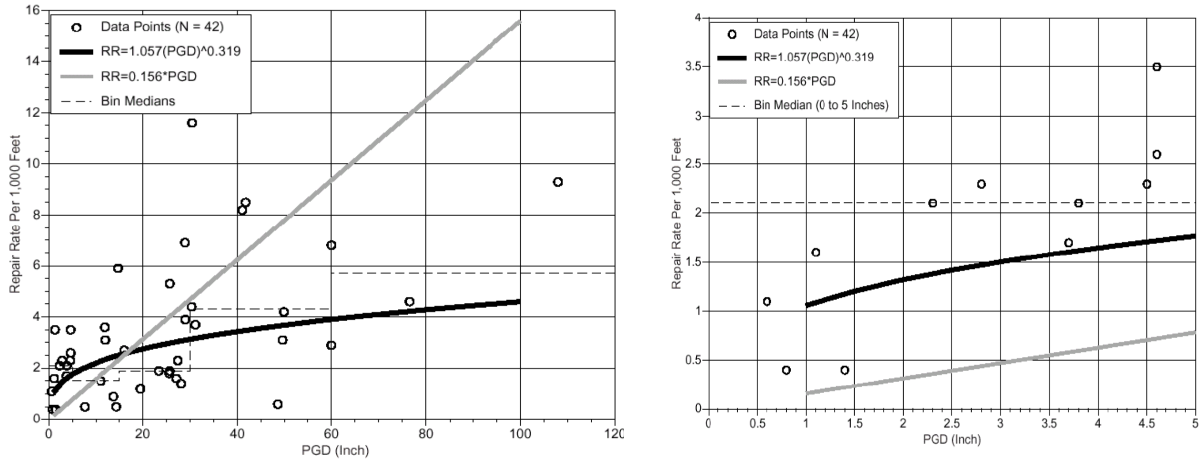
Table 2: K_1 and K_2 Factors for Select Pipeline Types (ALA, 2001)

Pipeline Type	Joint Type	K_1	K_2
Cast Iron	Cement	1.0	1.0
Ductile Iron	Rubber Gasket	0.5	0.5
Concrete Cylinder Pipe	Cement	1.0	1.0
Welded Steel (small diameter)[1]	Rubber Gasket	0.7	0.7
Welded Steel (large diameter)[1]	Rubber Gasket	0.15	0.15
PVC	Rubber Gasket	0.5	0.8
Other Pipelines[2]	Various	1.0	1.0

Note:

1. Small diameter welded steel pipes are defined as those with diameters less than 12 inches. Large diameter welded steel pipes are defined as those having diameters equal to or greater than 12 inches.
2. "Other Pipelines" include copper, iron, polyethylene, and unspecified materials. There is limited empirical data available for these pipeline types and values of 1.0 were assumed for the K_1 and K_2 coefficients.

The ALA empirical relationships for PGD were based on 42 data points from four earthquakes (1989 Magnitude 6.9 Loma Prieta, 1983 Magnitude 7.8 Nihonkai-Chubu, 1971 Magnitude 6.6 San Fernando, and the 1906 Magnitude 7.9 San Francisco earthquakes) with liquefaction as the predominant mechanism of ground failure. As described in the ALA, there is widespread scatter in these data points and oftentimes, large areas were assessed with a single shaking intensity value, ignoring microzonation issues, actual mileages of pipe, pipe type, and level of shaking and/or induced PGD. Databases with detailed documentation of pipe damage in earthquakes is relatively limited (Figure 2), leading to significant uncertainty in estimates. ALA provides lognormal standard deviation for 1.15 and 0.74 for repair rates computed for TGD and PGD, respectively.



(a) All Data (b) Expanded Scale (PGD<5)

Figure 2: Repair Rates as a Function of PGD (ALA, 2001)

Other sources of uncertainty include estimates of peak ground acceleration (PGA), PGV, PGD. The lognormal standard deviation for PGA is based on the standard deviation of ground motion prediction equations (GMPE) used by DOGAMI to compute the ShakeMap for an M9 earthquake on the Cascadia Subduction Zone (CSZ). The PGV values in this study use the Newmark and Hall (1982) relationship between PGA and PGV. The lognormal value represents the average of standard deviation for the 1.0 second spectral acceleration (S_{a1}) for the three GMPEs used in the M9 CSZ ShakeMap. Standard deviation for S_{a1} to estimate standard deviation for PGV was based on recommendations by Gregor et al., 2002.

The cumulative uncertainty for pipelines in liquefiable areas was obtained using the square root sum of squares (SRSS) combination of individual uncertainties in PGA, PGD, and ALA pipeline repair estimate for PGD. Similarly, the cumulative uncertainty for pipelines in non-liquefiable areas were obtained using the SRSS combination of the uncertainty in PGV and ALA pipeline repair estimate for PGV.

PGD estimates were computed using the methodology described by Zhang et al., 2004. The study shows that about 90 percent of the calculated lateral spread displacement using their approach showed variations between 50 to 200 percent of the measured values. This variation is approximately equivalent to a lognormal distribution with a standard deviation of 0.42, which was used for this study. This uncertainty is similar to the uncertainty estimated in other lateral spreading studies (Youd et al., 2002; Franke and Kramer, 2014).

The lognormal standard deviations used for this study are presented in Table 3.

Table 3: Lognormal Standard Deviation for Pipeline Repairs

Parameter	Lognormal Standard Deviation
Peak Ground Acceleration (PGA)	0.63
Peak Ground Velocity (PGV)	0.73
Permanent Ground Deformation (PGD)	0.42
ALA Pipeline repair for PGD	0.74
ALA Pipeline repair for PGV	1.15
Cumulative, Liquefiable Zone	1.06[1]
Cumulative, Non-liquefiable Zone	1.36[2]

[1] Based on square root of the sum of squares (SRSS) of 0.63, 0.42, and 0.74.
[2] Based on SRSS of 0.73, and 1.15.

Our analyses show that on average, the pipeline network for the City experiences less than 2 inches of PGD. At small deformations, there are very limited data points available in the ALA database (only 4 points for PGD less than 2 inches). Therefore, repair rate estimates for small values of PGD are not well constrained. In areas subjected to small PGD estimates, it is possible that the empirical ALA relationship may overestimate the total number of repairs. It is our engineering judgement that PGD of less than 1-inch should result in negligible repairs; however, for such values, the ALA relationship predicts significantly higher repair estimates.

Repair rates were computed assuming a PGD cutoff of 1, 2 and 3 inches to evaluate the impact of small PGD values. In other words, in these evaluations, repair rates from PGD were evaluated (using Equation 2) only for areas experiencing greater than an inch of deformation (1-inch cutoff), then in areas experiencing greater than 2 inches of deformation (2-inch cutoff), and in areas experiencing greater than 3 inches of deformation (3-inch cutoff). Areas with deformations smaller than the specified cutoff were assumed to experience zero pipeline breaks and leaks resulting from PGD. In these areas, repair rates were estimated using the TGD relationship (Equation 1). Additionally, an evaluation considering all PGD (i.e., no PGD cutoff) was performed for comparison.

The results presented in the Water System SRP represent repair rates considering PGD that are greater than 1 inch. Where PGD is less than an inch, TGD relationship was used to compute breaks and leaks.

For the purposes of this study, the median number of repairs refers to the calculated repairs for the 1-inch PGD cutoff. Cumulative lognormal standard deviation (Table 3) was used for computing uncertainty in repair estimates.

3.0 PIPELINE REPAIR ESTIMATES

3.1 BACKBONE PIPELINES

The City's backbone water system includes 9.1 miles of the raw water transmission main (RWTM), 1.6 miles of 24-inch Joint Water Commission (JWC) finished water transmission line (TL) and 13.4 miles of distribution system pipelines. The following sections summarize estimated repair rates for different component of backbone pipelines. The backbone water system is highlighted in Plate 1 of the Water System SRP report.

3.1.1 Raw Water Transmission Main (Backbone)

The RWTM runs almost parallel to Gales Creek and is subject to the significant liquefaction hazard present along the creek. Median repair estimates for the various PGD cutoffs for the first-tier (Stringtown Road Bridge to WTP) and second-tier (river intakes to the Stringtown Road Bridge) pipelines in an M9 CSZ earthquake are presented in Table 4. Values in parenthesis show results from a PGD cutoff of 3, 2 and 0 inches. The results presented in the Water System SRP (referred to as the median) are shown in bold and represent the 1-inch PGD cutoff.

Table 4: Raw Water Transmission System Pipeline Repairs Sensitivity to PGD

Pipeline Type	First-Tier Backbone		Second-Tier Backbone	
	Total Length (miles)	Total Repairs[1]	Total Length (miles)	Total Repairs[1]
Concrete Cylinder Pipe[2]	1.8	**2** *(0, 1, 6)*	6.0	**11** *(1, 1, 30)*
Cast Iron[3]	-	N/A	1.2	**0** *(0, 0, 2)*
Total[4]	1.8	**2** *(0, 1, 6)*	7.3	**11** *(1, 1, 32)*

Note:

1. In Total Repairs columns, the italicized numbers in the parenthesis represents total repairs considering PGD cutoff of: (3-inch, 2-inch, 0-inch). The bold number represents the results presented in the Water SRP, which considers a PGD cutoff of 1-inch.
2. Concrete Cylinder Pipe includes pipelines marked as CCP in City GIS files.
3. Cast Iron pipe includes pipelines marked as CI and CI TYTON in City GIS files.
4. Minor differences in total length of pipelines due to rounding.

The median ±1 standard deviation repair rates were estimated using the cumulative standard deviations presented in Table 3. The estimated repair rates range from 1 to 6 for the first-tier RWTM backbone and from 4 to 32 for the second-tier backbone RWTM.

3.1.2 Backbone Distribution System

The City's backbone distribution pipelines are primarily cast iron and ductile iron pipelines, of which cast iron pipelines have shown to be highly vulnerable to damage in earthquakes. The lengths and estimated repairs for a PGD cutoff of 0, 1, 2, and 3 inches for the different classifications of backbone distribution pipelines are presented in Table 5. The results presented in the Water System SRP (referred to as the median) are shown in bold and represent the 1-inch PGD cutoff.

Table 5: Backbone Distribution Pipeline Repairs Sensitivity to PGD

Pipeline Type	First-Tier Backbone		Second-Tier Backbone		Future Backbone	
	Length (mi)	Total Repairs[1,5]	Length (mi)	Total Repairs[1,5]	Length (mi)	Total Repairs[1,5]
Cast Iron[2]	5.8	**25** *(1, 16, 32)*	2.0	**5** *(0, 1, 11)*	0.2	**1** *(0, 0, 1)*
Ductile Iron[3]	2.2	**4** *(0, 2, 6)*	2.4	**1** *(0, 0, 4)*	0.5	**2** *(0, 0, 2)*
Other[4]	<0.1	**0** *(0, 0, 1)*	<0.1	**0** *(0, 0, 1)*	<0.1	**0** *(0, 0, 1)*
Total[5]	8.0	**29** *(1,18, 39)*	4.6	**6** *(1, 1, 15)*	0.8	**2** *(0, 1, 3)*

Note:

1. In Total Repairs columns, the italicized numbers in the parenthesis represents total repairs considering PGD cutoff of: (3-inch, 2-inch, 0-inch). The bold number represents the results presented in the Water SRP, which considers a PGD cutoff of 1-inch.
2. Cast Iron pipe includes pipelines marked as CIP in City GIS files
3. Ductile Iron pipe includes pipelines marked as DIP City GIS files
4. Other pipelines include pipelines include unspecified pipelines in City GIS files.
5. Minor differences in total pipeline length and total repairs due to rounding.

The median ±1 standard deviation repairs estimates range from 10 to 84 for the first-tier distribution backbone, 2 to 17 for the second-tier backbone RWTM, and 1 to 7 for future distribution backbone.

3.1.3 JWC Finished Water Transmission Pipeline (Backbone)

As shown in Plates 9 of the Water System SRP, most of the 24-inch JWC TL (approximately 1.3 miles out of a total length of 1.6 miles) is subject to liquefaction hazard. There are an estimated 11, 10, 8, and 4 repairs for the 0, 1, 2, and 3-inch PGD cutoff. The results presented in the Water System SRP (referred to as the median) represents the 1-inch PGD cutoff. The numbers of repair for the median ±1 standard deviation range from 3 to 28.

3.2 DISTRIBUTION SYSTEM PIPELINES

Most of the distribution system pipelines (43.7 miles, approximately 62 percent of total) are located within liquefaction hazard zones (Plate 9 of Water System SRP).

Using the ALA empirical fragility relationships, the estimated repairs for the various PGD cutoffs for the distribution system pipelines are summarized in Table 6. As shown in the table, there are a total of 213 estimated repairs for the non-backbone distribution pipeline. The median ±1 standard deviation for repairs range from 74 to 616.

Table 6: Non-Backbone Distribution Pipeline Repairs Sensitivity to PGD

Pipeline Type	Length (mi)	Total Repairs[1]
Cast iron[2]	25.3	**106** (3, 50, 137)
Ductile iron[3]	40.9	**86** (4, 34, 113)
Other[4]	4.9	**22** (4, 9, 28)
Total[5]	71.1	**213** (11, 94, 278)

Note:

1. In Total Repairs columns, the italicized numbers in the parenthesis represents total repairs considering PGD cutoff of: (3-inch, 2-inch, 0-inch). The bold number represents the results presented in the Water SRP, which considers a PGD cutoff of 1-inch.
2. Cast Iron pipe includes pipelines marked as CIP in City GIS files
3. Ductile Iron pipe includes pipelines marked as DIP City GIS files
4. Other include pipelines marked as C900, (PVC), PVC, COPPER (Copper), GALV/GALVINIZED (Galvanized Steel), GI (Galvanized Iron), POLY (Polyethylene?), STEEL (Steel), and unspecified in City GIS Files
5. Minor differences in total repairs due to rounding.

3.3 SUMMARY AND DISCUSSION OF RESULTS

Total repairs for each pipeline system for 0, 1, 2, and 3-inch PGD cutoff and for the ±1 standard deviation around the 1-inch PGD cutoff are summarized in Table 7. Values shown in bold are the median results presented in the Water System SRP. As shown in the table, there is a significant difference between the 3-inch and 2-inch PGD cutoff. For example, for the non-backbone distribution pipelines, the number of repairs for the 2-inch PGD cutoff is about 9 times the number of repairs for the 3-inch PGD cutoff whereas the 1-inch PGD cutoff (median) is only about 2 times the number of repairs for the 2-inch cutoff.

The 0, 1, 2, and 3-inch PGD cutoff repair estimates are generally within or similar to the median ±1 standard deviation range around the 1-inch PGD cutoff. Although generally outside of the median ±1 standard deviation range around the 1-inch PGD cutoff, the 3-inch PGD cutoff estimate is within the same order of magnitude as the median -1 standard deviation for the 1-inch PGD cutoff case, with differences of 3 or fewer repairs. The exceptions include:

- the non-backbone distribution pipelines, where the 3-inch PGD cutoff shows estimates (11 repairs) that are significantly less than the median –1 standard deviation for 1-inch PGD cutoff case (74 repairs) and
- the first-tier backbone distribution pipelines, where the 3-inch PGD cutoff shows estimates (1 repair) that are an order of magnitude smaller than the median -1 standard deviation for 1-inch PGD cutoff case (10 repairs).

It is our engineering judgment that the 1-inch PGD cutoff is the best estimate for the number of anticipated repairs. The ±1 standard deviation around the 1-inch PGD cutoff provides the lower and upper bound estimates and represents the uncertainties related to ground shaking, deformation estimates, and ALA methodology.

Table 7: Comparison of Total Repairs for Different PGD Cutoff Values

Pipeline Category	3-inch PGD cutoff	2-inch PGD cutoff	1-inch PGD cutoff		No PGD cutoff
			Median	Median ±1 Standard Deviation	
First-Tier Backbone	0	1	**2**	1-6	6
Second Tier Backbone	1	1	**11**	4-32	32
24-inch JWC TL	4	8	**10**	3-28	11
First Tier Backbone Distribution	1	18	**29**	10-84	39
Second Tier Backbone Distribution	1	1	**6**	2-17	15
Future Backbone Distribution	0	1	**2**	1-7	3
Non-backbone Distribution	11	94	**213**	74-616	278

Note:

1. Median represents the 1-inch PGD cutoff estimate and considered our best estimate of repairs.

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Appendix E

Reservoir Seismic Assessment

Reservoir Seismic Assessment

City of Forest Grove

Water System Seismic Resiliency Plan

Prepared by:
InfraTerra, Inc.
Date: May 2022

InfraTerra

TABLE OF CONTENTS

TABLES

FIGURES

1.0 INTRODUCTION

This technical memorandum summarizes preliminary seismic assessment of the 5 million gallon (MG) Water Treatment Plant (WTP) Reservoir and the 1 MG David Hill Reservoir. The scope of work includes only a simplified assessment of the reservoirs to assess their likely seismic performance.

This technical memorandum is part of the study to develop Water System Seismic Resiliency Plan (Water System SRP) for the City of Forest Grove (City). The Water System SRP has adopted post-earthquake performance goals of the Oregon Resilience Plan (ORP) for the study. ORP seeks to reduce risk from a Moment Magnitude (M_w) 9.0 (M9) earthquake on the Cascadia Subduction Zone (CSZ).

2.0 APPROACH

2.1 SEISMIC HAZARD

The primary earthquake hazard for this project is from an M9 CSZ earthquake. Studies by the United States Geological Survey (USGS) show that the probability of such an earthquake affecting the entire Pacific Northwest is about 7 to 15 percent over the next 50 years (Goldfinger et al., 2016). In addition to an earthquake on the CSZ, the City may experience earthquakes from nearby local earthquake sources, of which the Gales Creek fault is the most significant. Seismic activity on the Gales Creek fault is significantly lower than CSZ. Due to higher probability of a major earthquake on the CSZ and its region wide impact, the Water System SRP study adopted the ORP as the basis for this study.

Geologic assessment performed as part of this study shows that the reservoir sites do not have a liquefaction hazard and have a low (but not zero) slope stability hazard. Detailed discussion of liquefaction and slope stability hazards are included in a separate memorandum on geologic hazards (Appendix C of the Water System SRP report).

Median ground motion estimates from the M9 CSZ earthquake at a distance of about 40 km and an M_w 6.8 (M6.8) Gales Creek fault earthquake at a distance of about 3 km are presented in Table 1. The ground motions from a CSZ earthquake are based on surface values presented in DOGAMI's CSZ scenario (Madin and Burns 2013). Ground motions from a Gales Creek fault earthquake were estimated based on a USGS Shakemap scenario (USGS, 2017). The table shows that the ground motions from the Gales Creek event are significantly higher than the CSZ event. Additional discussion on the earthquake scenario selected for this study is presented in the main body of the Water System SRP report.

Table 1: Spectral Acceleration for Earthquake Scenarios at the WTP and David Hill Reservoirs

Reservoir	Scenario	Period		
		PGA	0.2 sec	1.0 sec
5 MG WTP	Cascadia Subduction Zone	0.21g	0.52g	0.24g
	Gales Creek	0.54g	1.34g	0.63g
1 MG David Hill	Cascadia Subduction Zone	0.21g	0.52g	0.24g
	Gales Creek	0.56g	1.40g	0.56g

Ground motion spectra for the M9 CSZ earthquake for the two sites used in this assessment are shown in Figure 1. The spectra are developed from spectral acceleration at 0.2 and 1.0 second values (ASCE 7-16).

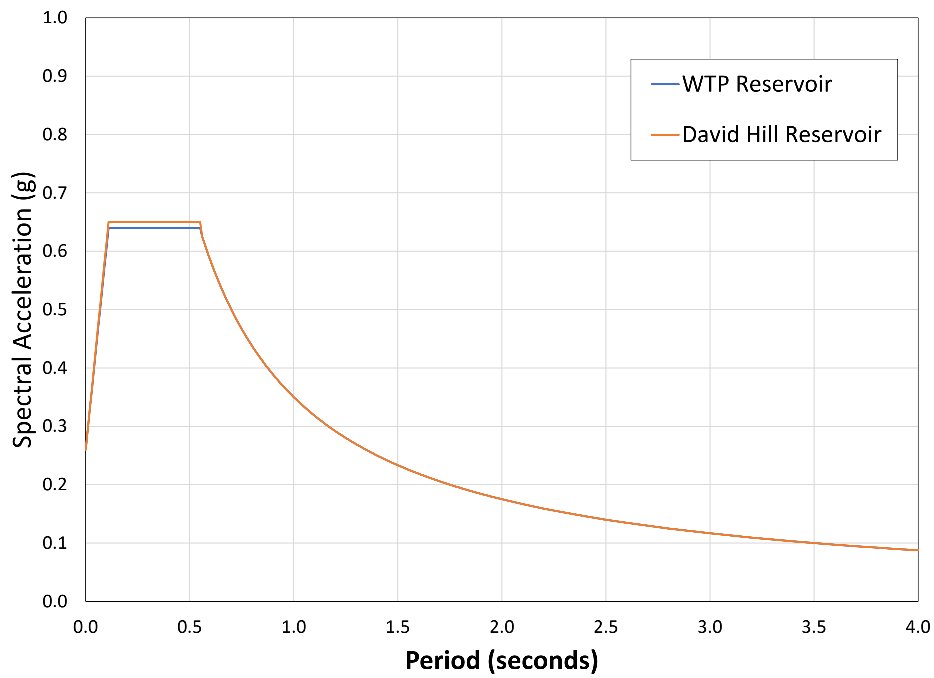

Figure 1: M9 CSZ Scenario Earthquake Median Response Spectra

2.2 STRUCTURAL ASSESSMENT APPROACH

Calculations for the structural assessment of the WTP and the David Hill Reservoirs were based on fundamental principles of structural engineering and followed the guidelines of ACI 318-14 and ACI 350.3-06. Material properties and dimensions of the structures were obtained from the available structural drawings. Conservative assumptions were made whenever necessary such as to overestimate demand and underestimate capacity. However, engineering judgment was used so that the final results are reasonable and not unrealistic.

3.0 WTP RESERVOIR

3.1 RESERVOIR DESCRIPTION

The WTP Reservoir was originally designed by Cornell, Howland, Hayes, and Merryfield and constructed in 1948. It measures approximately 150 feet long by 300 feet wide and has a depth of approximately 19 feet. Although the original reservoir did not include a roof over the reservoir basin, the design anticipated the construction of a roof and included footings and vertical reinforcement for future columns. A roof with dimensions nearly identical to the original 1948 design was designed in 1980 with the construction completed in 1981.

Figure 2 and Figure 3 show historical photos of the 1981 roof construction. Figure 4 shows the WTP Reservoir in its current state. A total of 72 new columns were constructed on top of the existing footings. A leveling pad was installed on the existing walls to support the new roof structure on 3/4-inch-thick neoprene bearing pads.

The reservoir floor slabs are 6 inches thick and the walls vary in thickness from 9 to 12 inches. The roof columns are 18-inches square and supports the roof slab, which is 8-inches thick. Drop panels are 8-ft square and 3.5 inches thick. The reservoir is divided into two equal square bays, designated as the north bay and the south bay, separated by a 12-inch-thick and 10-ft high wall.

An interior and exterior structural inspection of the WTP Reservoir was performed by OBEC Consulting Engineers (OBEC) in 2017 to assess the overall structural condition, identify the source of an existing leak, and provide repair recommendations and associated cost estimates. OBEC's recommendations for high priority repairs included waterproofing and joint sealing of the north bay, repairing concrete spalling at the roof, and replacing of the sump wire mesh screen (OBEC, 2017).

Figure 2: WTP Reservoir prior to the Construction of the Roof, 1980

Figure 3: WTP Reservoir Roof Construction, 1981

Figure 4: WTP Reservoir, March 2018

3.2 STRUCTURAL ASSESSMENT

Structural assessment was performed using the ACI 318-14 and ACI 350.3-06. For the assessment, the response modification factors for the impulsive and convective components of R_i = 3.0 and R_c = 1.0, respectively were used. Response modification factor represents earthquake energy dissipation capacity of a structure. ACI 350.3 provides an importance factor of 1.5 for tanks containing hazardous materials; 1.25 for tanks that are intended to remain usable for emergency purposes after an earthquake, or tanks that are part of lifeline systems; and 1.0 for all other tanks. Structural assessment included in this memorandum used an importance factor I of 1.25. In addition, as recommended in the code, 1-percent damping was used for the sloshing component.

The following sections summarize assessment results for critical structural members.

3.2.1 Roof Support Columns

The 8-inch thick roof slab is supported by a total of 72 columns. At the location of each column the slab has 8-foot square 11.5-inch thick drop panel. The roof slab is divided into eight 77 ft by 77.08 ft sections (approximately 77 ft square), separated by 3/4-inch separation gaps. Each of the eight roof slab sections is supported by nine columns. For this assessment, a typical central column is selected because it has the largest tributary slab area of 24 ft by 24 ft. A representative column height of 18 ft is selected. Elevation and plan for a typical column are shown in Figure 5.

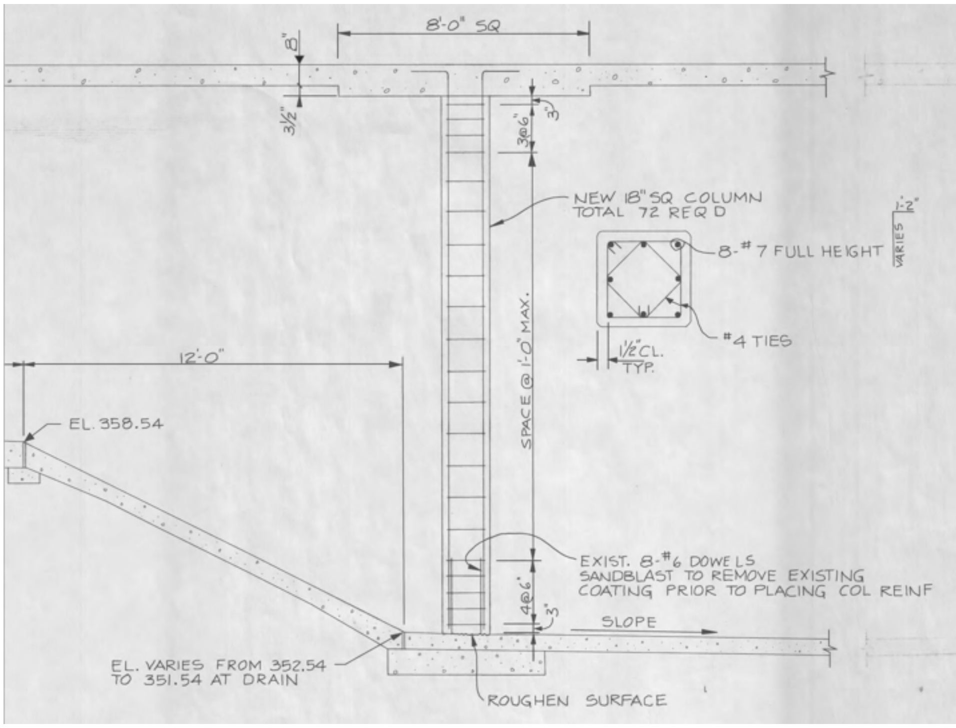

Figure 5: WTP Reservoir Typical Column Elevation and Cross-Section

The typical column is reinforced with eight #7 bars evenly spaced around the perimeter of the square cross-section. Each rebar is anchored into the slab with 90-degree hooks. Column transverse reinforcement consists of #4 ties at 12 inches spacing along the height of the columns and at 6 inches spacing at the bottom and top ends of the column. Clear cover of 1.5 inch is provided. Key column parameters are summarized in Table 2.

Results of our assessment for different column failure modes are presented below:

- **Column Compression:** The axial compression capacity of the column is calculated using the contributions of the concrete and the steel reinforcement (ACI 318 Section 10.3.6). Slenderness effects were neglected because the KL/r ratio for the typical column is less than 22 (ACI 318 Section 10.10.1). The analysis shows that the column compression capacity exceeds the demand with a large factor of safety.
- **Column Shear:** Shear capacity of the column was calculated using the equations included in ACI 318-14 Chapter 11. Total shear demand on a single column was approximately calculated using cracked properties, a computed period of 0.74 seconds and response spectrum shown in Figure 1. The assessment shows that the column capacity in shear is significantly more than the demand with the Demand to Capacity Ratio (DCR) of 0.24.
- **Column Bending:** Bending demand on the column was calculated using the period of 0.74 seconds and response spectrum shown in Figure 1. The computed

bending moment was plotted on the moment-axial interaction diagram calculated for the WTP reservoir column in Figure 6. The point M_u, P_u is located outside of the moment-axial envelope, and therefore the column bending capacity is not sufficient to resist demand due to an M9 CSZ scenario event.

Table 2: WTP Reservoir Assumed Column Parameters

Parameter		Value
Concrete compressive strength, f'_c		3,000 psi
Steel rebar yield strength, f_y		40,000 psi
Steel dowels yield strength, f_y		33,000 psi
Column width and depth, b_w		18 inches
Cross-section area, gross, A_g		324 inches^2
Column height, h		18 ft
Dowels at column base	Bar size	#6
	Diameter	0.750 inch
	Area, one bar, A_s	0.44 inches^2
	Number of bars	8
	Area all bars, A_{st}	3.52 inches^2
Longitudinal reinforcement	Bar size	#7
	Diameter	0.875 inch
	Area, one bar, A_s	0.60 inches^2
	Number of bars	8
	Area all bars, A_{st}	4.80 inches^2
Transverse reinforcement	Bar size	#4
	Diameter	0.50 inch
	Area, one bar, A_v	0.20 inches^2
	Spacing, s	12 inches

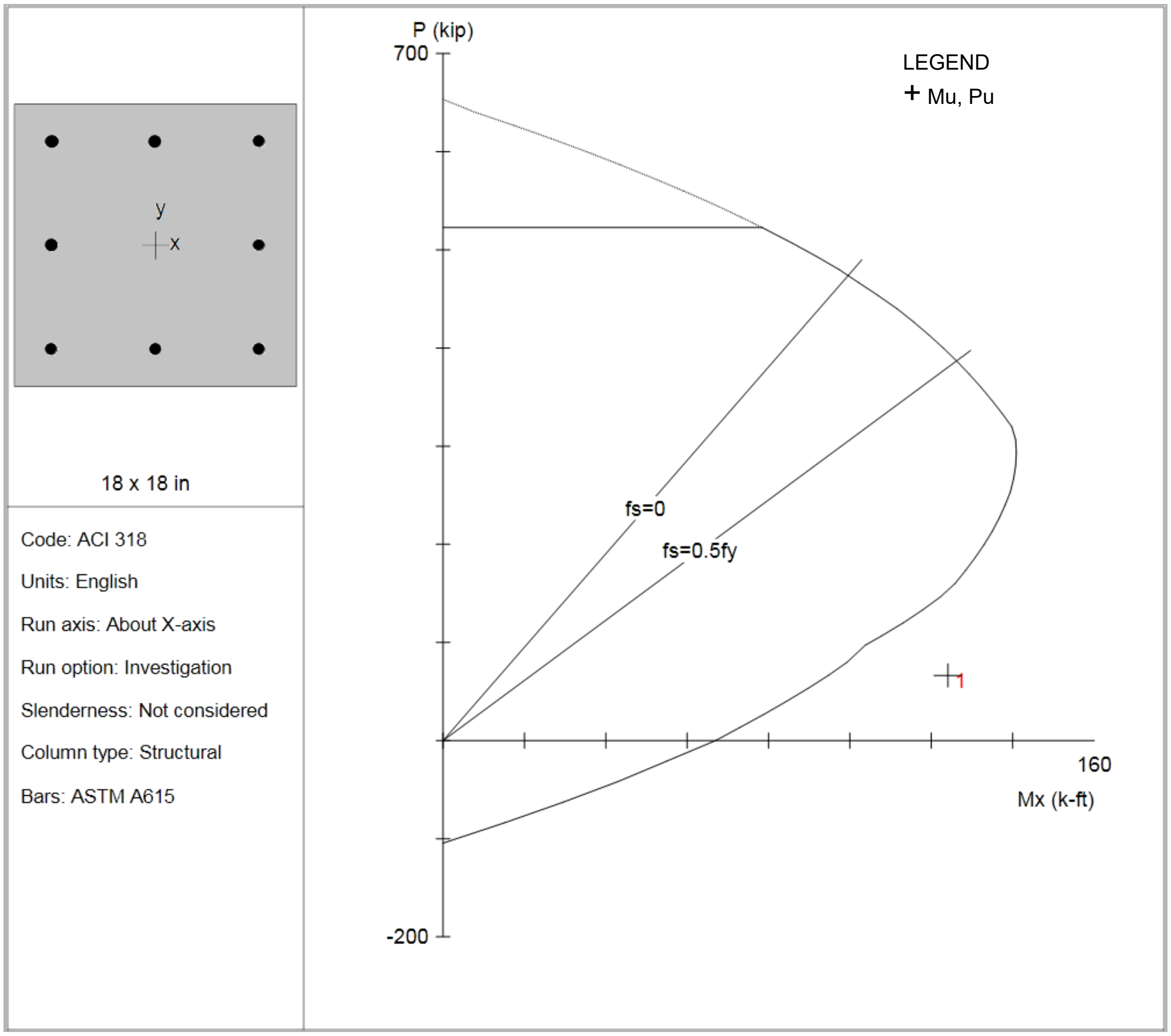

Figure 6: Moment-Axial Force Interaction Diagram for WTP Reservoir Column

3.2.2 Central Wall

The central wall divides the north and the south bays. The cross-section elevation of the central wall is shown in Figure 7. Key central wall parameters are summarized in Table 3. The wall has a height of 10 feet and thickness at the base of 12 inches. Vertical reinforcement consists of #6 bars along both faces spaced every 12 inches. Horizontal reinforcement consists of #5 bars along both faces spaced 11.5 inches. The central wall supports the weight of the tributary roof slab and resists lateral hydrostatic and hydrodynamic forces. Lateral roof slab forces are not transferred to the central wall due to the ¾-inch-thick neoprene isolation layer between the top of the wall and the roof slab.

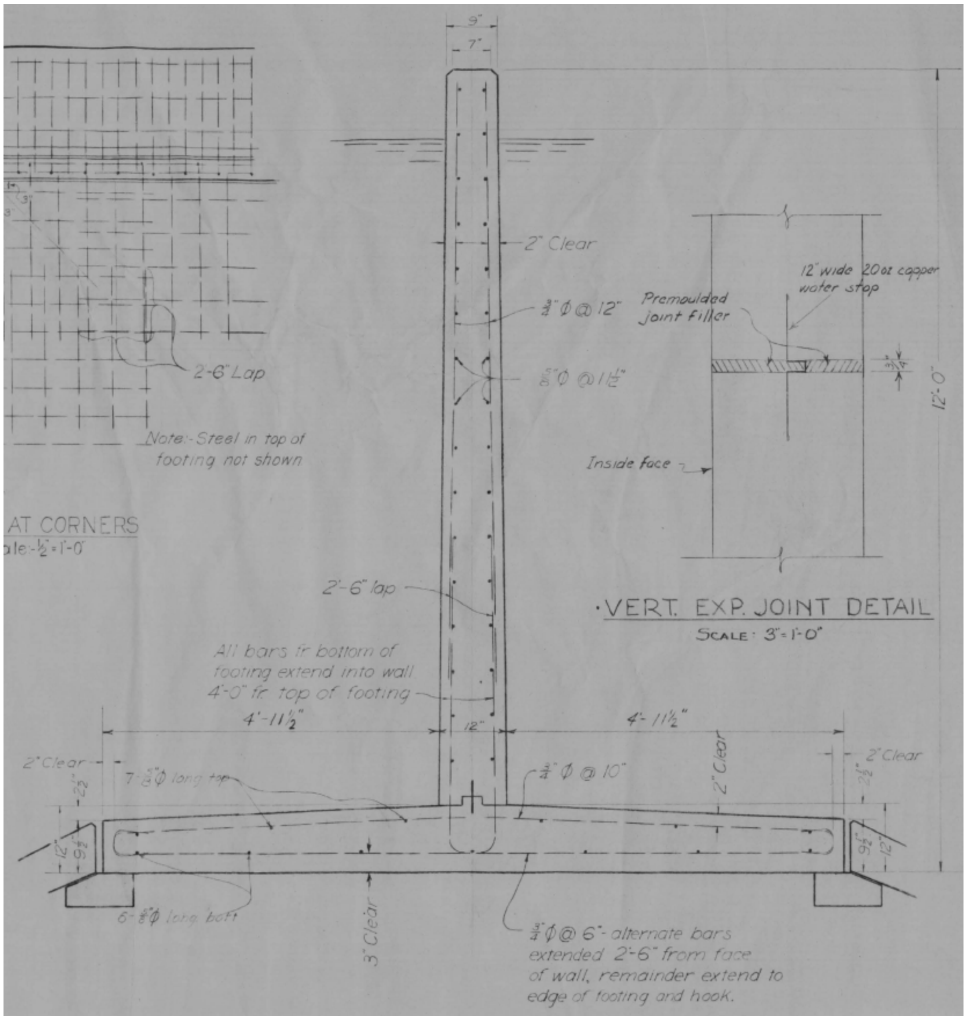

Figure 7: Central Wall Cross-Section Elevation

Table 3: WTP Reservoir Central Wall Parameters

Parameter		Value
Concrete compressive strength, f'_c		3,000 psi
Steel rebar yield strength, f_y		40,000 psi
Wall width at base, b_w		12 in
Distance to steel centroid, bending, d		9.6 in
Water level, H_L		10 ft
Wall height, H_W		11 ft
Wall length parallel to the direction of the ground motion, L		152.5 ft
Vertical reinforcement, 1-ft wall segment	Bar size	#6
	Diameter	0.750 in
	Area, one bar, A_s	0.44 in^2
	Number of bars	2
	Area all bars, A_{st}	0.88 in^2
Horizontal reinforcement	Bar size	#5
	Diameter	0.625 in
	Area, one bar, A_v	0.31 in^2
	Spacing, s	11.5 in, both faces

Results of our assessment for different failure modes for the central wall are presented below:

- **Wall Compression:** The axial compression capacity of the central wall is calculated using the contributions of the concrete and the steel reinforcement (ACI 318 Section 10.3.6). The capacity is calculated for a 1-ft segment of the central wall. The compression capacity of the central wall exceeds the demand with a large factor of safety.
- **Out-of-Plane Bending:** Hydrodynamic forces for the central wall are calculated using ACI 350.3-06 by calculating separately the impulsive and convective components of the hydrodynamic lateral forces. The computed impulsive and convective periods were 0.19 seconds and 17.0 seconds, respectively. The total force on the wall was computed as the sum of hydrostatic and hydrodynamic forces. The axial force and moment demands are plotted on the moment-axial interaction diagram calculated for the WTP Reservoir central wall in Figure 8. The point M_u, P_u is located outside the moment-axial envelope, therefore the bending moment capacity of the central wall is exceeded.

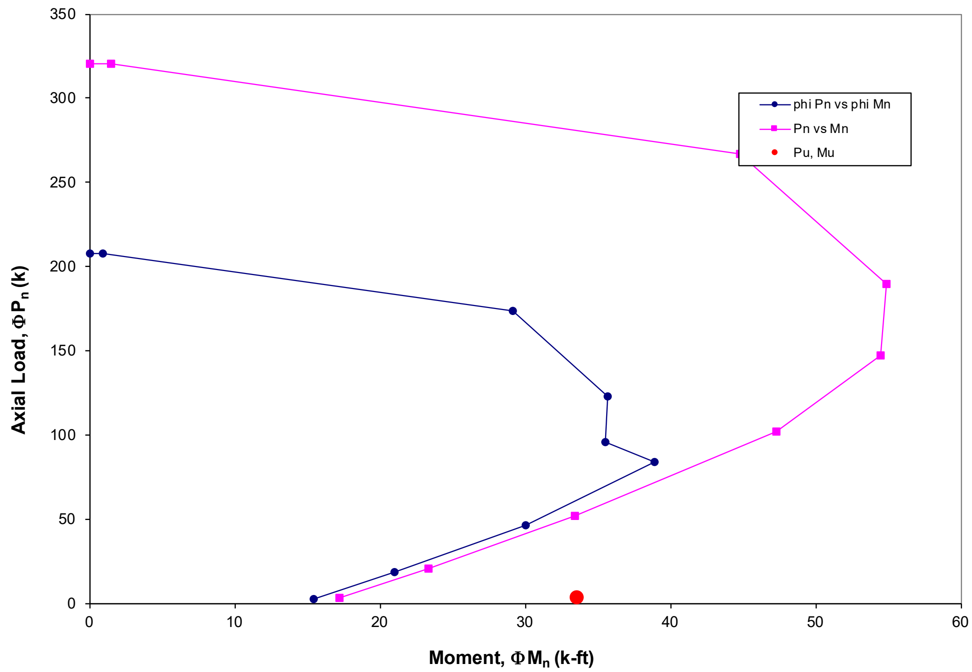

Figure 8: Moment-Axial Force Interaction Diagram for WTP Reservoir Central Wall

3.2.3 Perimeter Walls

The cross-section elevation of a typical wall is shown in Figure 9. Key perimeter wall parameters are summarized in Table 4. The wall has a height of 10 feet and thickness at the base of 12 inches. Vertical reinforcement consists of #6 bars spaced every 12 inches along the inside face, and 20 inches along the outside face. Horizontal reinforcement consists of #5 bars along both faces spaced 11.5 inches. The perimeter walls support the weight of the tributary roof slab and resists lateral hydrostatic and hydrodynamic forces. Lateral roof slab forces are not transferred to the perimeter walls due to the 3/4-inch-thick neoprene isolation layer between the top of the wall and the roof slab.

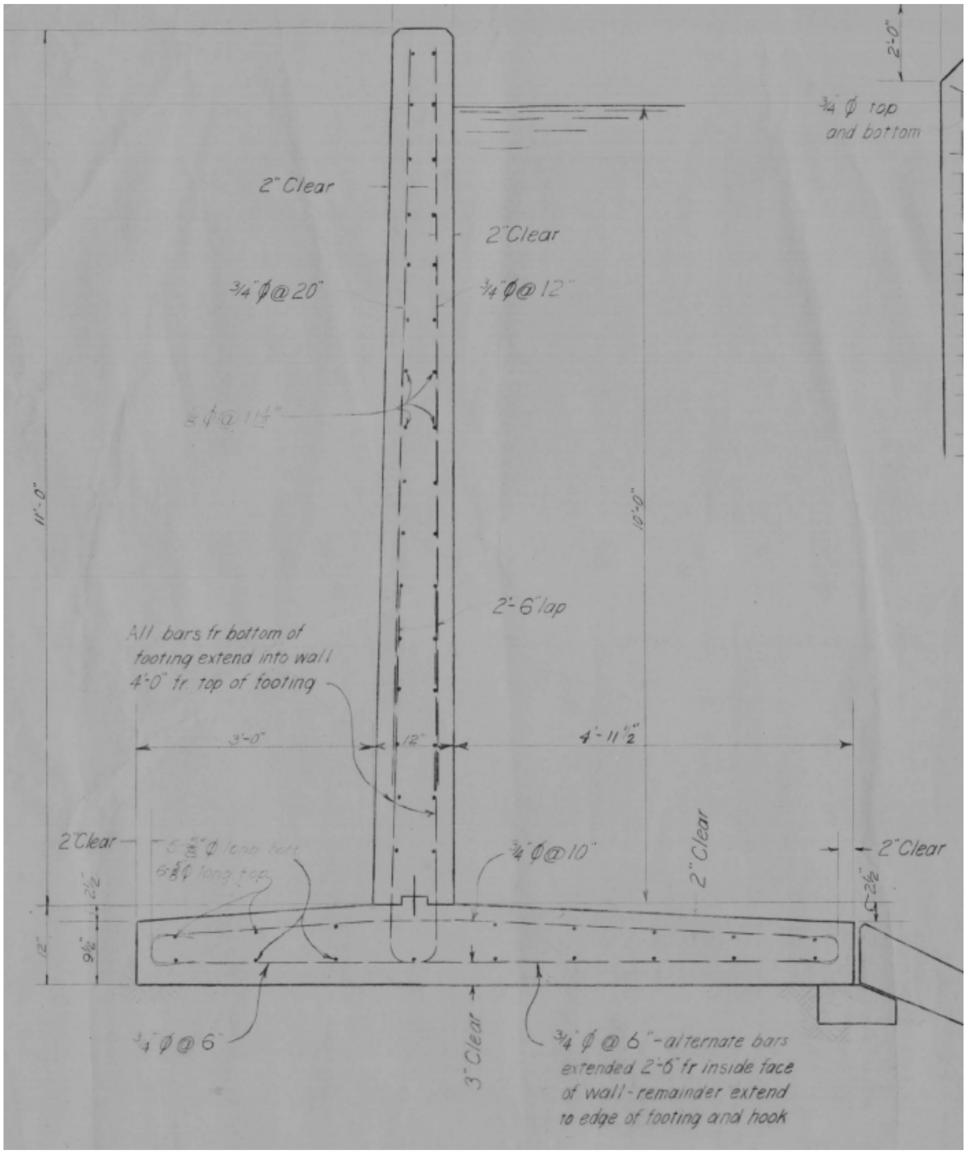

Figure 9: Perimeter Wall Cross-Section Elevation

Table 4: WTP Reservoir Perimeter Wall Parameters

<table>
<tr><th colspan="2">Parameter</th><th>Value</th></tr>
<tr><td colspan="2">Concrete compressive strength, f'_c</td><td>3,000 psi</td></tr>
<tr><td colspan="2">Steel rebar yield strength, f_y</td><td>40,000 psi</td></tr>
<tr><td colspan="2">Wall width at base, b_w</td><td>12 in</td></tr>
<tr><td colspan="2">Distance to steel centroid, bending, d</td><td>9.6 in</td></tr>
<tr><td colspan="2">Water level, H_L</td><td>10 ft</td></tr>
<tr><td colspan="2">Wall height, H_W</td><td>11 ft</td></tr>
<tr><td colspan="2">Wall length parallel to the direction of the ground motion, L</td><td>152.5 ft</td></tr>
<tr><td rowspan="6">Vertical reinforcement, 1-ft wall segment</td><td>Bar size</td><td>#6</td></tr>
<tr><td>Diameter</td><td>0.750 in</td></tr>
<tr><td>Area, one bar, A_s</td><td>0.44 in^2</td></tr>
<tr><td>Number of bars</td><td>1</td></tr>
<tr><td>Inner face bar spacing</td><td>12 in</td></tr>
<tr><td>Outer face bar spacing</td><td>20 in</td></tr>
<tr><td rowspan="4">Horizontal reinforcement</td><td>Bar size</td><td>#5</td></tr>
<tr><td>Diameter</td><td>0.625 in</td></tr>
<tr><td>Area, one bar, A_v</td><td>0.31 in^2</td></tr>
<tr><td>Spacing, s</td><td>11.5 in, both faces</td></tr>
</table>

Results of our assessment for different failure modes for the perimeter wall are presented below:

- **<u>Wall Compression:</u>** The axial compression capacity of the central wall is calculated using the contributions of the concrete and the steel reinforcement (ACI 318 Section 10.3.6). The capacity is calculated for a 1-ft segment of the perimeter wall. The compression capacity of the perimeter wall exceeds the demand with a large factor of safety.
- **<u>Out-of-Plane Bending (Reservoir Empty - Case 1):</u>** For the empty reservoir, static soil pressure was computed using the internal friction angle of the soil, ϕ = 30°. The dynamic soil pressure was calculated using both the Mononobe-Okabe (1926 and 1929) and the Seed and Whitman (1970) methods to be 1.10 kips. Lateral forces from the static and dynamic soil pressures were combined to compute bending moment in the empty reservoir wall. The axial force and moment demand was plotted on the moment-axial interaction diagram as shown in Figure 10. The point M_u, P_u falls outside the moment-axial interaction diagram,

therefore the perimeter wall does not meet the seismic demand from the static and dynamic soil lateral forces in the scenario earthquake.

- **<u>Out-of-Plane Bending (Reservoir Full – Case 2):</u>** This case assumes the formation of a gap between the perimeter wall and the surrounding soil. In this case, hydrostatic and hydrodynamic loads act on the wall but the opposing static and dynamic soil lateral forces no longer act on the wall. The axial force and moment demand was plotted on the moment-axial interaction diagram as shown in Figure 11. The point M_u, P_u falls outside the moment-axial interaction diagram, therefore the perimeter does not meet the seismic demand from the static and dynamic soil lateral forces in the scenario earthquake.
- **<u>Out-of-Plane Bending (Reservoir Full – Case 3):</u>** This load case considers the combination of static and dynamic soil loads together with hydrostatic and hydrodynamic loads. For earthquake direction away from the wall, the hydrodynamic component acts in the opposite direction to the hydrostatic component up to the point of canceling out the hydrodynamic component. Negative pressure cannot be created by the hydrodynamic component. The combination of hydrostatic and hydrodynamic lateral forces that results in the highest bending moment demand at the base of the perimeter wall, occurs when the earthquake action accelerates the water mass against the perimeter wall. In this case, loads from the hydrostatic component, the hydrodynamic component, the wall inertia, and the dynamic component of the soil act in the same direction and opposite to static soil pressure. The computed axial force and moment demand was plotted on the moment-axial interaction diagram as shown in Figure 12. The point falls outside the moment-axial interaction diagram, therefore the perimeter wall does not meet the seismic demand from the static and dynamic soil lateral forces in the scenario earthquake.

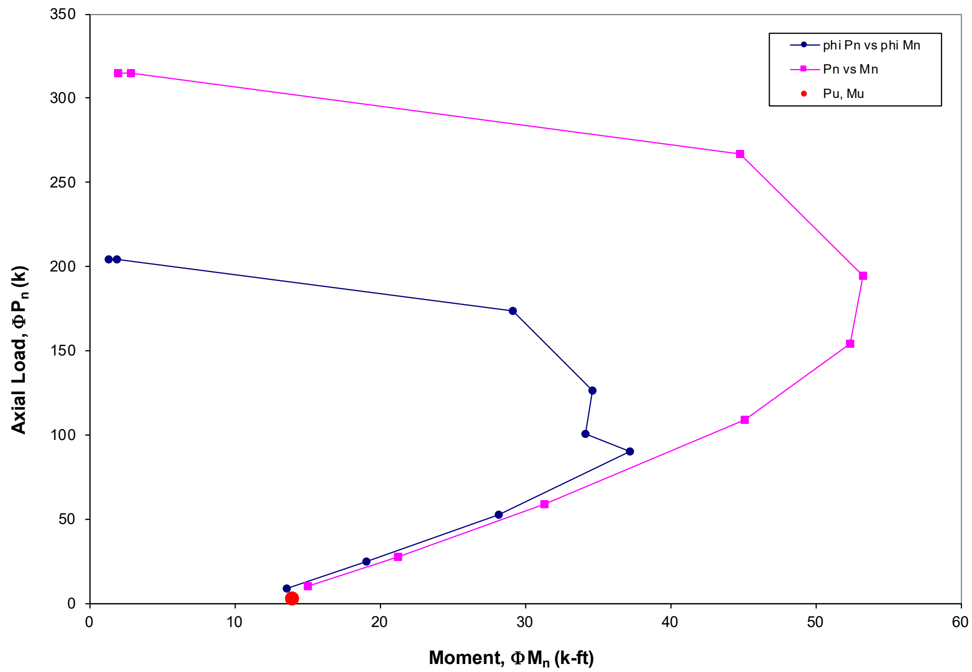

Figure 10: Moment-Axial Force Interaction Diagram for WTP Reservoir Perimeter Wall, Case 1 (Wall Inertia and Soil Hydrostatic and Hydrodynamic Lateral Forces Only)

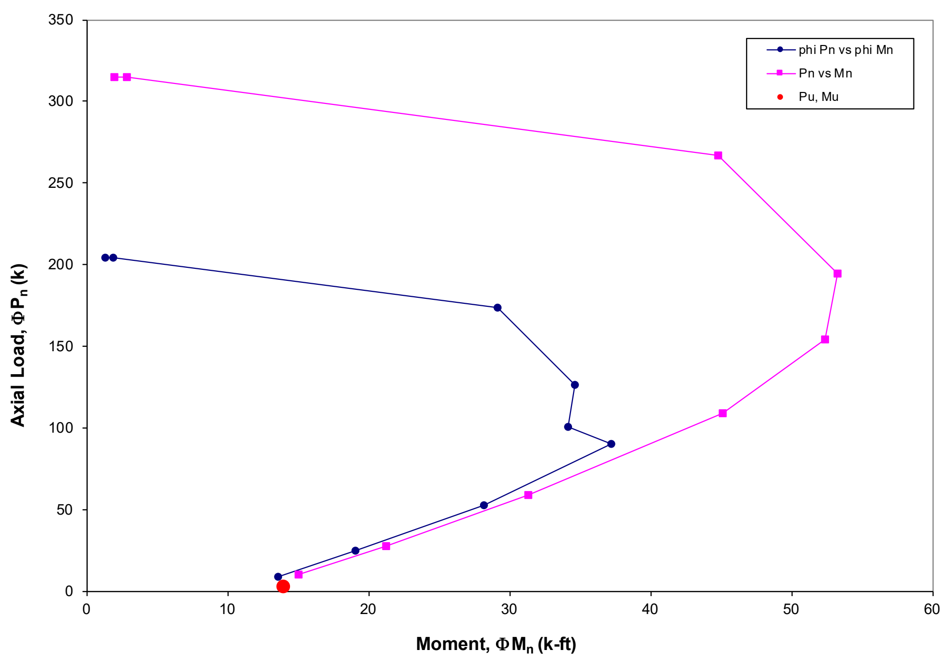

Figure 11: Moment-Axial Force Interaction Diagram for WTP Reservoir Perimeter Wall, Case 2 (Wall Inertia and Water Hydrostatic and Hydrodynamic Lateral Forces Only)

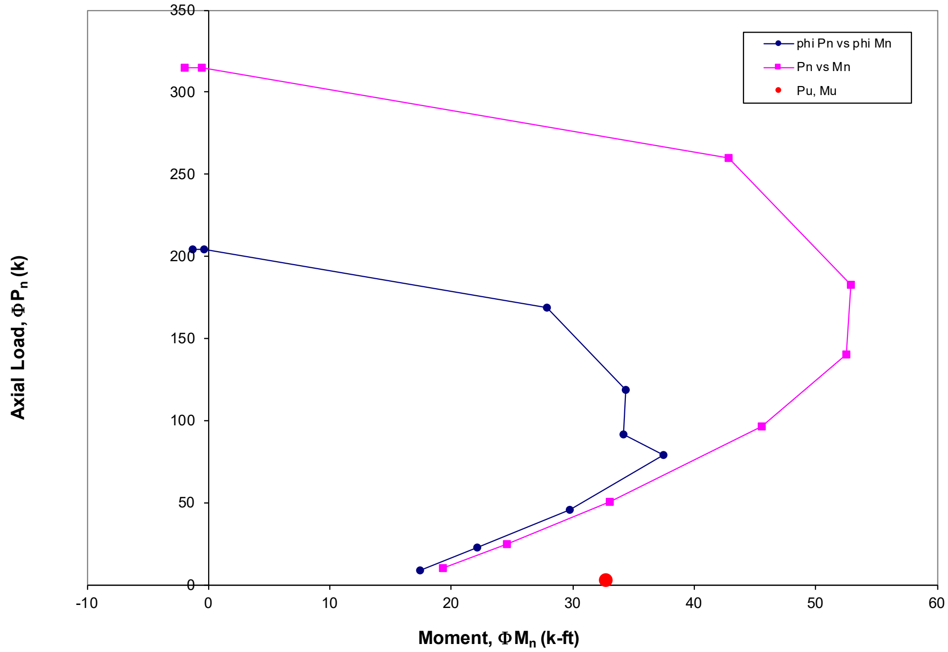

Figure 12: Moment-Axial Force Interaction Diagram for WTP Reservoir Perimeter Wall, Case 3 (Wall Inertia, Water and Soil Hydrostatic and Hydrodynamic Lateral Forces)

3.2.4 Roof Slab Assessment

The roof slab is positively connected to the interior columns but not to the perimeter walls. On the perimeter walls, the roof sits on a 3/4-inch neoprene pad. The maximum expected lateral displacement of the roof slab is calculated using a response modification factor R = 1 and an importance factor, I = 1.25 based on deformation of the supporting columns assuming fixed-fixed boundary conditions. A maximum displacement of 3.2 inches is computed. With the wall thickness of 9 inches and the typical roof slab overhang of 4 inches (Figure 13), it is unlikely that the roof slab could slide off the perimeter wall.

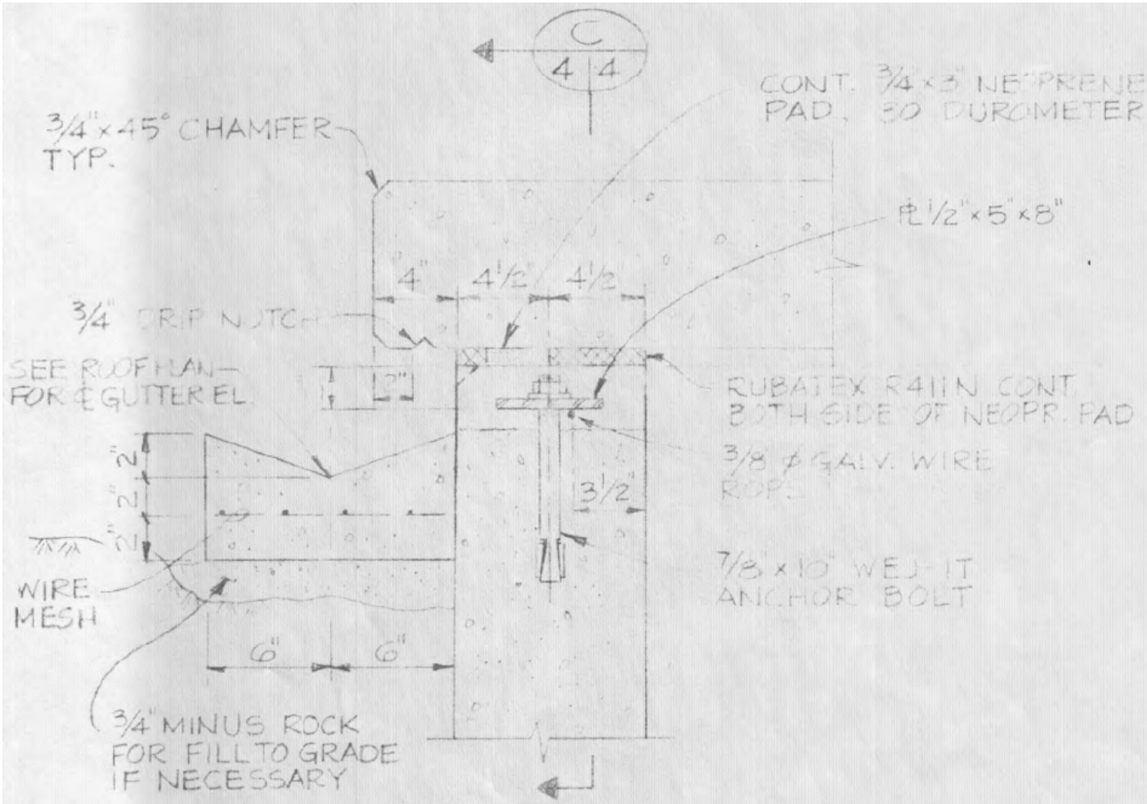

Figure 13: Roof Slab to Wall Connection Detail

Other failure modes such as flexure and punching shear failure have a low likelihood. The former due to two-way slab condition and the latter due to the presence of 12-inch thick drop panels.

3.2.5 20-INCH SUPPLY LINE

Slope stability assessment (Appendix C of Water System SRP report) show that deformations of about 1 to 3 inches could occur in the fill slope east of the reservoir in the CSZ event. These deformations could extend to the depth of the supply line that connects the reservoir to the water distribution system. The 1978 Water Treatment Plant Modification as-built drawings show that the 20-inch ductile iron supply line extends from the southeast corner of the reservoir and runs parallel to the slope for about 100 ft. Based on the relatively modest expected deformations, the composition of the pipe, and the limited length of pipeline exposed to slope stability deformations, we estimate the likelihood of damage from slope instability is low. However, damage to the line could occur at the pipe penetration into the reservoir wall. It is recommended that flexibility be provided to this connection.

3.2.6 RESULTS SUMMARY

Results of the assessment for an M9 CSZ scenario earthquake shows that roof support columns, and the central and perimeter walls have a safety factor of less than one for seismic loading. Therefore, the reservoir does not meet the immediate occupancy performance criteria for a backbone element of the water system. It is recommended that the reservoir be retrofitted or replaced. A detailed numerical analysis of the reservoir can provide further insights in the seismic performance of the reservoir and could reduce the levels of conservatism inherent in simplified analyses. For other failure modes, simplified analysis show that the DCRs are less than 1.0 and meet code requirements.

A seismic evaluation and retrofit design for the WTP reservoir was also performed by others (OBEC, 2018) using the ASCE 41-17 standard. For this assessment, the reservoir was evaluated as a Risk Category III structure for the Basic Performance Objective of Existing Buildings (BPOE) for two seismic hazard levels. ASCE 41-17 defines these hazard levels as Basic Safety Earthquake (BSE) Level 2E and BSE Level 1E. For existing structures, BSE 2E and BSE 1E correspond to 5% and 20% probability of exceedance in 50 years, respectively (equivalent return periods of 950 years and 225 years). The evaluation concluded that the column and column footings of the reservoir did not meet the acceptable limits of the BPOE and presented options for retrofit or replacement of the reservoir. The other components of the reservoir (exterior and interior walls and roof slab) were found to be within the acceptable limits of the BPOE. The recommended retrofit included (1) thickening the columns with cast-in-place concrete, (2) pouring new footings on top of the existing basin slab at the base of the columns, and (3) connecting the new footings to the new columns with reinforcing bars.

4.0 DAVID HILL RESERVOIR

This section describes the seismic assessment of the David Hill Reservoir, which is located approximately 0.9 miles (1.4 km) northwest of the Water Treatment Plant on an unnamed road off NW David Hill Road.

4.1 RESERVOIR DESCRIPTION

The partially buried David Hill Reservoir was constructed in 1985 and consists of an approximately 76 by 96 feet rectangular concrete structure that is embedded between 13 and 16 feet deep. The reservoir has a capacity of 1 million gallons.

The reservoir roof consists of an 8-½-inch reinforced concrete slab and is supported by 14-inch thick reinforced concrete reservoir walls and a 3-by-4 array of 20-inch diameter circular reinforced-concrete columns, spaced 20-feet apart center-to-center. The floor slab is 6 inches thick and is underlain by a 12-inch thick layer of drain rock over the native material.

4.2 STRUCTURAL ASSESSMENT

The structural components and failure modes considered in the structural assessment of the David Hill Reservoir was performed using the methodology similar to what was used for the WTP Reservoir. The assessment was performed for an M9 CSZ scenario using ACI 318-14 and ACI 350.3-06. For the assessment, the response modification factors for the impulsive component (Ri) of 3.0 and of 1.0 for the convective component (Rc) and an importance factor I of 1.25 were used.

The following sections summarize assessment results for critical structural members.

4.2.1 Roof Support Columns

David Hill Reservoir has a total of 12 columns supporting the roof slab. For this assessment, a typical central column was selected because it has the largest tributary slab area of 20 ft by 20 ft. A representative column height of 20.4 ft was selected. Typical column cross-sections are shown in Figure 14 and Figure 15.

The typical column is reinforced with #7 bars evenly spaced around the circumference of the circular cross-section. Spiral transverse reinforcement is provided by 3/8-inch cold drawn wire at a 2-inch pitch. Clear cover of 2.0 inch is provided. Key column parameters are summarized in Table 5.

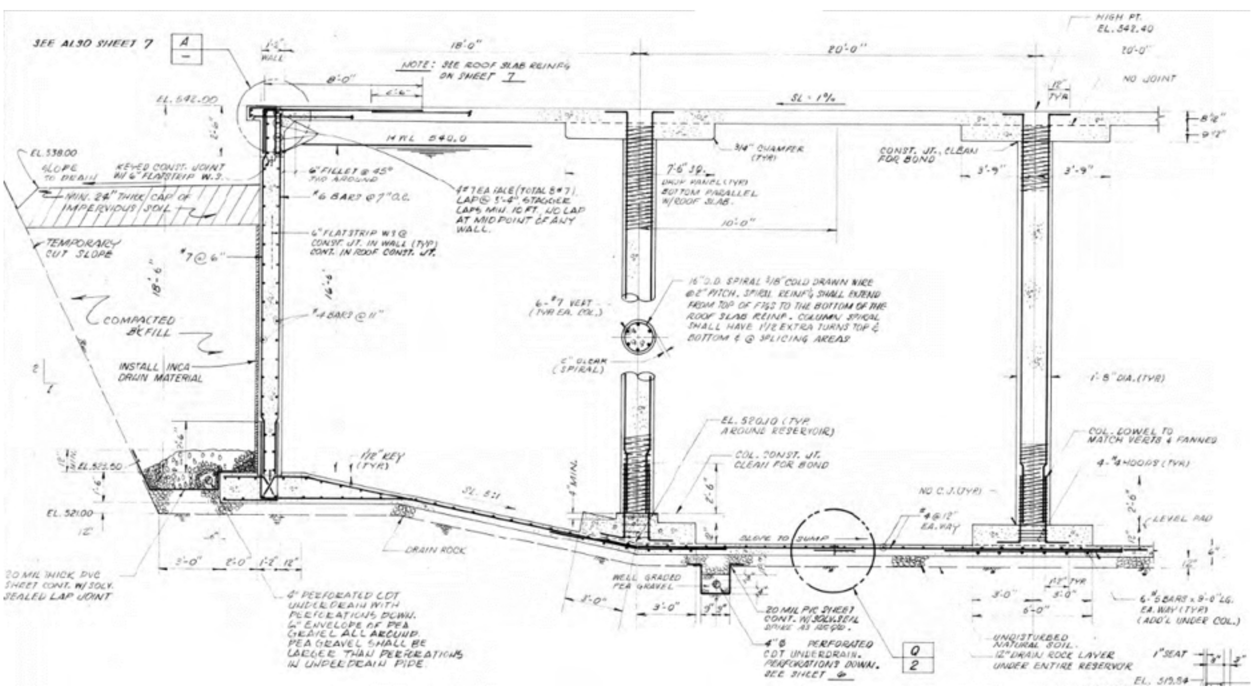

Figure 14: David Hill Reservoir, Typical Cross-Section

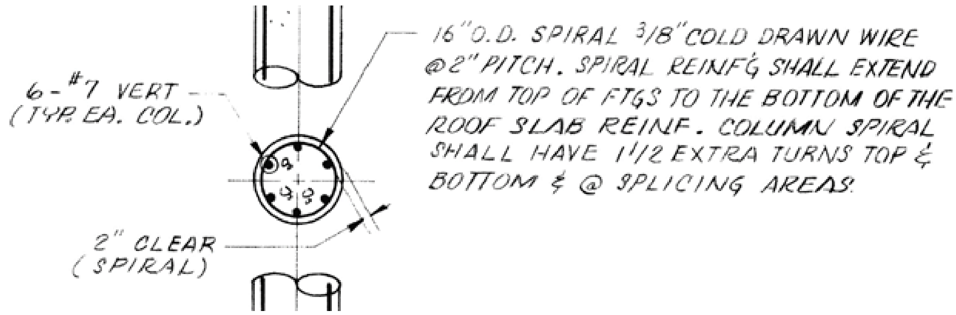

Figure 15: David Hill Reservoir Typical Column Elevation and Cross-Section

Results of our assessment for different column failure modes are presented below:

- **Column Compression:** The axial compression capacity of the column was calculated using the contributions of the concrete and the steel reinforcement (ACI 318 Section 10.3.6). Slenderness effects were neglected because the KL/r ratio for the typical column is less than 22 (ACI 318 Section 10.10.1). The analysis show that the column compression capacity exceeds the demand with a large factor of safety.
- **Column Shear:** Shear capacity of the column was calculated using the equations included in ACI 318-14 Chapter 11. Total shear demand on a single column was approximately calculated assuming peak of the response spectrum shown in Figure 1. The analysis show that the column shear capacity significantly exceeds the demand with the conservatively computed Demand to Capacity Ratio (DCR) of 0.19 for shear.
- **Column Bending:** Deformation and bending demand on the column is low because most of the seismic load is resisted by the reservoir walls.

Table 5: David Hill Reservoir Column Parameters

Parameter		Value
Concrete compressive strength, f'_c		3,000 psi
Steel rebar yield strength, f_y		40,000 psi
Column diameter, Ø		20 in
Cross-section area, gross, A_g		314 in^2
Column height, h		20.4 ft
Longitudinal reinforcement	Bar size	#7
	Diameter	0.875 in
	Area, one bar, A_s	0.60 in^2
	Number of bars	6
	Area all bars, A_{st}	3.60 in^2
Transverse reinforcement	Type	Spiral

	Diameter	3/8 in
	Area, one bar, A_v	0.11 in^2
	Spacing, *s*	2-inch pitch

4.2.2 PERIMETER WALLS

Key perimeter wall parameters are summarized in Table 6. The wall has a height of 18.5 feet and thickness of 14 inches. The wall is 98 ft 4 inches along the long axis and 78 ft 4 inches along the short axis. Vertical reinforcement consists of #6 bars at 7 inches on center along the interior face and #7 bars at 6 inches on center along the exterior face. Transverse reinforcement consists of #4 bars at 11 inches on center along both faces. Additional transverse reinforcement details for the corners is shown in Figure 16. The perimeter walls support the weight of the tributary roof slab and resist lateral hydrostatic and hydrodynamic forces. Lateral roof slab forces are transferred directly to the perimeter walls due to continuous reinforcement between the top of the wall and the roof slab.

Table 6: Assumed David Hill Reservoir Perimeter Wall Parameters

Parameter		Value
Concrete compressive strength, f'_c		3,000 psi
Steel rebar yield strength, f_y		40,000 psi
Wall width at base, b_w		14 in
Distance to steel centroid, bending, d		11 in
Wall height, H_W		18.5 ft
Water depth, H_L		16.5 ft
Wall length parallel to the direction of the ground motion, L		98 ft 4 inches by 78 ft 4 inches
Longitudinal reinforcement, interior face,1-ft wall segment	Bar size	#6
	Diameter	0.750 inches
	Area, one bar, A_s	0.44 inches^2
	Spacing	7 inches
Longitudinal reinforcement, exterior face, 1-ft wall segment	Bar size	#7
	Diameter	0.875 inches
	Area, one bar, A_s	0.60 inches^2
	Spacing	6 inches
Transverse reinforcement	Bar size	#4
	Diameter	0.50 inches
	Area, one bar, A_v	0.20 inches^2
	Spacing, s	11 inches, both faces

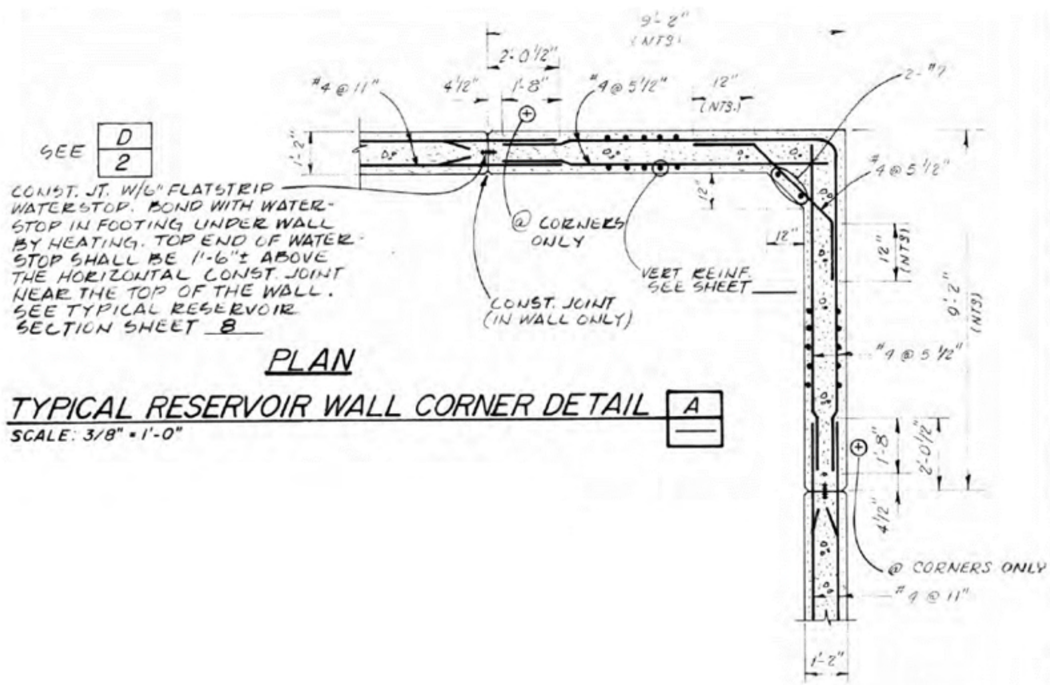

Figure 16: David Hill Reservoir Wall Reinforcement Detail

Results of our assessment for different failure modes for the perimeter wall are presented below:

- **Wall Compression:** The axial compression capacity of the central wall was calculated using the contributions of the concrete and the steel reinforcement (ACI 318 Section 10.3.6). The capacity is calculated for a 1-ft segment of the perimeter wall. The compression capacity of the perimeter wall exceeds the demand with a low DCR (large factor of safety).
- **In-Plane Shear:** Shear force demand on the perimeter walls was conservatively calculated assuming that all lateral earthquake forces would be resisted by two walls parallel to the direction of the ground motion. Lateral water hydrostatic and hydrodynamic forces on the walls perpendicular to the direction of the ground motion are conservatively assumed to be resisted through shear in the parallel walls. All water is assumed here to act as an impulsive component. The computed capacity is significantly greater than these conservatively computed demands.
- **Out-of-Plane Bending:** Simplified calculations were performed by applying hydrostatic and hydrodynamic loads to the perimeter wall. The hydrostatic and hydrodynamic forces on the perimeter walls were calculated using the ACE 350.3-06 approach for impulsive and convective loading. The bending moment demand was computed assuming a 1-ft strip of the wall with fixed-fixed boundary conditions with the hydrostatic, hydrodynamic, and self-weight inertial loads

applied. Assuming a one-way slab is a conservative assumption. The computed axial force due to gravity and moment demand was plotted on the moment-axial interaction diagram as shown in Figure 17. The point falls outside the moment-axial interaction diagram, therefore the perimeter wall does not meet the seismic demand from the scenario earthquake.

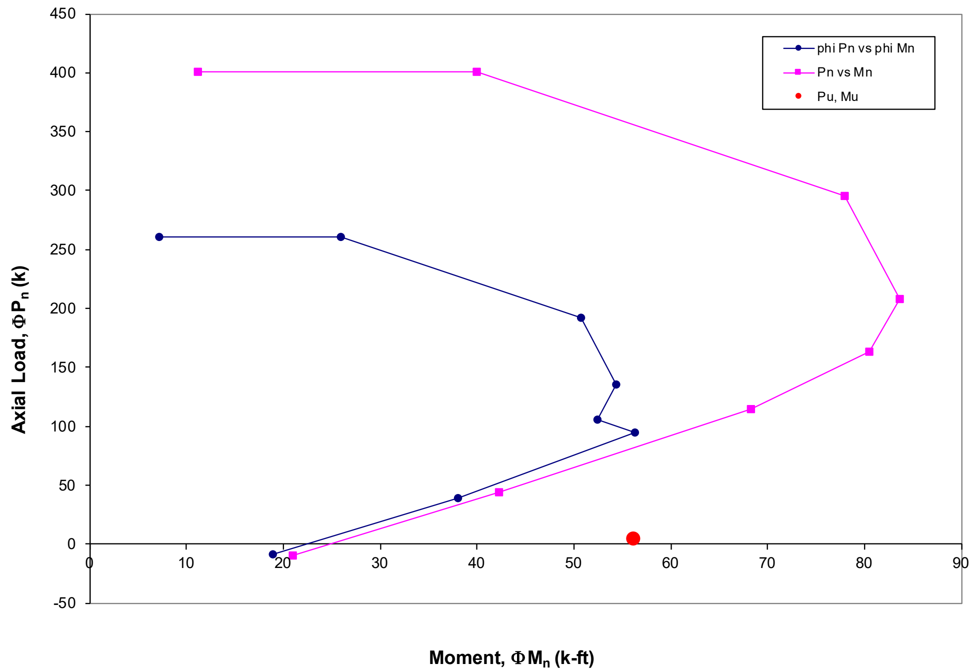

Figure 17: Moment-Axial Force Interaction Diagram for WTP Reservoir Central Wall

4.2.3 Results Summary

Results of the assessment show that bending moment capacity of the perimeter walls is exceeded for seismic loading. However, these results are based on conservative assumptions that may overestimate the imposed seismic demands. The reservoir has good seismic detailing with the walls anchored into the roof and base slab with continuous reinforcement (Figure 14). Furthermore, the walls are also tied into the perpendicular walls with continuous reinforcement (Figure 16). It is our judgment that a more detailed analysis will likely show that the reservoir walls have acceptable seismic performance. Therefore, we recommended that a more detailed analysis be performed for confirmation.

5.0 CONCLUSIONS

5.1 WTP RESERVOIR

The WTP Reservoir is located in an area characterized by low seismic geohazards. Liquefaction and slope stability are not expected to be significant hazards to the structural stability of the reservoir in an M9 CSZ scenario event.

Results of the assessment show that the roof support columns, and the central and perimeter walls have a safety factor of less than one for seismic loading. Therefore, the reservoir does not meet the immediate occupancy performance criteria for a backbone element of the water system. It is recommended that the reservoir be retrofitted or replaced. A detailed numerical analysis of the reservoir can provide further insights in the seismic performance of the reservoir and could reduce the levels of conservatism inherent in simplified analyses.

5.2 DAVID HILL RESERVOIR

The David Hill Reservoir is located in an area characterized by low to moderate seismic geohazards. Liquefaction and slope stability are not expected to be significant hazards to the structural stability of the reservoir in an M9 CSZ scenario event.

Simplified calculations show that the out-of-plane bending moment capacity of the reservoir perimeter walls is exceeded for seismic loading. However, the reservoir has good ductile seismic detailing, and it is likely that more refined calculations would show that the reservoir meets the imposed seismic demands. Therefore, additional seismic analysis is recommended.

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Appendix F

Facilities Seismic Review

Facilities Seismic Review

City of Forest Grove

Water System Seismic Resiliency Plan

Prepared by:
InfraTerra, Inc.
Date: May 2022

InfraTerra

TABLE OF CONTENTS

Page

FIGURES

1.0 INTRODUCTION

This technical memorandum describes structures of the Forest Grove water supply system and their expected seismic performance in a Moment Magnitude M_w 9.0 (M9) Cascadia Subduction Zone (CSZ) earthquake event. Site visits of these facilities were performed by Vladimir Calugaru, PhD, and Jenny Taing of InfraTerra on March 19 and 20, 2018.

This technical memorandum includes the following facilities:

- Water Treatment Plant
- David Hill Pump Station
- Watercrest Road Pump Station
- Raw Water Pump Station
- 10th Avenue Flow Control and Monitoring Station
- Public Works Facility
- Stringtown Road Bridge Crossing

The reservoirs at the Water Treatment Plant and David Hill are discussed in detail in a separate technical memorandum included as Appendix E of the Seismic Resiliency Plan (SRP) study.

2.0 WATER TREATMENT PLANT

The Water Treatment Plant located at 501 Watercrest Road. The layout of the Water Treatment Plant is presented in Figure 1. Various structures located at the plant include:

- Chemical Building
- Office Building/Pipe Gallery/Filters
- Shop
- Den
- Storage Facility
- Emergency Generator
- WTP Reservoir
- Sedimentation Basin
- Backwash Lagoon

The following sections document our field observations and seismic assessment of the various structures located at the plant.

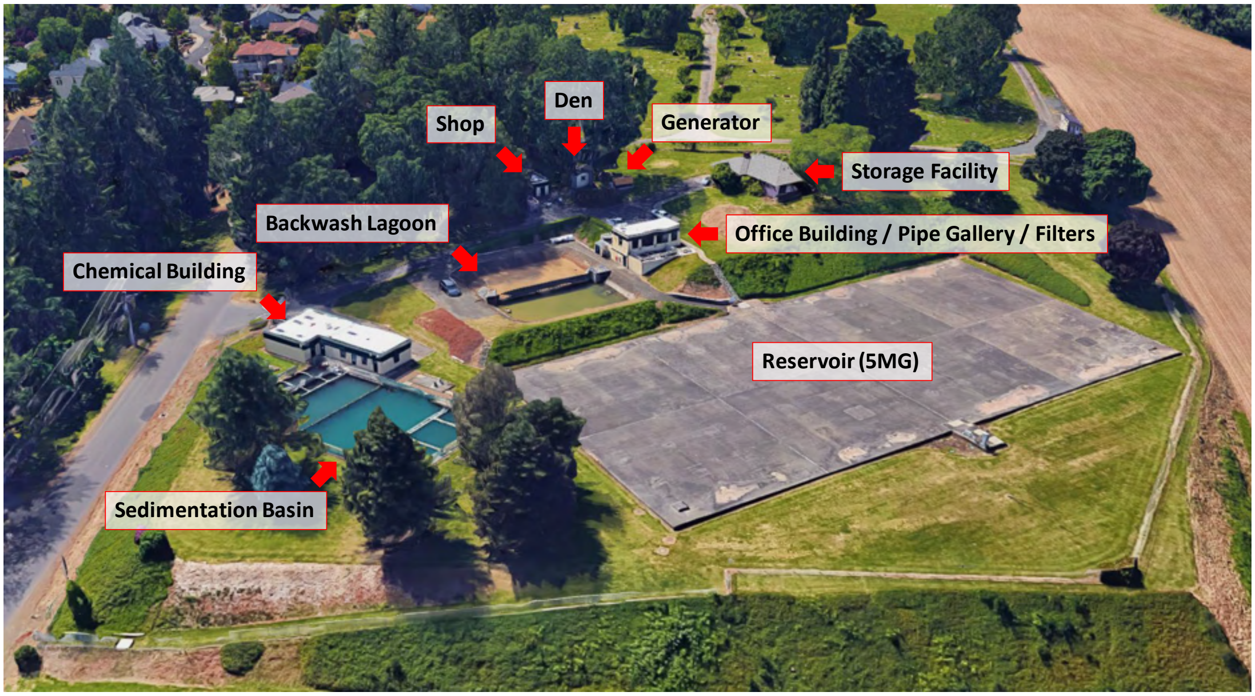

Figure 1: Water Treatment Plant and Reservoir Layout (Google, 2018)

2.1 CHEMICAL BUILDING

2.1.1 Description of Structure and Site Observations

The Chemical Building is a single-story "L"-shaped structure. The building has a total footprint of approximately 70 feet by 32 feet, and a total above-ground height of approximately 11 feet.

Photographs in Figures 2, 3, and 4 show the general layout of the building. Figure 5 shows the building's floorplan, while Figure 6 shows the southwest elevation cross-section.

The northeast section of the building was constructed in 1948. It has a rectangular 36 feet 7 inches by 22 feet floorplan, with reinforced concrete walls and a wood-frame roof. This section of the building included a second story that was removed during the construction of the southwest section in 1978 (Figure 7). An interior reinforced concrete column and two substantial reinforced concrete girders that supported the second story are still present (Figure 8). Several cracks were observed in the reinforced concrete walls (Figure 9 and Figure 10).

The southwest section of the building was constructed in 1978. It is approximately 33 feet 4 inches by 32 feet in plan. Its structural system consists of concrete masonry unit (CMU) walls and a wood-frame roof. Reinforcement of the CMU walls is specified in the available structural drawings as #4 vertical bars spaced every 32 inches, and #6 horizontal bars spaced every 48 inches.

A photograph of the southwest section under construction is shown in Figure 11. During the site visit, several cracks were observed in this portion of the building (Figure 12 and Figure 13).

Figure 2: Chemical Building and Sedimentation Basin, East Corner

Figure 3: Chemical Building, West Corner

Figure 4: Chemical Building, South Corner

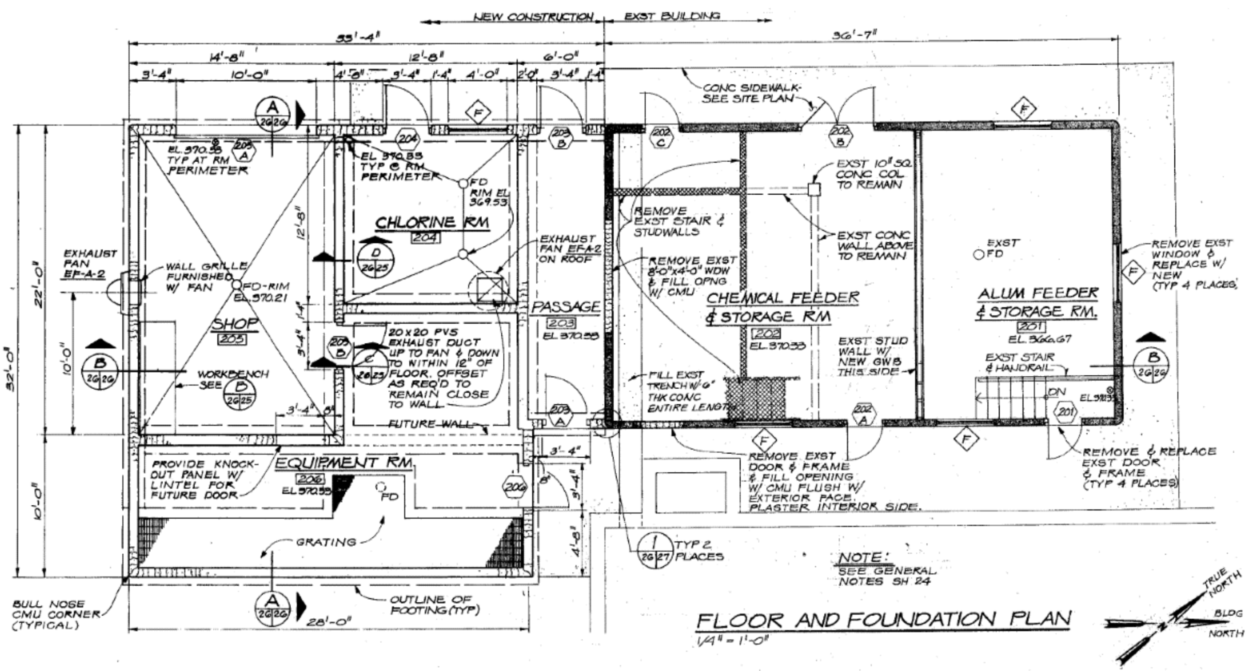

Figure 5: Floorplan, Chemical Building

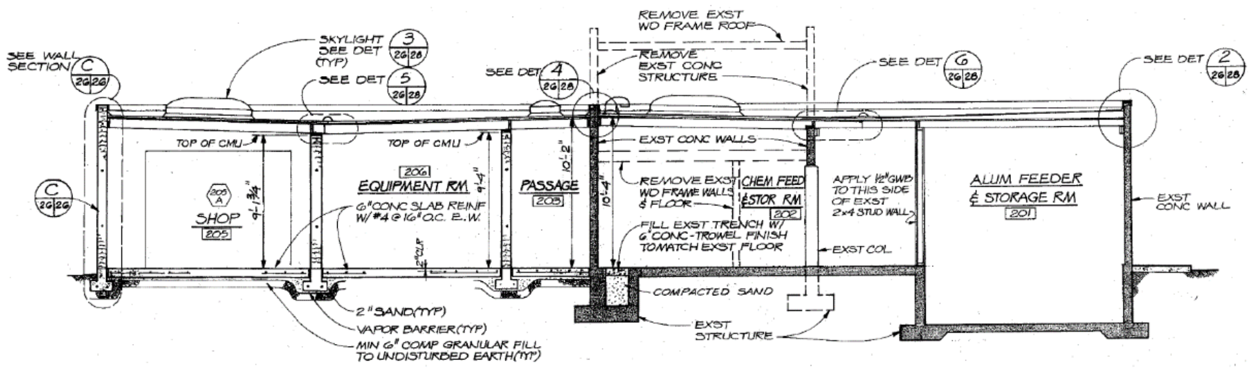

Figure 6: Southwest Elevation Cross-Section, Chemical Building

Figure 7: Chemical Building, 1978, Prior to Demolition of Second Story and Construction of Southwest Addition

Figure 8: Interior Reinforced Concrete Column and Girders, 1947 Section of Chemical Building

Figure 9: Vertical Crack, 1948 Section of Chemical Building

Figure 10: Horizontal Crack, 1948 Section of Chemical Building

Figure 11: Southwest Addition under Construction, 1978

Figure 12: Crack in Floor Slab, 1978 Section of Chemical Building

Figure 13: Vertical Crack Through CMUs, 1978 Section of Chemical Building

The 1948 section of the Chemical Building was likely designed using the 1941 edition of the Building Regulations for Reinforced Concrete (ACI 318-41) and prior to the implementation of the first provisions for seismic design criteria in the 1973 State of Oregon Structural Specialty Code and Fire and Life Safety Code (OSSC). The 1978 section of the Chemical Building was likely designed using the 1973 OSSC and is therefore expected to sustain less damage in an M9 CSZ scenario earthquake event than the 1948 section.

The wood framing of the roof in both sections of the Chemical Building appears to be in fair condition. Steel connection plates are used at the joints. Structural drawings for the 1978 addition show reasonable connection details between the wood frame roof joists and the CMU walls. Wood frame joist to reinforced concrete wall connection details for the 1947 section of the building are not available and could not be established during the site visit.

The 1948 and the 1978 sections of the Chemical Building are supported on separate foundations. Cracks were observed along the joint between the two sections (Figure 14). Pounding damage is possible between the two sections of the building in an M9 CSZ scenario earthquake event.

Figure 14: Crack Along Joint Between 1948 and 1978 Sections of Chemical Building

2.1.2 Structural Assessment

There are multiple door and window openings in the perimeter walls of the Chemical Building. The openings include a roll-up garage door, four doors, and two windows along the northeast face of the building; two door openings near the northeast corner of the 1978 section; two doors and two window openings along the southeast side of the 1947 section; and one window opening at the northeast wall of the 1948 section. There are no significant openings along the southwest and southeast walls of the 1978 section of the building. In an M9 CSZ scenario earthquake event, diagonal cracking may develop near the corners of the openings.

While cracking of the CMU and reinforced concrete structural elements is likely in an M9 CSZ scenario earthquake event, in our opinion, there is sufficient redundancy in the building's structural system to minimize the risk to life safety or structural collapse.

Base shear and roof connection checks were completed for the Immediate Occupancy performance level and were found to be compliant as per ASCE 41-17. The following is a summary of the assumptions and steps used to assess seismic performance of the building.

The base shear stress check is performed per ASCE 41-17 Section 4.4.3.3, Tier 1 Checklist 17-17.

The average shear stress in the shear wall is calculated as $V_{avg} = \frac{1}{M_s} \cdot \left(\frac{V_b}{A_w}\right)$, where M_s = 1.5 for Immediate Occupancy, V_b is the total base shear, and A_w is the summation of the net shear wall cross-sectional area in the direction of loading. To satisfy the base shear stress check, V_{avg} must be less than 70 psi per Table 17-17 of ASCE 41-17.

The northwest wall of the 1978 section is considered critical for the shear check because it has the most openings. For a single 8-inch CMU block, $A_{w,1}$ = 30 in^2 conservatively assuming no grout. The total length of each block unit in the wall including spacing between blocks is taken as 16 inches. The total A_w for the northwest wall that has a net length accounting for openings of 12.7 feet is A_w = 506 in^2.

The total base shear for the Chemical Building using S_s = 0.52g and assuming a response modification factor R = 1, importance factor I = 1.0, and conservatively assuming grouted walls and a roof load of 10 psf, is calculated as:

$$V_b = 0.52\left(2 \times 22 \times 11 \times \frac{8}{12} \times 145 + 2 \times 33.3 \times 11 \times \frac{8}{12} \times 145 + 22 \times 33.3 \times 10\right) = 65{,}000 lbs$$

Half of this base shear is assumed to be resisted by the northwestern wall.

Using $V_{b,\ NW\ Wall}$ = 32,500 lb, the corresponding V_{avg} is calculated as:

$$V_{avg,NW\ Wall} = \frac{1}{M_s} \cdot \left(\frac{V_b}{A_w}\right) = \frac{1}{1.5} \cdot \left(\frac{32{,}500 lb}{506 in^2}\right) = 43\ psi < 70\ psi\ \therefore OK$$

The average shear is below the ASCE 41-17 threshold of 70 psi (Table 17-17 of ASCE 41-17) even with the conservative assumptions; therefore, the CMU walls are found to be compliant for Immediate Occupancy.

The roof connection check is also performed using conservative assumptions. The wood frame roof is anchored to the CMU walls using ¾-inch dimeter anchors at 3-foot spacing. The effective shear capacity of a single anchor is $F_v = 0.6 \times 36 \times 0.75 \times 0.44 = 7.1\ kips$.

The shear demand per anchor using S_s = 0.52g and assuming response modification factor R = 1, is calculated as:

$$V_{ab} = 0.52\left(10 \times 11 \times 3 + 2 \times 11.2 \times 0.5 \times 11 \times \frac{8}{12} \times 145 \times \frac{3}{33.3}\right) = 730 lbs$$

The shear capacity per anchor significantly exceeds the demand even with conservative assumptions, therefore the roof connection is found to be compliant for Immediate Occupancy.

2.1.3 Nonstructural Assessment

The sodium fluoride tank (Figure 15) located in the 1948 section and the sodium hypochlorite tank (Figure 16) located in the 1978 section and of the Chemical Building were observed to be unanchored. Damage to the tanks and connected pipes is possible in an M9 CSZ scenario earthquake event. Other tanks within the Chemical Building were observed to be anchored. It is recommended that a complete inventory list be prepared of all equipment and their anchorage status, and unanchored equipment anchored. Observations from past earthquakes show that unanchored equipment is a significant source of seismic damage and resulting economic and operational continuity.

Figure 15: Unanchored Sodium Fluoride Tank, Chemical Building

Figure 16: Unanchored Sodium Hypochlorite Tank, Chemical Building

2.2 OFFICE BUILDING/PIPE GALLERY/FILTERS

2.2.1 Description of Structure

The Office Building/Pipe Gallery/Filters structure was built in 1948 and modified in 1978. The building has a total footprint of approximately 36 feet by 17 feet 6 inches. The ground level is used as the office and control room, while the lower level contains the Pipe Gallery. The Filters are partially buried reinforced concrete rectangular reservoirs connected to the Pipe Gallery along the southwest and northeast walls. Figures 17, 18, and 19 show elevations of the structure. Figure 20 shows the Office Building floor plan. Figures 21 and 22 show the structure during construction.

Figure 17: Office Building/Pipe Gallery/Filters, Southwest Elevation

Figure 18: Office Building/Pipe Gallery/Filters, Northeast Elevation

Figure 19: Office Building/Pipe Gallery/Filters, South Corner, and Backwash Lagoon

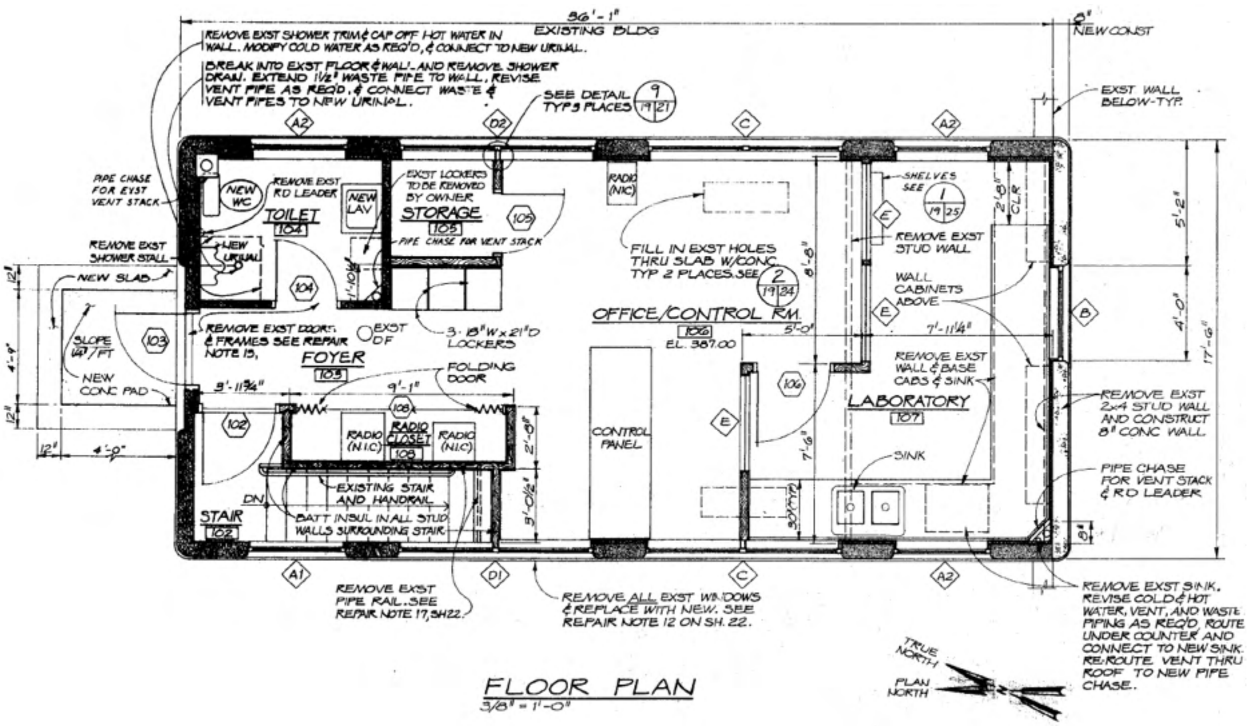

Figure 20: Office Building Floorplan

Figure 21: Office Building, 1978, Prior to Construction of Backwash Lagoon

Figure 22: Office Building, 1979, Chemical Building and Backwash Lagoon Construction Nearly Completed

2.2.2 Site Observations

Concrete deterioration possibly due to water damage from the adjacent Filters was observed at the staircase between the Pipe Gallery and the Office Building (Figure 23). Horizontal cracks in the reinforced concrete wall were observed above windows at ground level (Figure 24). The walls of the Filters were observed to be in generally good condition with no significant cracks.

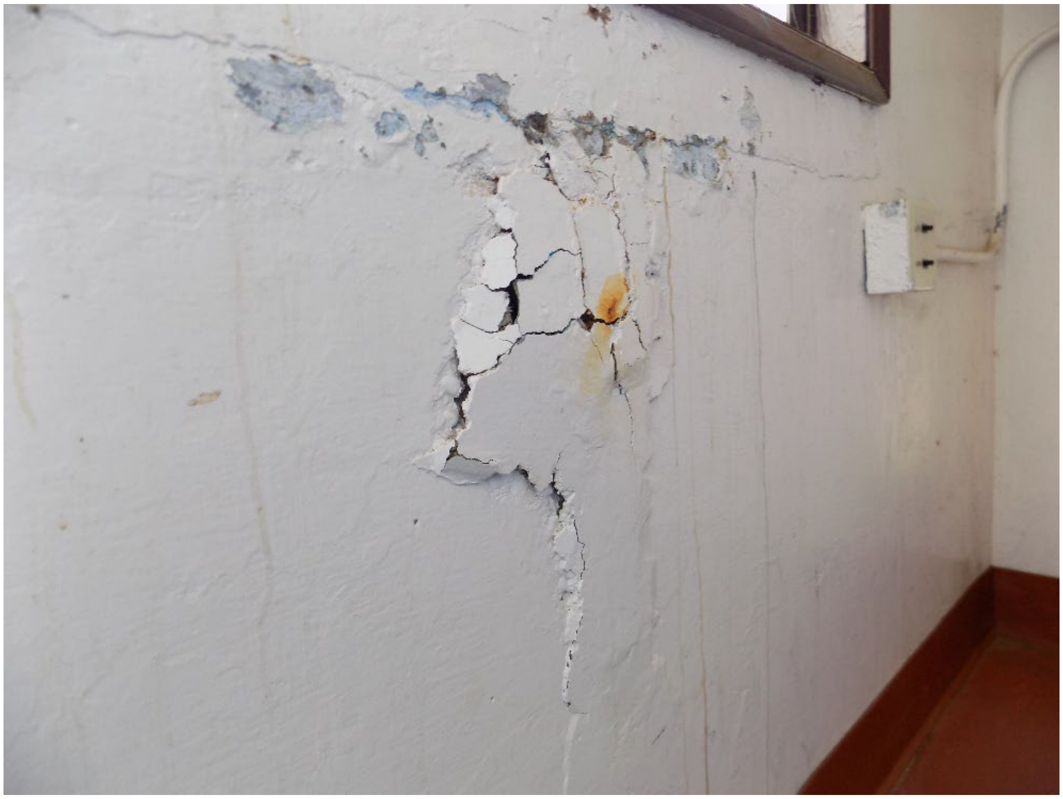

Figure 23: Concrete Deterioration, Office Building

Figure 24: Horizontal Cracks Above Office Building Windows at Ground Level

2.2.3 Office Building: Structural Assessment

The building's 8-inch-thick concrete walls are reinforced with #5 vertical bars at 18-inch spacing and #5 horizontal bars at 15-inch spacing. The horizontal and vertical reinforcement is located along the centerline of the wall. The building has multiple door and window openings at the ground level, including two 4'0"W x 5'0"H and two 8'0"W x 5'0"H window openings in each of the southwest and northeast walls, a 3'0"W x 7'0"H door in the northwest wall, and a 4'0"W x 5'0"H window opening in the southeast wall. Cracking is possible in the reinforced concrete walls adjacent to the openings in an M9 CSZ scenario earthquake event. However, according to the available structural drawings, additional reinforcement is provided at edges of openings (two #5 bars that extend 2'0" past each side of openings and additional two #5 diagonal bars 4'0" in length are provided at each corner), so that loads around the openings have a continuous path and there is a reasonable amount of steel present to limit extensive concrete damage due to ground shaking.

An ASCE 41-17 Tier 1 check was completed using Checklist 17-25 and the building was found to be compliant for Immediate Occupancy. The following is a summary of the assumptions and steps made as part of the shear stress and the roof slab connection checks.

The shear stress check is performed per ASCE 41-17 Section 4.4.3.3, Tier 1 Checklist 17-25. The shear stress in the concrete shear walls is to be less than the greater of 100 psi or $2\sqrt{f_c'}$. The average shear stress in the shear wall is calculated as $V_{avg} = \frac{1}{M_s} \cdot \left(\frac{V_b}{A_w}\right)$, where M_s = 1.5 for Immediate Occupancy, V_b is the total base shear, and A_w is the summation of the net shear wall cross-sectional area in the direction of loading.

The total base shear is calculated conservatively assuming a response modification factor of R = 1.0 and an importance factor of I = 1.0 for S_s = 0.52g as:

$$\begin{aligned} V_b = 0.52 \times 145\big(&36'9 \times 17'6" \times 12'2 - 1'10" \times 35'5 \times 16'2" \ - 35'5 \times 16'2" \times 9'10 \\ &- \ 2 \times 24'0" \times 5'0 \times 8" - 4'0 \times 5'0" \times 8 - 3'0" \times 7'0" \times 8"\big)/1000 \ = 72.2\ kips \end{aligned}$$

Half of this base shear is assumed to be resisted by each wall.

The net shear wall cross-sectional area, A_w, is calculated at an elevation of 3'6" at the base of the window openings as: $A_w = 8" \times (36'9" - 2 \times 4' - 2 \times 8') \times 12 = 1{,}224\ in^2$.

Using $V_{b,\text{ One Wall}}$ = 36,100 lb, the corresponding V_{avg} is calculated as:

$$V_{avg,NW\ Wall} = \frac{1}{M_s} \cdot \left(\frac{V_b}{A_w}\right) = \frac{1}{1.5} \cdot \left(\frac{36{,}100 lb}{1{,}224 in^2}\right) = 20\ psi < 100\ psi\ \ \therefore OK$$

The average shear is below the ASCE 41 threshold of 100 psi even with the conservative assumptions; therefore, the walls are found to be compliant for Immediate Occupancy.

The roof slab connection check is also performed using conservative assumptions. The reinforced concrete roof is anchored to the reinforced concrete walls using 5/8-inch diameter anchors at 3-foot spacing. The effective shear capacity of a single anchor is $F_v = 0.6 \times 36 \times 0.75 \times 0.31 = 5.0\ kips$.

The shear demand per anchor using S_s = 0.52g and assuming response modification factor R = 1, is calculated as:

$$V_{ab} = 0.52 \times 145 \times 3'/17'6"(0.5 \times 6" \times 36'9" \times 17'6" + 2 \times 0.5 \times 0.5 \times 36'9" \times 12'2" \times 8")/1000 = 4.0\ kips$$

The shear capacity per anchor exceeds the demand even with conservative assumptions, therefore the roof connection is found to be compliant for Immediate Occupancy.

2.2.4 Office Building: Nonstructural Assessment

Minor damage to the nonstructural components in the Office Building (Figure 25 and Figure 26) in an M9 CSZ event is possible but is not expected to affect operations.

Figure 25: Filters, Mechanical Components

Figure 26: Filters, Mechanical Components

2.2.5 Pipe Gallery: Structural Assessment

The Pipe Gallery has a 36’2” by 16’0” floor plan and height of 11’4” (Figure 27). The walls are 10”-thick, the ceiling slab is 8”-thick, and the floor slab is 8” to 10” thick. The walls and the floor slab are reinforced with ½”-diameter bars at 6” in each direction, located along the centerline. The ceiling slab is reinforced with ½”-diameter bars at 12” top and bottom along the long dimension, and ½”-diameter bars at 4.5” and 6” top and bottom along the short dimension, respectively (Figure 28). Figure 29 shows the interior of the Pipe Gallery.

The Pipe Gallery is a mostly buried structure with only one wall exposed. Buried structures have performed well in past earthquakes if not subjected to permanent ground deformation (PGD). The WTP structures are not subjected to PGD in an M9 CSZ event. Cracking in the walls of the Pipe Gallery is possible due to ground shaking but is expected to be limited and is not expected to affect operations.

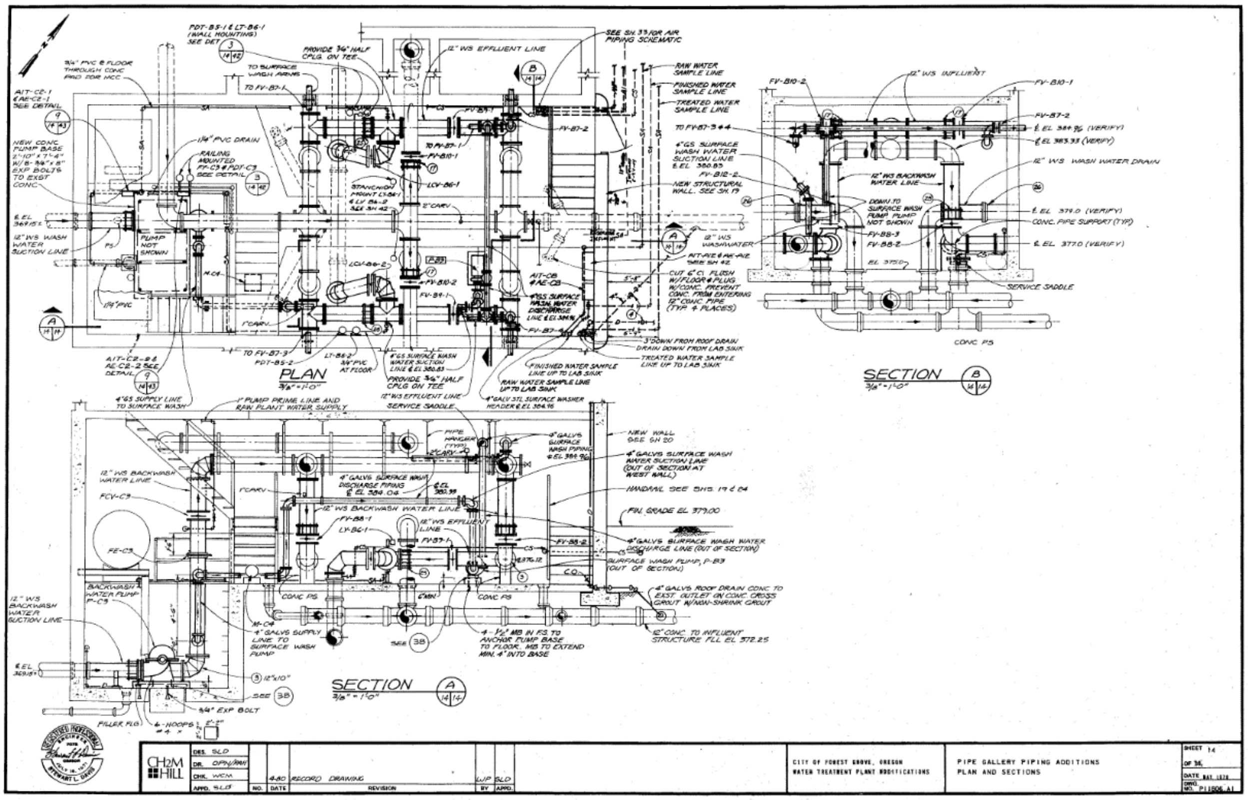

Figure 27: Pipe Gallery Plan and Sections

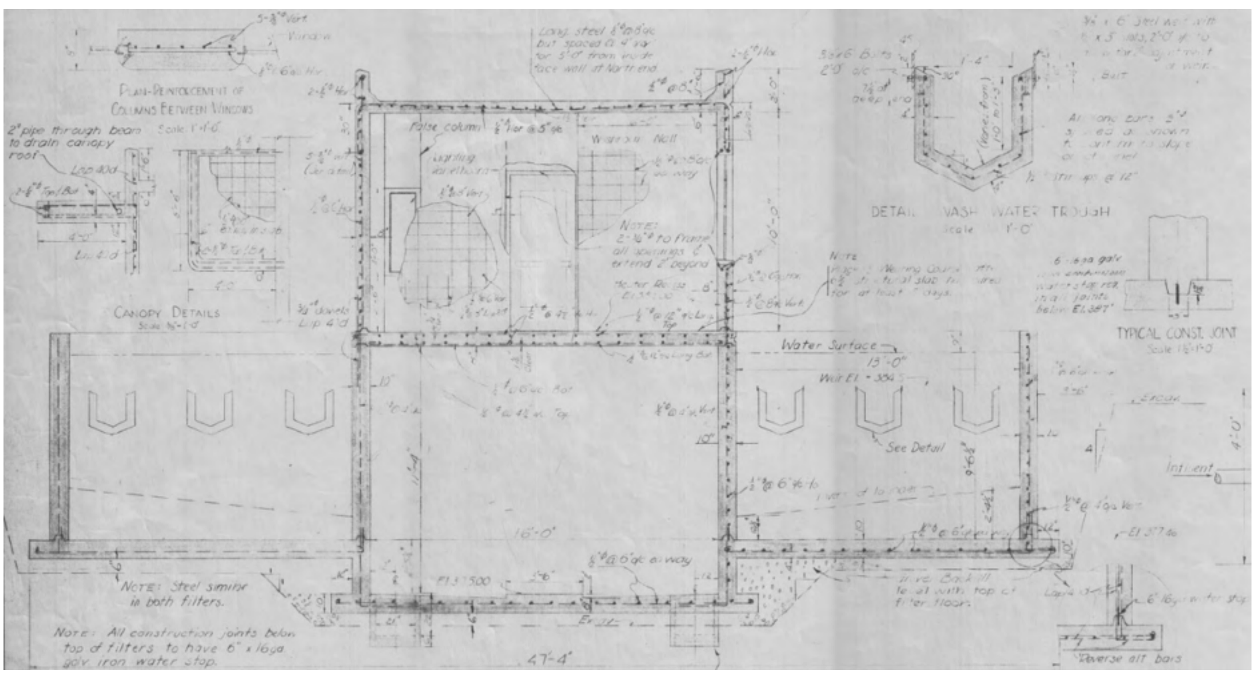

Figure 28: Office Building/Pipe Gallery/Filters Reinforcement Details

Figure 29: Pipe Gallery

2.2.6 Pipe Gallery: Nonstructural Assessment

Pumps and pipes in the Pipe Gallery were observed to be anchored to the floor slab. Water leakage was observed (Figure 30). No significant evidence of structural distress was observed.

Figure 30: Pipe Gallery Anchorage and Water Leakage

2.2.7 Filters: Structural Assessment

The Filters are reinforced concrete rectangular water-containing structures adjacent to the Pipe Gallery, along the southwest and the northeast walls. Figures 31 to 34 show the Filters in relation to the Pipe Gallery and the Office Building structures. Each of the two filter structures is 25’6” by 14’8” in plan with 9’6.5”-high walls (Figure 35). Perimeter walls are 10”-thick and the interior walls are 8”-thick. Vertical reinforcement in the walls consists of ½”-diameter bars spaced 4” located along the centerline. Horizontal reinforcement consists of ½”-diameter bars spaced 6” on center (Figure 36). Corners are reinforced with continuous bars that make a 90-degree bend and extend 40 bar diameters beyond the bend (Figure 37).

The Filters are a mostly buried structure with only one wall and a portion of a second wall exposed. Buried structures have performed well in past earthquakes if not subjected to permanent ground deformation (PGD). The WTP structures are not subjected to PGD in an M9 CSZ event. Cracking in the walls of the Filters is possible due to ground shaking but is expected to be limited and is not expected to affect operations.

Figure 31: Office Building/Pipe Gallery/Filters, Southeast Elevation

Figure 32: Office Building/Pipe Gallery/Filters, South Corner

Figure 33: Northeast Filters, Northeast Elevation

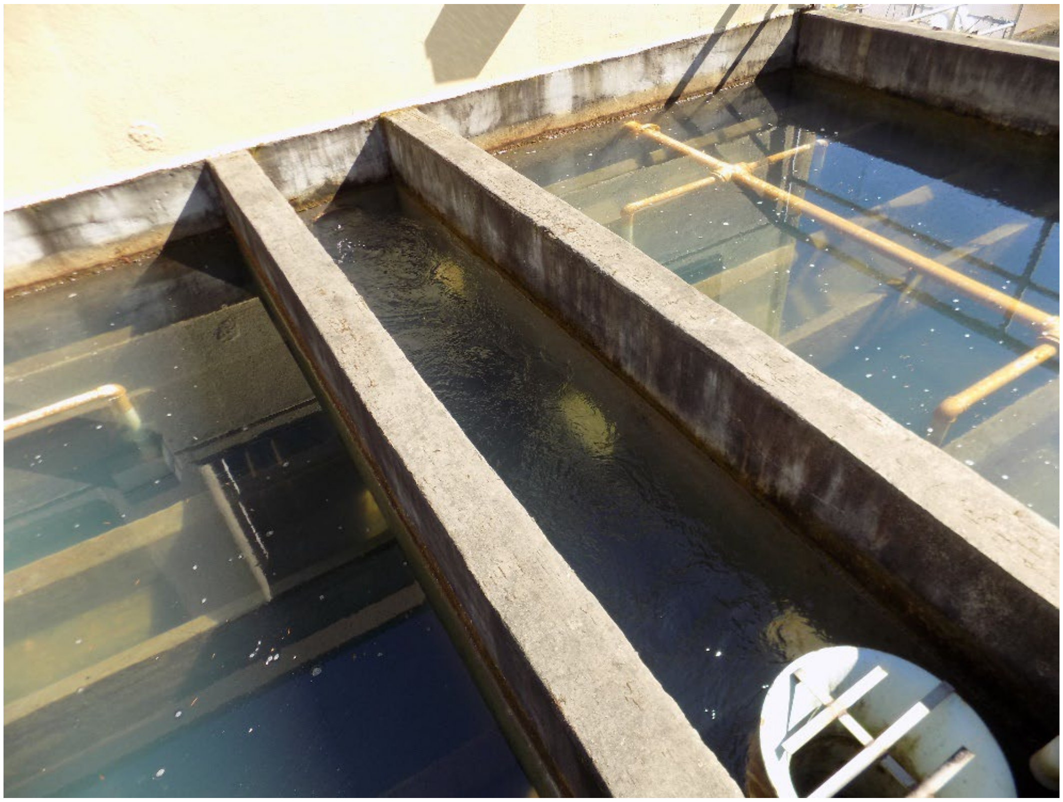

Figure 34: Southwest Filters Detail

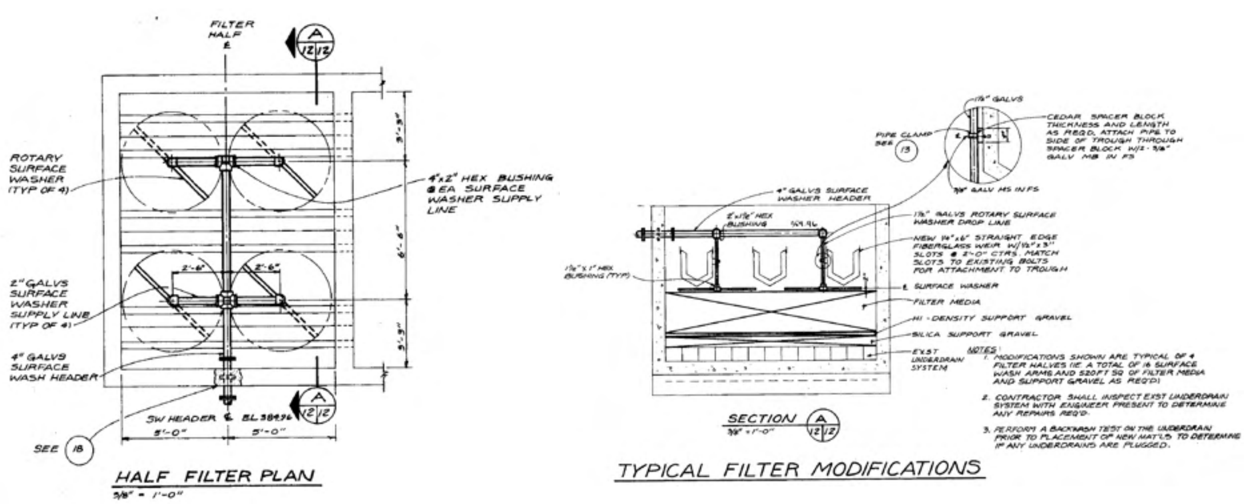

Figure 35: Filter Plan and Section, 1978

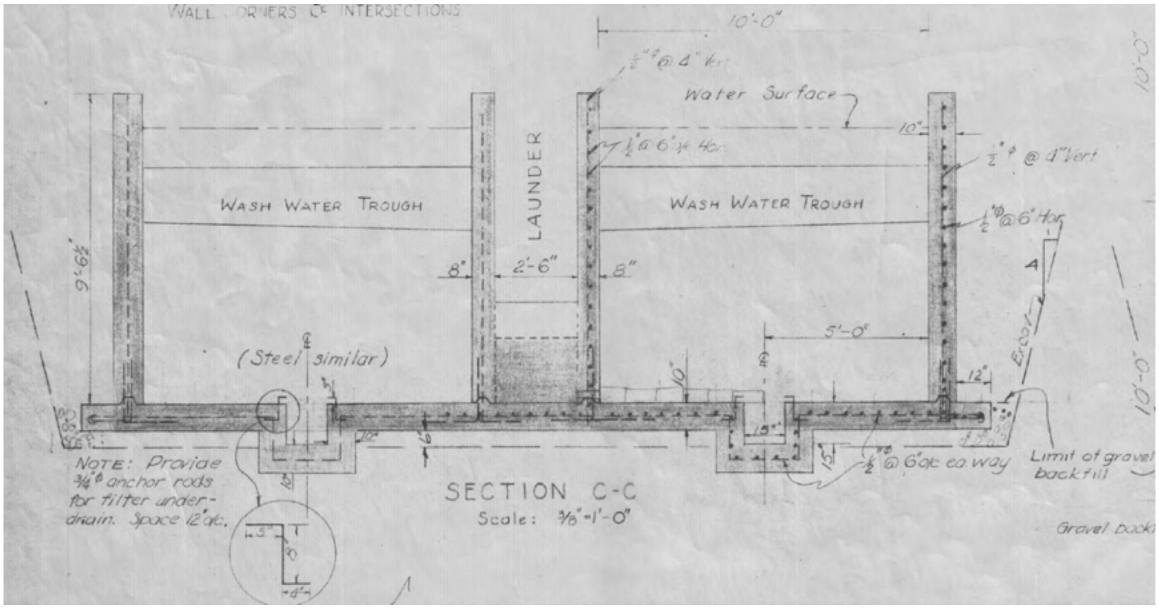

Figure 36: Filters Elevation, 1947

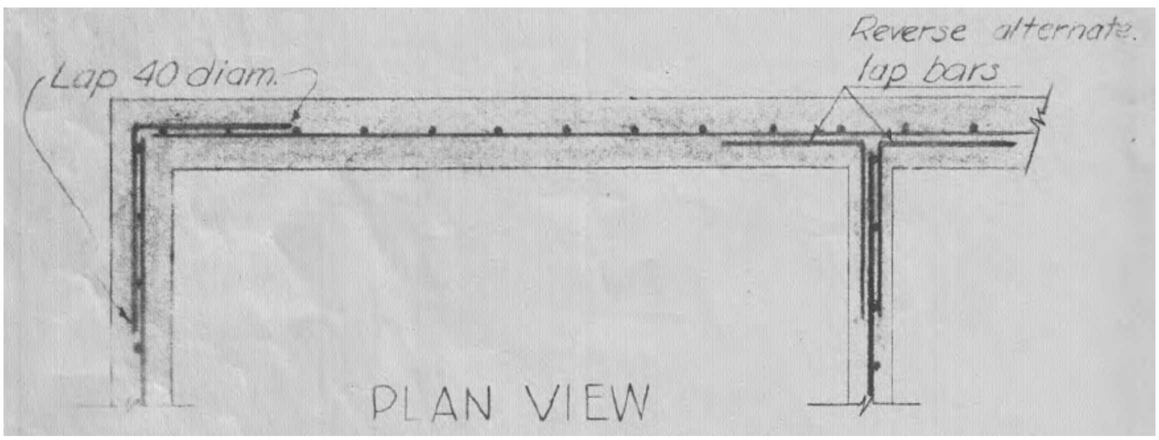

Figure 37: Typical Reinforcement of Wall Corners and Intersections, 1947

2.2.8 Filters: Nonstructural Assessment

Minor damage to the mechanical components of the Filters (Figure 38) in an M9 CSZ event is possible but is not expected to affect operations.

Figure 38: Filters, Mechanical Components

2.3 SHOP

The Shop is a single-story structure with reinforced concrete masonry unit (CMU) walls and a wood frame roof. The building's exterior elevations are shown in Figures 39 and 40. The typical wood roof framing is shown in Figure 41. The Shop was likely constructed in the 1980s. The Shop contains the drum machine, which operates approximately 180 days a year. The Shop is not a critical facility. The structure has a wide garage-door opening and a door opening in the east wall. There are no openings in the other three walls. No visually apparent significant structural distress, such as settlement or structural cracking, was observed during the site visit. Pumps within the Shop building were observed to be anchored to the floor slab.

While cracking of the CMU walls, particularly near the corners of the door openings in the east wall, is likely in an M9 CSZ scenario earthquake event, in our opinion, there is sufficient redundancy in the building's structural system to minimize the risk to life safety or structural collapse.

Figure 39: Shop, East Elevation

Figure 40: Shop, Northwest Corner

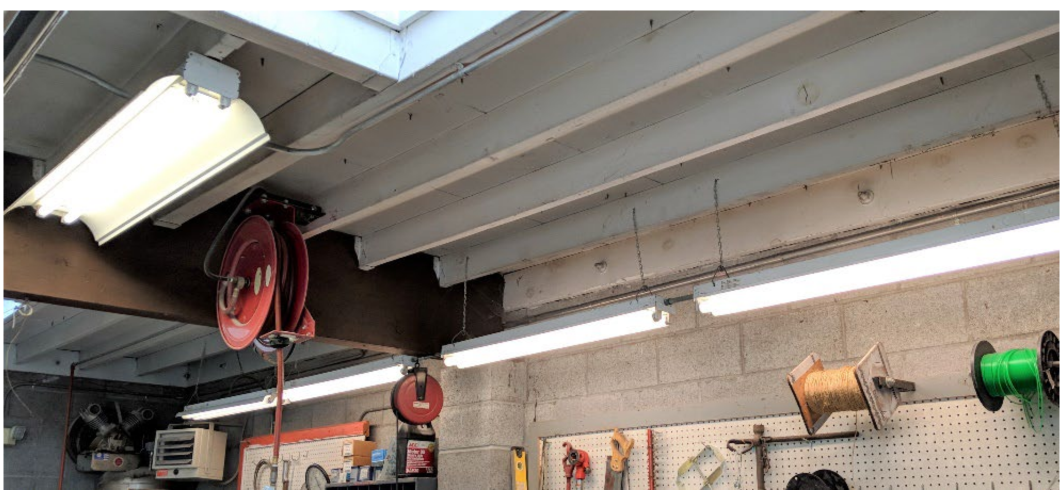

Figure 41: Shop, Wood Frame Roof

2.4 DEN

The single-story wood frame Den was constructed in 2002. According to Brian Dixon, under whose supervision the structure was constructed, the structure was not engineered. The structure is used to store a tractor and various tools. The Den is not a critical facility. Typical elevations are shown in Figures 42 and 43. Typical roof wood framing is shown in Figure 44. The Den is built above a pre-existing foundation slab (Figure 45), which was leveled prior to construction of the Den. The wood frame structure uses diagonal bracing and plywood sheathing for lateral force resistance. The structure is anchored to the foundation slab. The Den is not expected to sustain significant damage in the M9 CSZ scenario earthquake event.

Figure 42: Den, Southeast Corner

Figure 43: Den, West Elevation

Figure 44: Wood Framing Detail

Figure 45: Den Foundation Detail

2.5 STORAGE FACILITY

The wood frame building currently used a storage facility was historically used as housing for the plant manager. The exact date of construction is not known. Based on a 1978 photograph (Figure 46), the building was constructed prior to 1978. The building is currently in fair condition (Figure 47). No obvious signs of structural deterioration were observed. The building may benefit from structural seismic retrofit improvements. It is our understanding that the building may be demolished in the future. A detailed structural inspection is recommended if the building will be continued to be used in the future.

Figure 46: Building Currently Used as Storage Facility, 1978

Figure 47: Building Currently Used as Storage Facility, 2018

2.6 GENERATOR

An emergency generator is located at ground level between the Den and the Storage Facility buildings (Figure 48). The generator is anchored to the reinforced concrete platform, on which the generator is supported (Figure 49). Electrical cabinets are supported on a separate reinforced concrete platform (Figure 50). Anchorage status of the larger electrical cabinet could not be confirmed during the site visit.

The generator is capable of supplying electricity to operate the water treatment plant at full capacity for 32 hours. The generator comes on-line automatically in case power is lost for more than three seconds. The generator is load tested once a month and maintained annually by Caterpillar.

Sliding and overturning checks were completed for the generator and the nearby electrical cabinet using basic engineering principles. The generator is anchored to the base slab using four small-diameter anchor bolts along each longer dimension. These anchor bolts may fail in shear or yield in tension but are expected to limit significant sliding or overturning. Assuming that the electrical cabinet is not anchored properly, limited sliding on the base slab is possible, but overturning is unlikely, given S_s of 0.52g and the approximately 2 to 3 width to height ratio.

Due to the importance of the generator to provide emergency power following a major earthquake. It is recommended that additional anchorage that is designed to withstand ground motions from an M9 CSZ earthquake be provided for the generator and electrical panel.

Figure 48: Electric Generator

Figure 49: Electrical Generator Anchorage Detail

Figure 50: Electrical Cabinets

2.7 WTP RESERVOIR

The WTP reservoir is covered in detail in the Reservoir Technical Memo, which is included as Appendix E to the Water System SRP report.

2.8 SEDIMENTATION BASIN

The Sedimentation Basin was constructed in 1910 and was originally used as a reservoir. It is the second oldest sedimentation basin in Oregon. Figure 51 shows the general layout of the Sedimentation Basin within the WTP. Pumps adjacent to the Sedimentation Basin pump water from the Sedimentation Basin to the Backwash Lagoon (Figure 52). No structural design details are available. Based on available schematic drawings, the walls are supported by counterforts, which are buttress-like elements that provide lateral strength and stability to the walls.

Significant concrete deterioration of the perimeter walls was observed during the site visit (Figure 53 and Figure 54). If not subjected to permanent ground deformation such as from liquefaction, landslide, or fault rupture, buried structures have performed well in past earthquakes. The WTP is located on a competent site with no significant permanent ground deformation hazard. Therefore, major damage such that it causes disruption in operation is unlikely. However, some cracking of the perimeter walls in an M9 CSZ scenario earthquake event could occur.

Figure 51: Sedimentation Basin, East Corner

Figure 52: Pumps Adjacent to Sedimentation Basin

Figure 53: Historical Inscription (1910), Concrete Deterioration

Figure 54: Current Condition of Perimeter Wall, Concrete Deterioration

2.9 BACKWASH LAGOON

The Backwash Lagoon was constructed in 1978-1979. Construction of the dividing wall between the Backwash Lagoon's two ponds is shown in Figure 55. The current condition of the Backwash Lagoon is shown in Figure 56 and Figure 57. No signs of significant structural deterioration were observed.

Moment-axial force interaction check for the divider wall of the Backwash Lagoon subjected to hydrodynamic forces and the wall's own inertia load was completed and shows that the capacity of the divider wall is not exceeded (Figure 58). Although the divider wall may develop minor cracks in an M9 CSZ event, the operations of the backwash lagoon are not expected to be impacted.

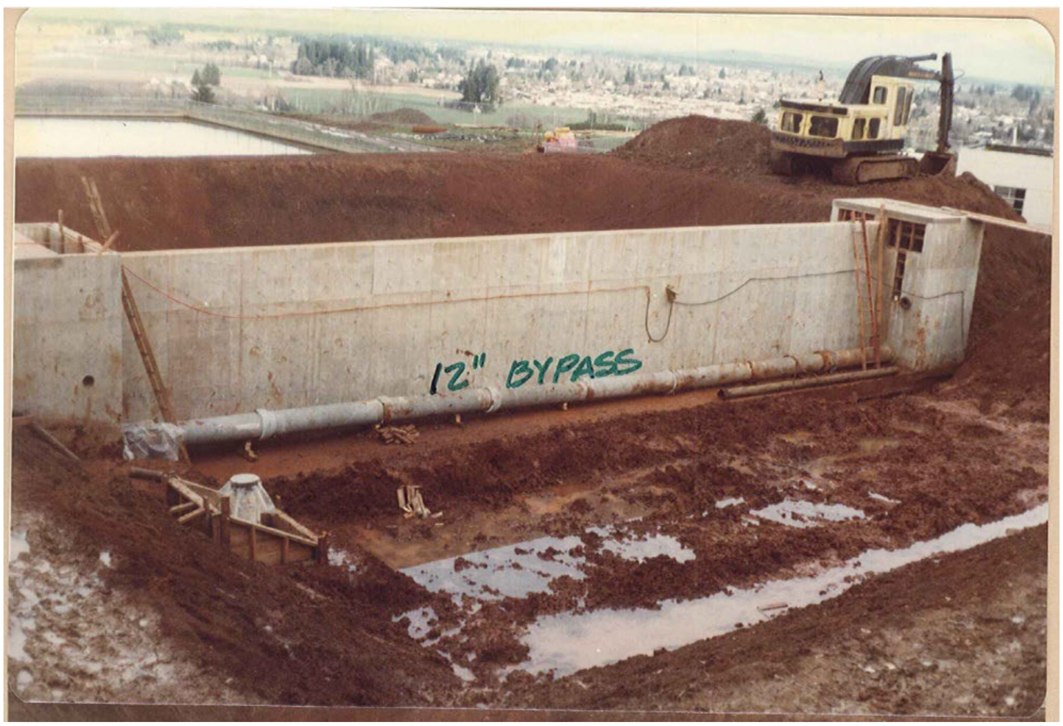

Figure 55: Backwash Lagoon Under Construction, 1979

Figure 56: Backwash Lagoon, 2018

Figure 57: Current Condition of Dividing Wall, Backwash Lagoon

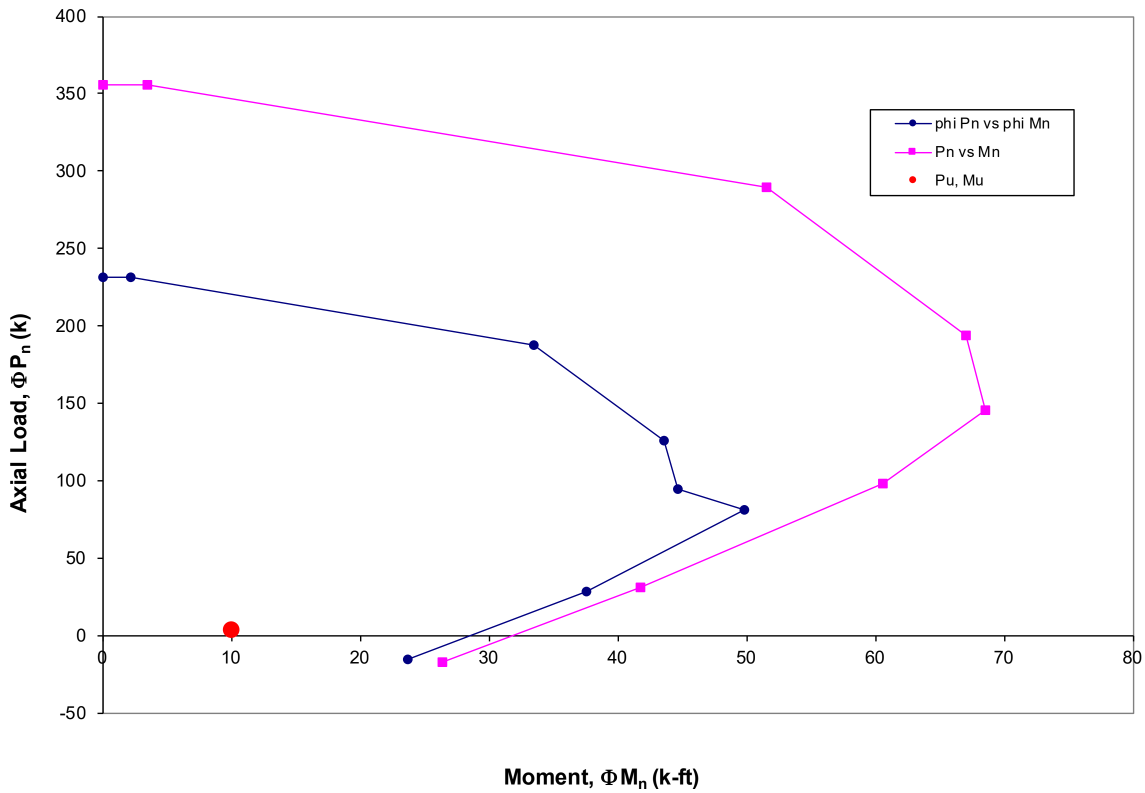

Figure 58: Moment-Axial Interaction Diagram for Divider Wall

3.0 DAVID HILL RESERVOIR AND PUMP STATION

David Hill Reservoir is covered in detail in the Reservoir Technical Memorandum, which is included as Appendix E to the Water System SRP report.

David Hill Pump Station is a single-story structure with CMU walls (Figure 59 and Figure 60) and a wood frame roof (Figure 61). The building was constructed in 1982 and designed using the 1980 Oregon Structural Specialty Code (OSSC). The building has a rectangular 15 feet 4 inches by 16 feet 8 inches footprint and a total height of approximately 11 feet. Vertical reinforcement is specified in structural drawings as #5 bars spaced 48 inches (Figure 63). Horizontal reinforcement also consists of #5 bars, but the spacing could not be established based on the available drawings.

During the site visit, the structure and its components appeared to be in good condition. No cracks or water leakage was observed. Pumps and pipelines within the pump station were observed to be anchored (Figure 62). There is only one opening in the CMU walls – a door opening in the east wall.

While cracking of the CMU walls, particularly near the corners of the door opening in the east wall, is possible in an M9 CSZ scenario earthquake event, in our opinion, there is sufficient redundancy in the building's structural system to minimize the risk to life safety or structural collapse.

Furthermore, base shear and roof connection checks were completed for the Immediate Occupancy performance level and were found to be compliant as per ASCE 41-17. The following is a summary of the assumptions and steps used to assess seismic performance of the building.

The base shear stress check is performed per ASCE 41-17 Section 4.4.3.3, Tier 1 Checklist 17-17.

The average shear stress in the shear wall is calculated as $V_{avg} = \frac{1}{M_s} \cdot \left(\frac{V_b}{A_w}\right)$, where M_s = 1.5 for Immediate Occupancy, V_b is the total base shear, and A_w is the summation of the net shear wall cross-sectional area in the direction of loading. To satisfy the base shear stress check, V_{avg} must be less than 70 psi.

The total A_w for the shorter wall is $A_w = 15'4" \times 8" = 1{,}472\ in^2$.

The total base shear using S_s = 0.52g and assuming a response modification factor R = 1, importance factor I = 1.0, and conservatively assuming grouted walls and a roof load of 10 psf, is calculated as:

$$V_b = 0.52\left(2 \times 16'8" \times 8'6" \times 8" \times 145 + 2 \times 15'4" \times 8'6" \times 8" \times 145\ + 16'8" \times 15'4" \times 10"\right) = 28{,}800\ lbs$$

Half of this base shear is assumed to be resisted by each wall.

Using $V_{b,\text{ One Wall}}$ = 14,400 lb, the corresponding V_{avg} is calculated as:

$$V_{avg} = \frac{1}{M_s} \cdot \left(\frac{V_b}{A_w}\right) = \frac{1}{1.5} \cdot \left(\frac{14{,}400 lb}{1{,}472 in^2}\right) = 7\ psi < 70\ psi\ \therefore OK$$

The average shear is well below the ASCE 41 threshold of 70 psi even with the conservative assumptions; therefore, the CMU walls are found to be compliant for Immediate Occupancy.

The roof connection check is also performed using conservative assumptions. The wood frame roof is anchored to the CMU walls using ½-inch dimeter anchors at 4-foot spacing. The effective shear capacity of a single anchor is $F_v = 0.6 \times 36 \times 0.75 \times 0.2 = 3.2\ kips$.

The shear demand per anchor using S_s = 0.52g and assuming response modification factor R = 1, is calculated as

$$V_{ab} = 0.52\left(2 \times 0.5 \times 0.5 \times 16'8" \times 8'6" \times 8" \times 145 \times 4'/15'4" + 0.5 \times 16'8" \times 15'4" \times 10" \times 4'/15'4"\right)/1000 = 0.9\ kips$$

The shear capacity per anchor exceeds the demand even with conservative assumptions, therefore the roof connection is found to be compliant for Immediate Occupancy.


Figure 59: David Hill Pump Station, South Elevation


Figure 60: David Hill Pump Station, Northwest Corner

Figure 61: David Hill Pump Station, Wood Frame Roof

Figure 62: David Hill Pump Station, Pumps and Pipelines

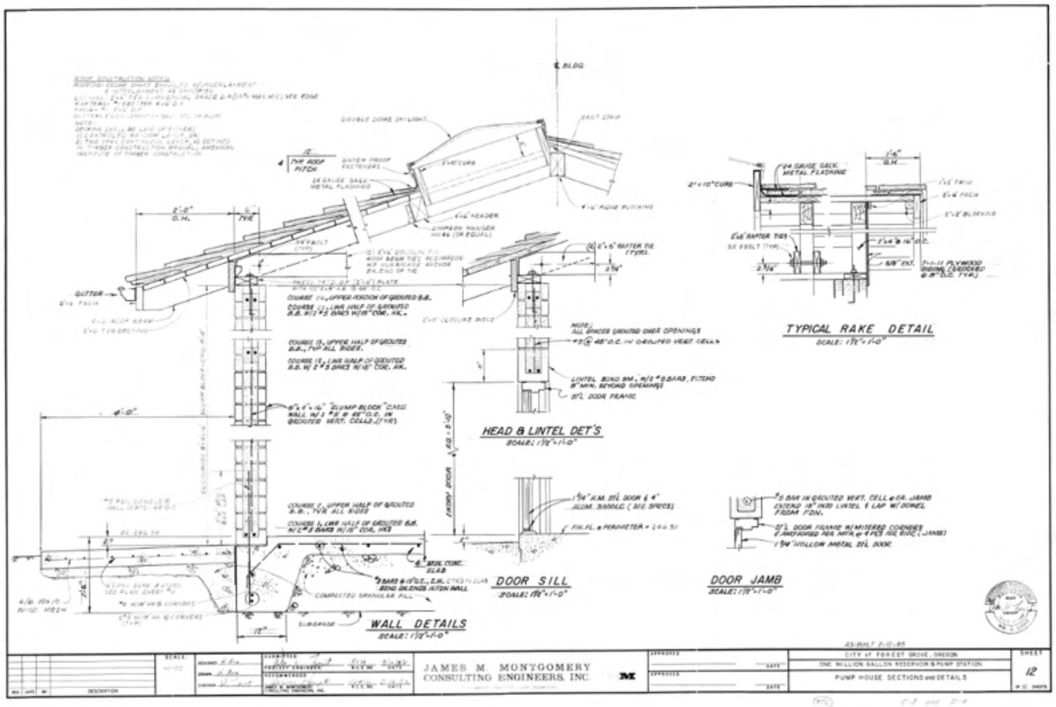

Figure 63: David Hill Pump Station Typical Details

4.0 WATERCREST ROAD PUMP STATION

Watercrest Road Pump Station is a buried reinforced concrete structure constructed in 1978. The exterior of the structure is covered in moss (Figure 64). No evidence of significant structural deterioration or water leakage was observed during the site visit (Figure 65 and Figure 66). The pump and pipelines were observed to be anchored. Watercrest Road Pump Station is not expected to sustain significant structural damage in an M9 CSZ scenario earthquake event.

Figure 64: Watercrest Road Pump Station

Figure 65: Watercrest Road Pump Station, Roof Slab Detail

Figure 66: Watercrest Road Pump Station, Anchored Pump and Pipeline

5.0 RAW WATER PUMP STATION

Raw Water Pump Station is a buried reinforced concrete structure constructed in 1978 (Figure 67). No evidence of significant structural deterioration was observed during the site visit. A diagonal crack was observed in one of the reinforced concrete walls (Figure 68). The pump and pipelines were observed to be anchored. Evidence of water leakage and corrosion of the pump pedestal were observed (Figure 69). Raw Water Pump Station is not expected to sustain significant structural damage in an M9 CSZ scenario earthquake event.

Figure 67: Raw Water Pump Station

Figure 68: Raw Water Pump Station, Diagonal Crack in Reinforced Concrete Wall

Figure 69: Raw Water Pump Station, Anchored Pump, Evidence of Corrosion

6.0 10TH AVENUE FLOW CONTROL AND METERING STATION

The 10th Avenue Station is a single-story structure with CMU walls (Figure 70 and Figure 71) and a wood frame roof (Figure 72). The building was constructed in the late 1970s and likely designed using the 1974 or later State of Oregon Structural Specialty Code and Fire and Life Safety Code (OSSC). The building has a rectangular footprint of approximately 31 by 23 feet and a total height of approximately 11 feet.

During the site visit, the structure and its components appeared to be in good condition. Pipelines and electric cabinets within the station were observed to be anchored. No water leakage was observed during the site visit. There is only one opening in the CMU walls – a door opening in the north wall. Diagonal cracking of the SMU wall was observed at the north wall near a large diameter pipe that penetrates the wall (Figure 73).

While cracking of the CMU walls, particularly near the corners of the door opening and the large diameter pipe at the north wall, is possible in an M9 CSZ scenario earthquake event, in our opinion, there is sufficient redundancy in the building's structural system to minimize the risk to life safety or structural collapse.

In general, CMU building with a relatively small footprint have performed well in past earthquakes. However, it is our understanding that this building is critical for continued water supply in an emergency, we recommend that a detailed evaluation of the building for continued operation in an M9 CSZ earthquake be performed. Special attention should be paid to the roof-to-wall connections.

Figure 70: 10th Avenue Station, North Elevation

Figure 71: 10th Avenue Station, South Elevation

Figure 72: 10th Avenue Station, Wood Frame Roof

Figure 73: 10th Avenue Station, Diagonal Crack

7.0 PUBLIC WORKS FACILITY

Public Works Facility includes the Office Building and Machine Shop, a covered storage structure, the Supply Storage Building, and the Equipment Storage Building.

Office Building and Machine Shop

The Office Building and Machine Shop is a single-story structure with CMU walls. The material used for the framing of the pitched roof could not be established during the site visit (Figure 74). The building was constructed in 1989 and appears to be in good condition. No evidence of structural deterioration was observed during the site visit. The building has multiple openings in the walls, including three large garage door openings in the Machine Shop part of the building (Figure 75).

In an M9 CSZ scenario earthquake event, cracking of the CMU walls is possible, particularly near the openings in the walls. Due to the difference in height, structural damage is possible at the interface between the Office Building and the Machine Shop section of the building. In our opinion, there is sufficient redundancy in the building's structural system to minimize the risk to life safety or structural collapse. However, due to the importance of the building, it is recommended that a more detailed assessment of the building for Immediate Occupancy performance level be performed.

Oil storage containers inside the Machine Shop were observed to be unbraced (Figure 76). The emergency electric generator located at ground level outside the Office Building was observed to be anchored to the ground slab (Figure 77).

Figure 74: Office Building and Machine Shop

Figure 75: Machine Shop, Large Garage Door Opening in Wall

Figure 76: Unbraced Oil Storage Containers

Figure 77: Emergency Generator

Storage Structure:

A covered storage structure located on the Public Works grounds is a simple wood frame structure, shown in Figure 78. The structure does not have lateral bracing along the open front side and could be at risk of significant lateral deformations and damage in an M9 CSZ scenario earthquake event.

Figure 78: Covered Storage Structure

Supply Storage Building:

The Supply Storage Building is a single-level light steel frame warehouse structure constructed in the mid-1990s. The building has a regularly-spaced structural system and was observed to be in generally good condition. The building has a large garage door opening in one of the walls (Figure 79). The building is not expected to sustain significant structural damage in an M9 CSZ scenario earthquake event and is expected to meet the life safety and Immediate Occupancy (for structure) performance level. However, multiple shelves and their content may present a falling hazard during an earthquake. It is recommended that the shelves and contents be secured in order for the building to meet the overall Immediate Occupancy performance level.

Figure 79: Supply Storage Building

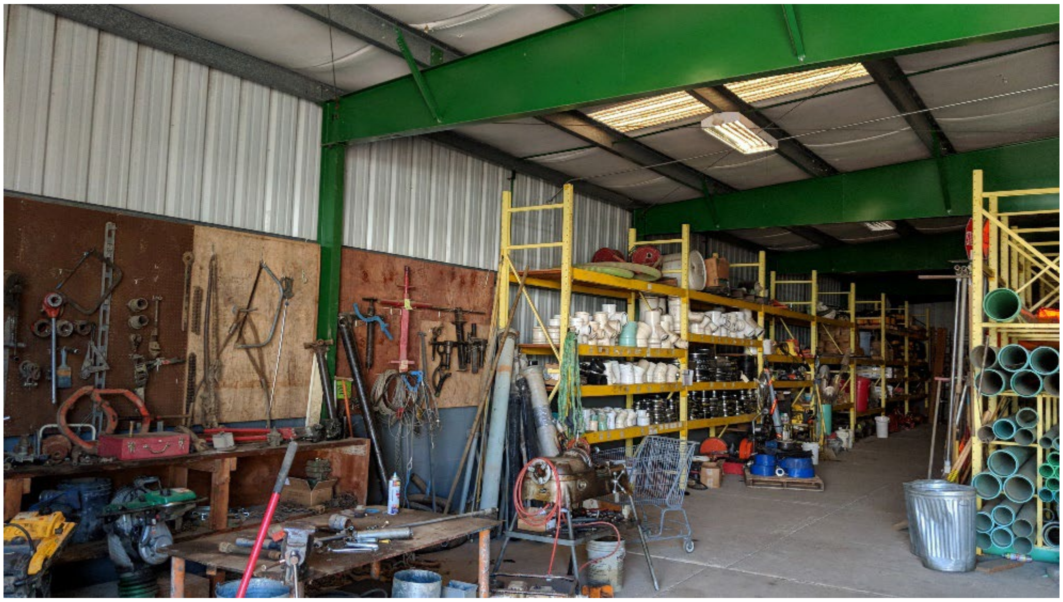

Figure 80: Supply Storage Building, Steel Frame

Equipment Building:

The Equipment Building is a two-story structure with CMU walls. The roof framing material could not be established during the site visit. The date of construction is not known, but in our opinion the building may be the oldest of the Public Works buildings. The building has multiple large opening in the CMU walls, including large garage doors, doors, and windows (Figure 81 and Figure 82). Some cracks were observed in the CMU walls, including a horizontal crack above one of the garage doors (Figure 83). Cracking of the CMU walls, particularly near the corners of the door openings, is likely in an M9 CSZ scenario earthquake event. A conclusive statement regarding life safety and collapse prevention performance criteria cannot be made for the Equipment Building without a more detailed assessment. It is recommended that a more detailed structural assessment be performed to evaluate the building for Life Safety and Immediate Occupancy performance levels.

Figure 81: Equipment Building

Figure 82: Equipment Building

Figure 83: Equipment Building, Horizontal Crack above Garage Door

8.0 STRINGTOWN ROAD BRIDGE CROSSING

Stringtown Road Bridge is owned and maintained by Washington County. The two-lane bridge is a reinforced concrete bridge that crosses Gales Creek northwest of Forest Grove. The bridge deck is supported on two substantial reinforced concrete piers on either side of Gales Creek (Figure 84). Two pipelines are suspended from approximately 24-in steel rods from the bridge (Figures 85 and 86). Due to the length of the span and the length of the steel rods supporting the pipelines, limited force and deformation transfer is expected to occur between the bridge and the pipelines. Potential cracking of the reinforced concrete bridge in an M9 CSZ scenario earthquake event is not expected to directly affect the pipelines.

Oregon Department of Transportation in 1995[1] performed a seismic vulnerability study to prioritize local agency bridges for seismic retrofit. The study assigned Group 2B to the Stringtown Road Bridge owned by Washington County. According to the study, Group 2B includes bridges that have three substructure deficiencies consisting of (1) inadequate splices of main longitudinal column reinforcement to the footing dowels, (2) inadequate confinement of main longitudinal reinforcement in concrete columns, and (3) inadequate footing anchorage or absence of reinforcement in the top of footing. In addition to these identified deficiencies the bridge will likely experience liquefaction-induced permanent ground deformation. It is recommended that the City considers 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.

[1] Oregon Department of Transportation (ODOT), 1995, Oregon Local Agencies, Seismic Vulnerability of Local Agency Bridges, Prepared by CH2MHill, November

Figure 84: Stringtown Road Bridge

Figure 85: Pipelines Suspended from Stringtown Road Bridge

Figure 86: Pipelines Suspended from Stringtown Road Bridge

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APPENDIX I
CIP PROJECT SHEETS

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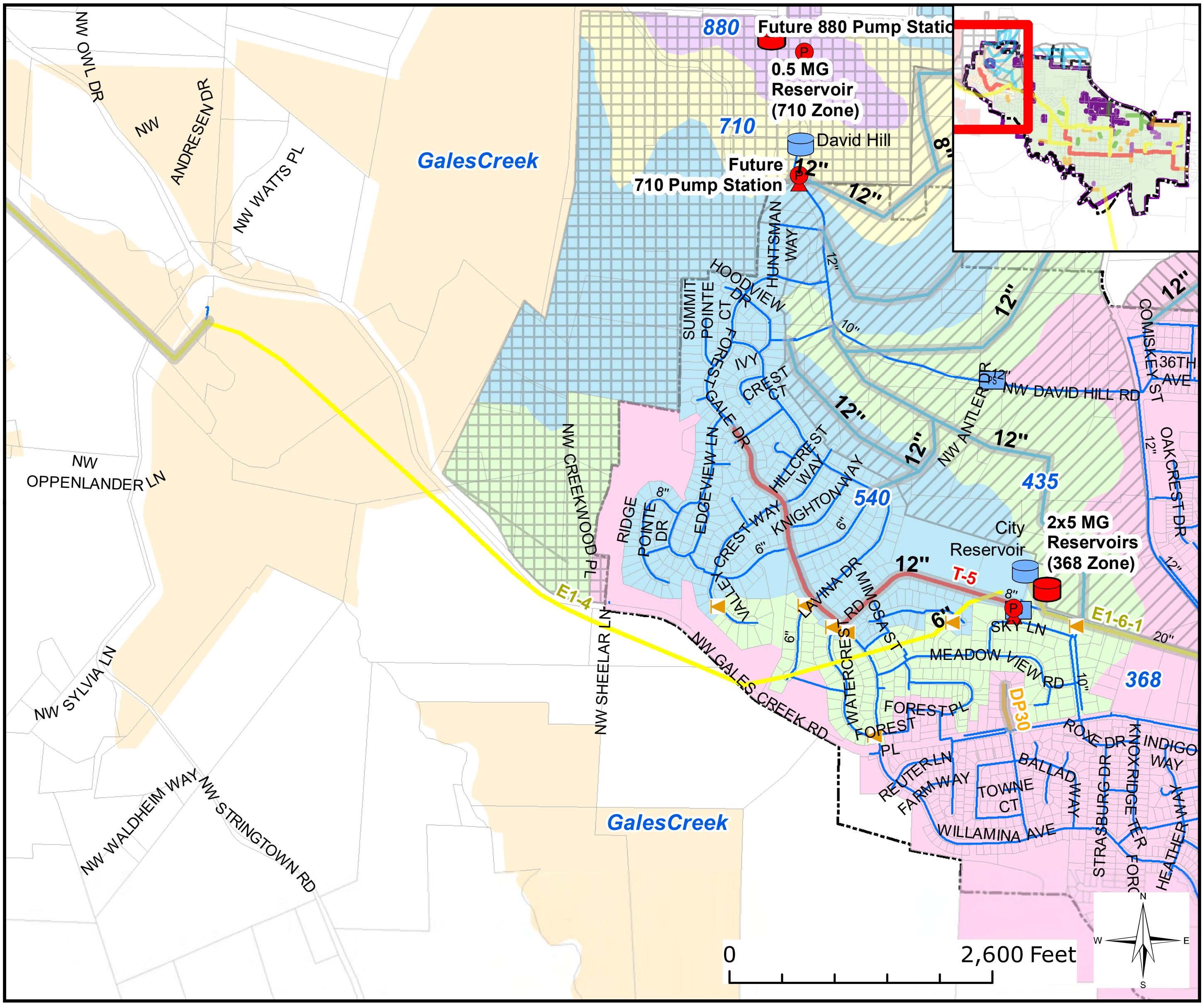

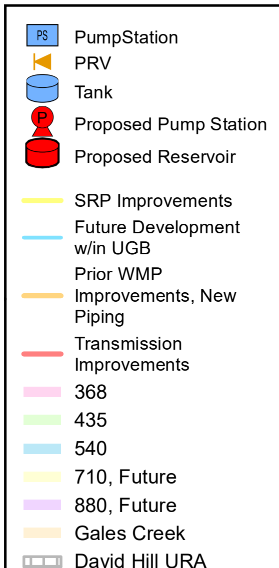

CIP Project E1-4

Project Type: Seismic Resiliency

Project Description: Seismic upgrades to Tier 1 RWTM from Stringtown Bridge to City WTP

Project Need: Improve seismic resiliency

Expected Timeframe: 0-5 Years

Priority: Medium

Project Cost: $3,940,000

Project Phasing: N/A

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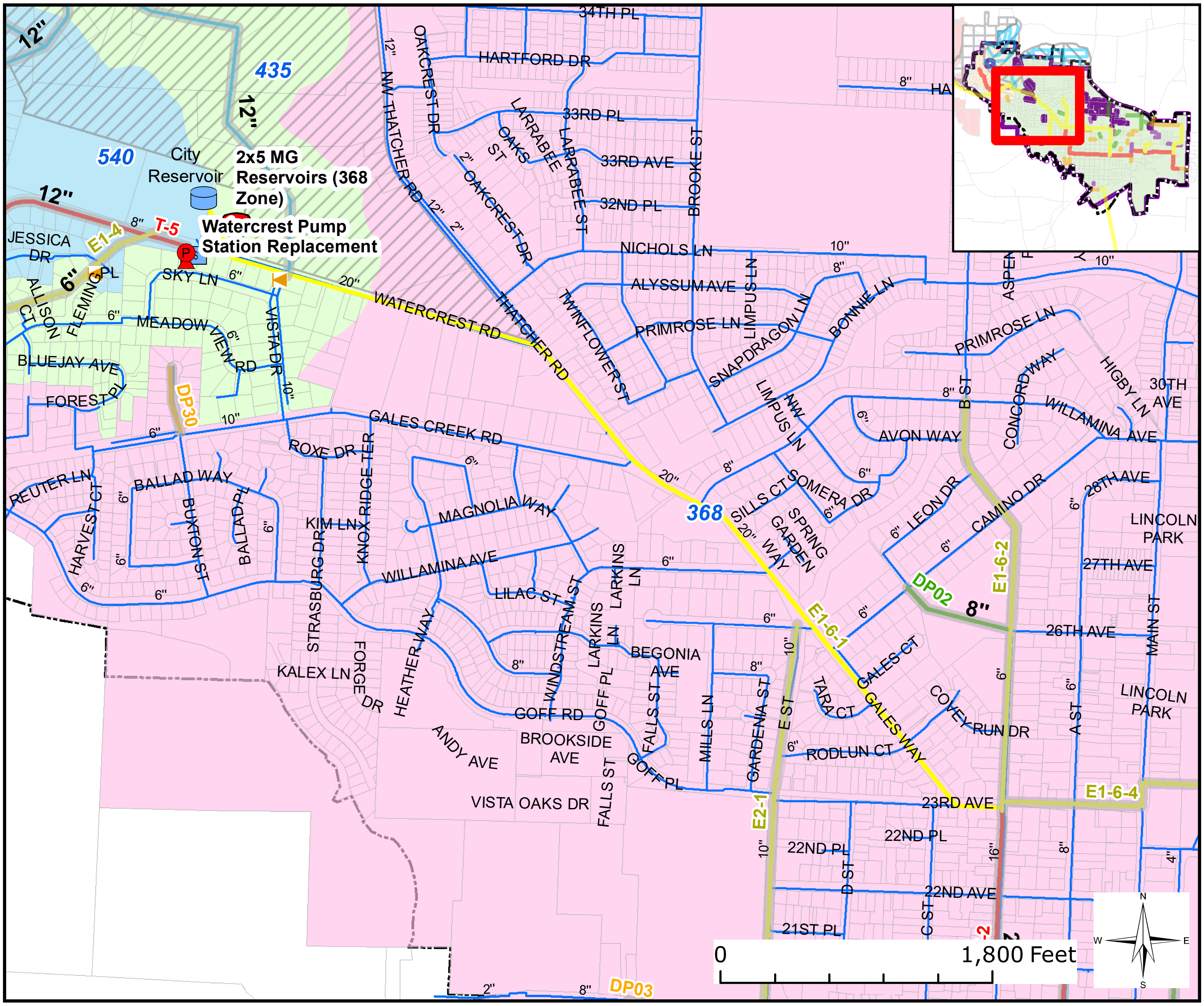
CIP Project Sheets



CIP Project E1-6-1

Project Type: Seismic Resiliency
Project Description: Seismic upgrades of 20" cast iron transmission from City WTP to B St, along Watercrest Rd, Thatcher Rd, Gales Ck Rd, and Gales Way
Project Need: Improve seismic resiliency
Expected Timeframe: 0-5 Years
Priority: High
Project Cost: $5,040,000
Project Phasing: N/A

PumpStation
PRV
Tank
Proposed Pump Station
Proposed Reservoir
SRP Improvements
Future Development w/in UGB
Prior WMP Improvements, Upsize Existing
Prior WMP Improvements, New Piping
Transmission Improvements
368
435
540
David Hill UGB

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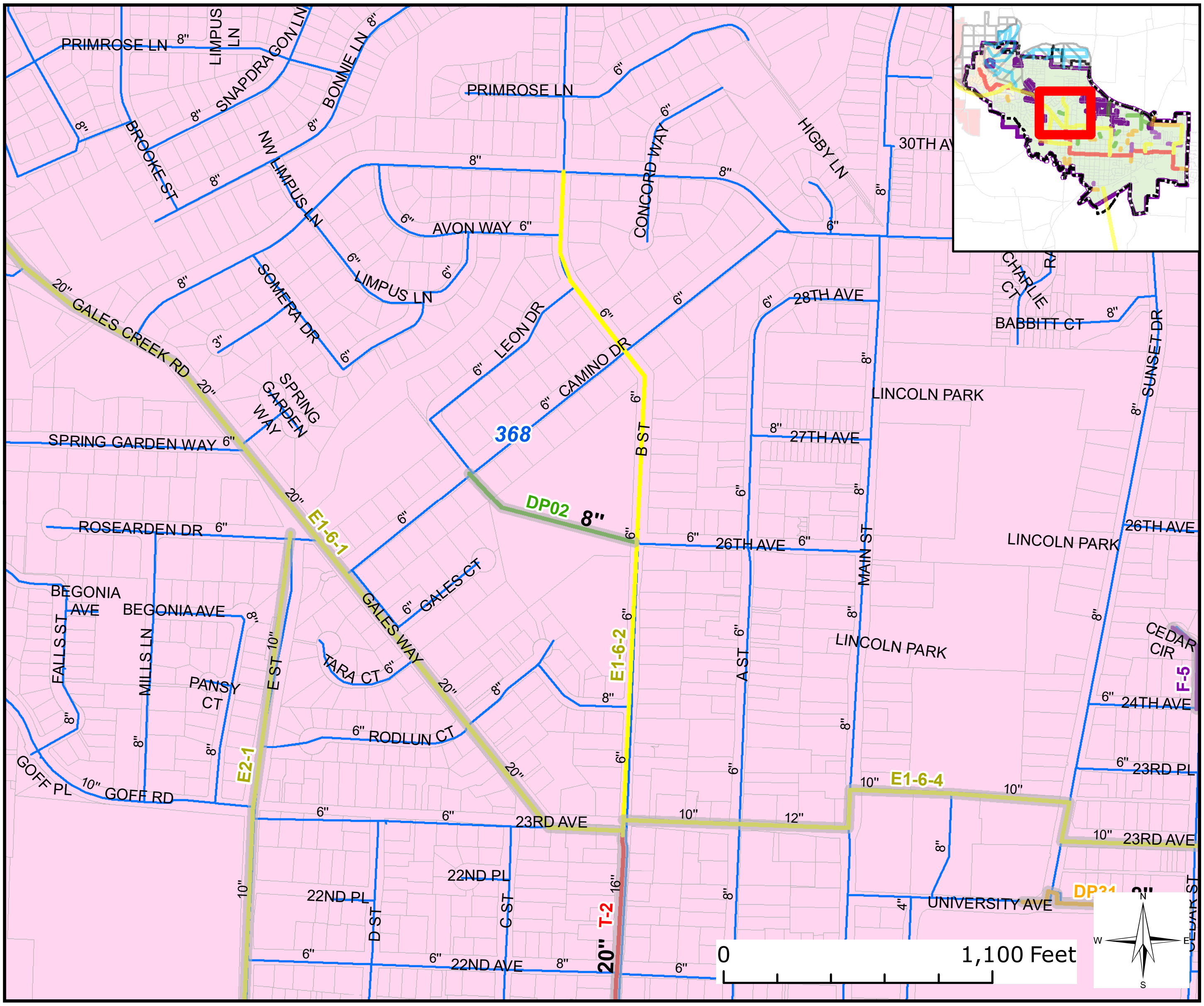
Water System Master Plan | **CIP Project Sheets**



CIP Project E1-6-2

Project Type: Seismic Resiliency

Project Description: Seismic upgrades of 6" cast iron and upsizing to at least 8" along B St to serve Forest Grove High School

Project Need: Improve seismic resiliency

Expected Timeframe: 0-5 Years

Priority: Medium

Project Cost: $820,000

Project Phasing: N/A

PumpStation
PRV
Tank
SRP Improvements
Fire Flow Improvements
Prior WMP Improvements, Upsize Existing
Prior WMP Improvements, New Piping
Transmission Improvements
368

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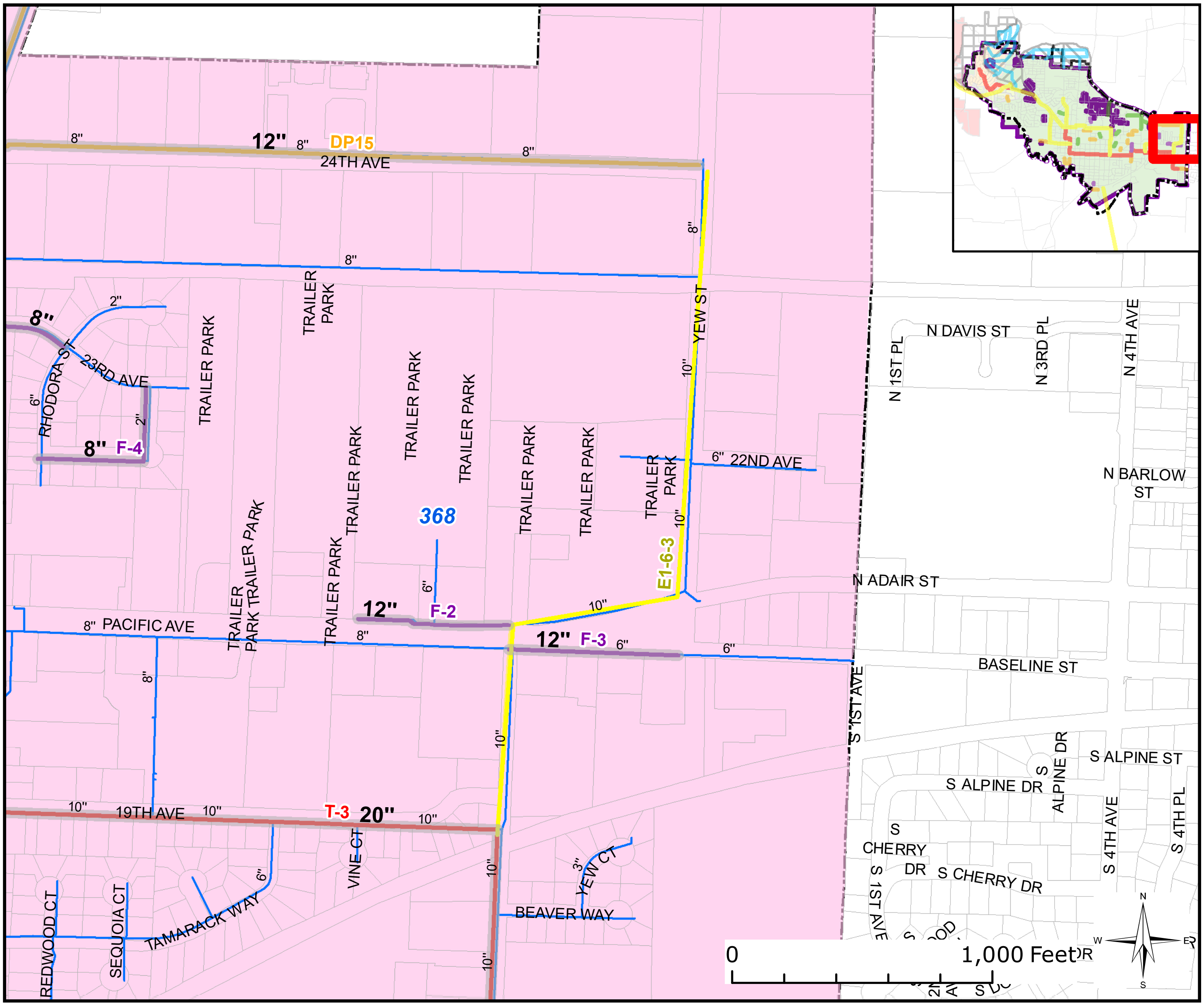

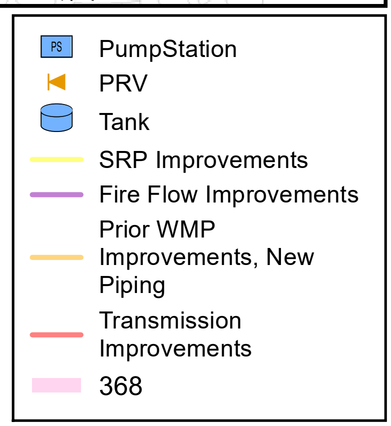

CIP Project E1-6-3

Project Type: Seismic Resiliency

Project Description: Seismic upgrades of 8-10" cast iron along Mountainview Ln and Yew St to loop to industrial center

Project Need: Improve seismic resiliency

Expected Timeframe: 0-5 Years

Priority: Low

Project Cost: $1,340,000

Project Phasing: N/A

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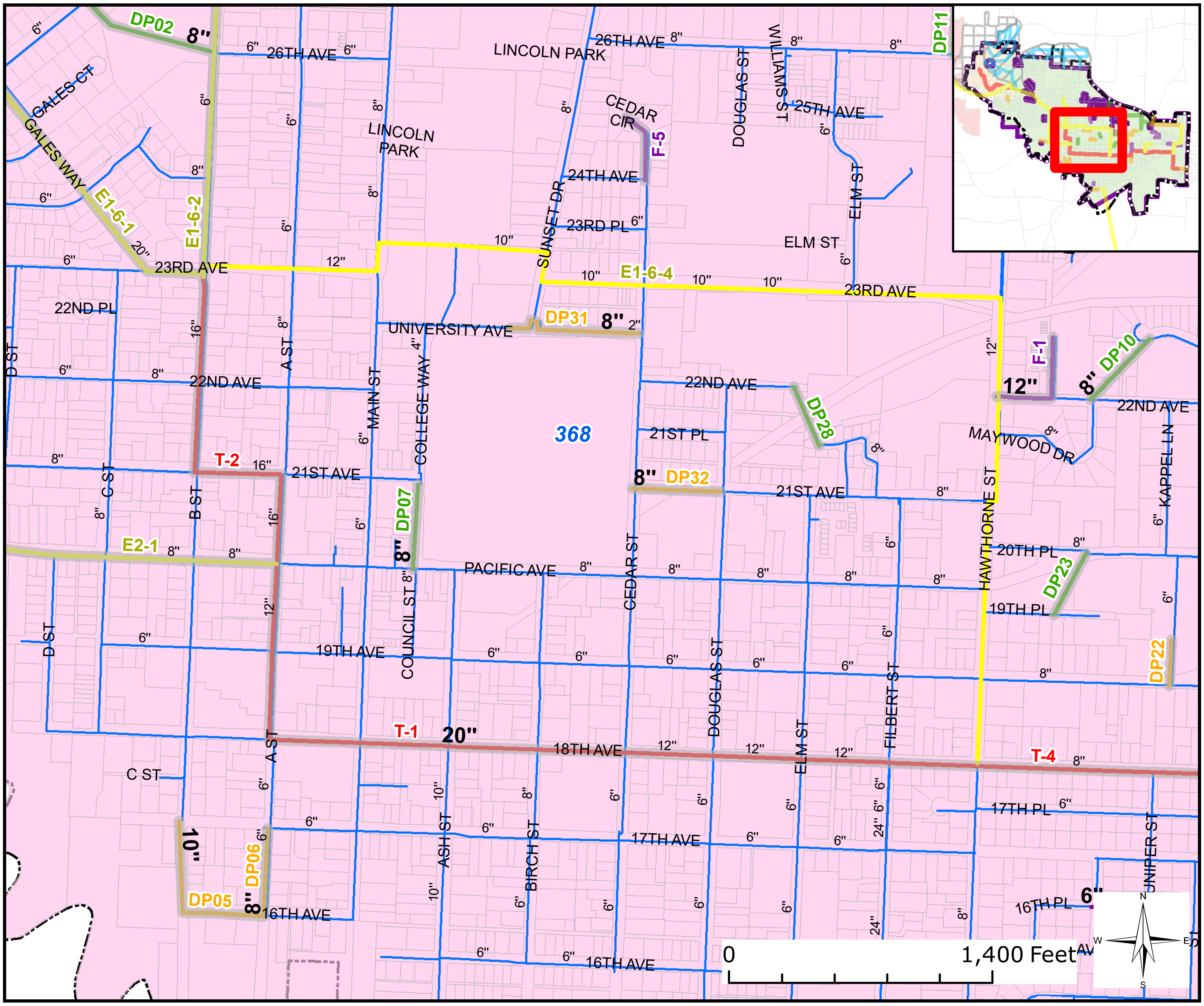

- PumpStation
- PRV
- Tank
- SRP Improvements
- Fire Flow Improvements
- Prior WMP Improvements, Upsize Existing
- Prior WMP Improvements, New Piping
- Transmission Improvements
- 368

CIP Project E1-6-4

Project Type: Seismic Resiliency

Project Description: Seismic upgrades of 10-12" cast iron looping north around Pacific University

Project Need: Improve seismic resiliency

Expected Timeframe: 0-5 Years

Priority: Medium

Project Cost: $2,050,000

Project Phasing: N/A

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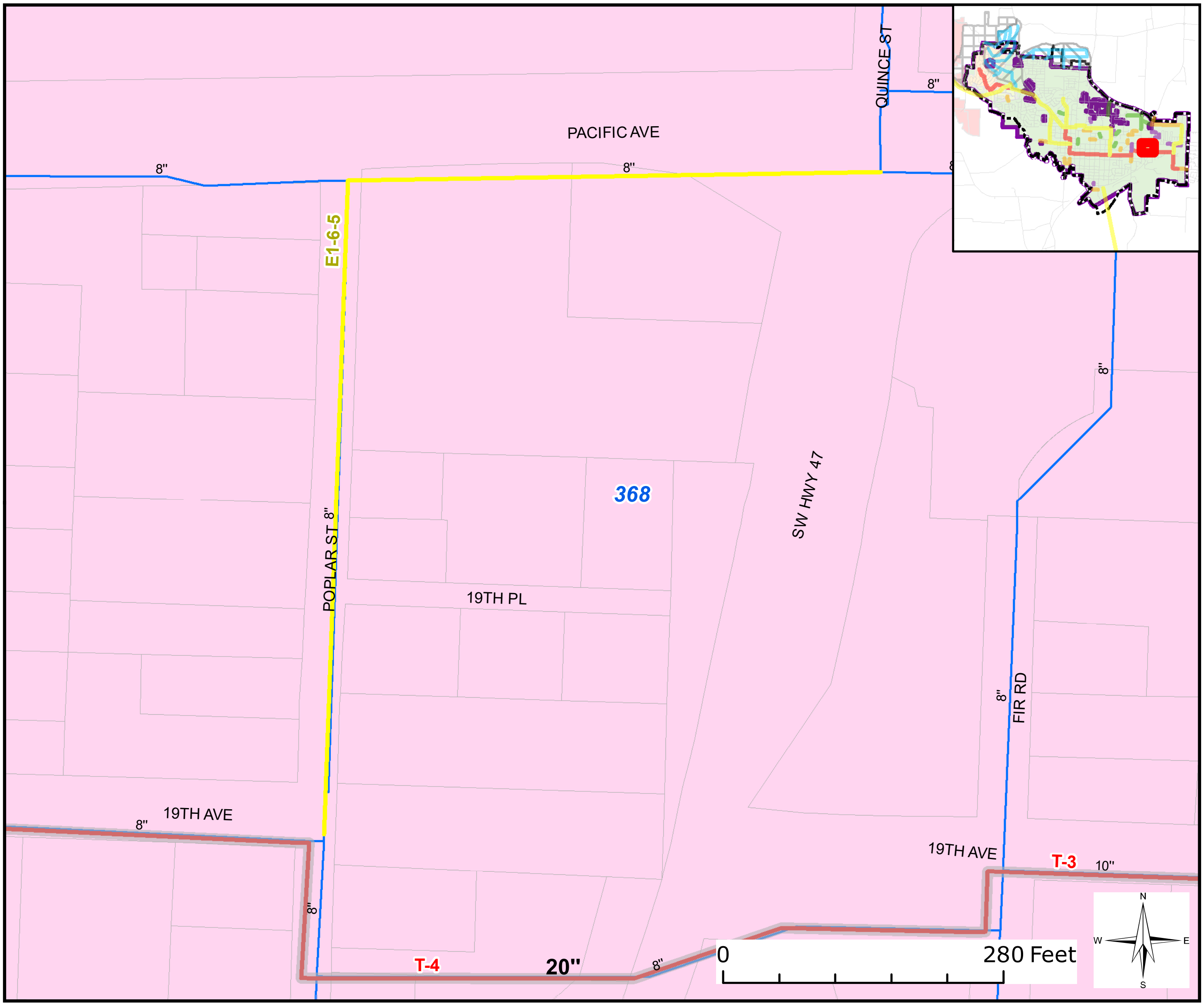

CIP Project E1-6-5

Project Type: Seismic Resiliency
Project Description: Seismic upgrades of 8" cast iron along Poplar St and Pacific Ave to loop to industrial center
Project Need: Improve seismic resiliency
Expected Timeframe: 0-5 Years
Priority: Medium
Project Cost: $430,000
Project Phasing: N/A

- PumpStation
- PRV
- Tank
- SRP Improvements
- Transmission Improvements
- 368

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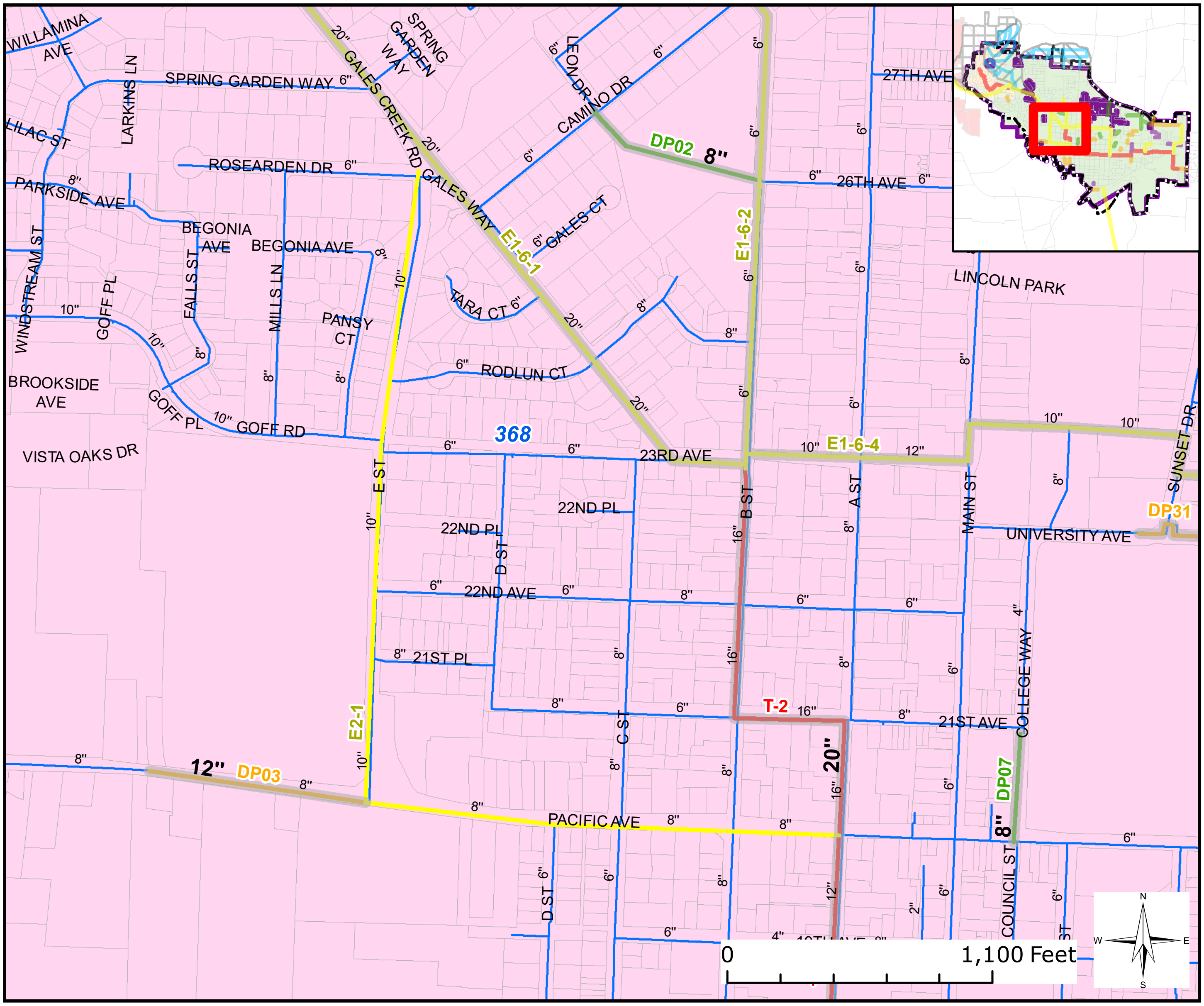
CIP Project Sheets



CIP Project E2-1

Project Type: Seismic Resiliency

Project Description: Seismic upgrades to Tier 2 backbone 8-10" cast iron to loop to Tom McCall Elementary and Middle Schools

Project Need: Improve seismic resiliency

Expected Timeframe: 10-20 Years

Priority: Low

Project Cost: $1,500,000

Project Phasing: N/A

PumpStation
PRV
Tank
SRP Improvements
Prior WMP Improvements, Upsize Existing
Prior WMP Improvements, New Piping
Transmission Improvements
368

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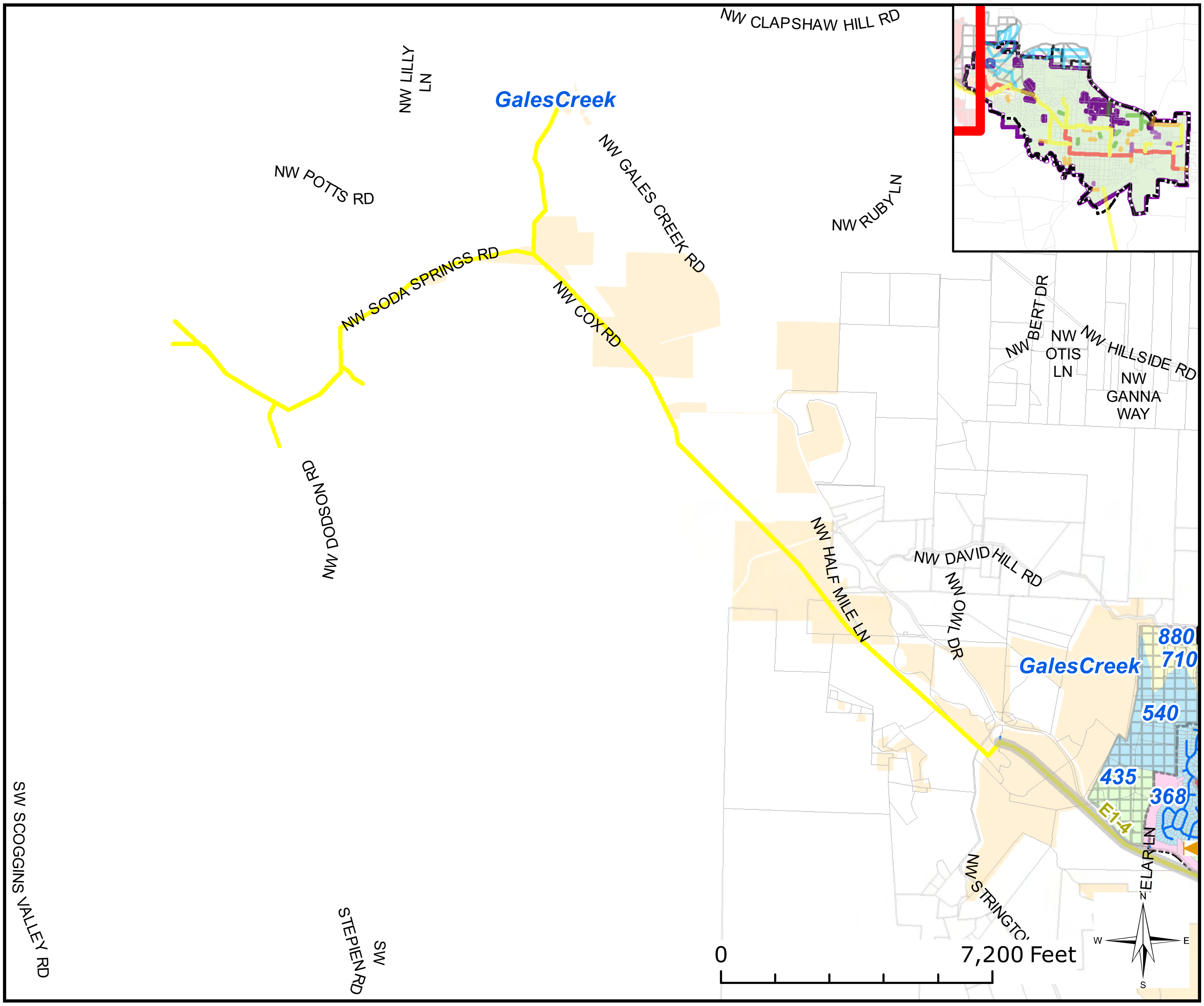

CIP Project E2-3

Project Type: Seismic Resiliency
Project Description: Seismic upgrades to Tier 2 RWTM from intakes to Stringtown Bridge
Project Need: Improve seismic resiliency
Expected Timeframe: 20+ Years
Priority: Low
Project Cost: $17,040,000
Project Phasing: N/A

PS PumpStation
PRV
Tank
Proposed Reservoir
SRP Improvements
Transmission Improvements
368
435
540
710, Future
880, Future
Gales Creek
David Hill URA

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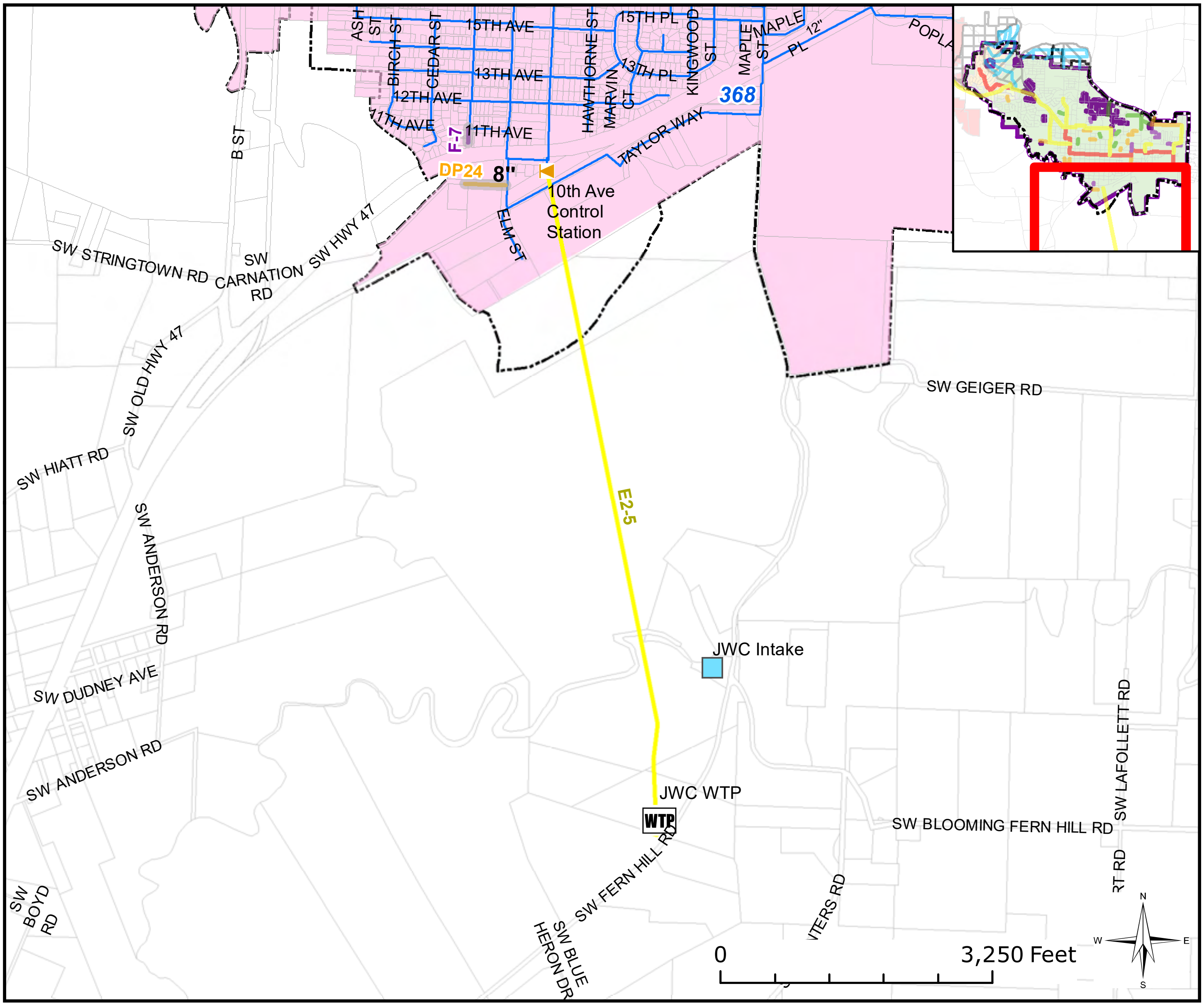

CIP Project E2-5

Project Type: Transmission and Seismic Resiliency
Project Description: Seismic upgrades to JWC Supply and increased capacity through either upsizing or leasing from Hillsboro
Project Need: Improve seismic resiliency and provide additional JWC transmission capacity
Expected Timeframe: 0-5 Years
Priority: High
Project Cost: $5,940,000
Project Phasing: N/A

- PS PumpStation
- PRV
- Tank
- SRP Improvements
- Fire Flow Improvements
- Prior WMP Improvements, New Piping
- Transmission Improvements
- 368

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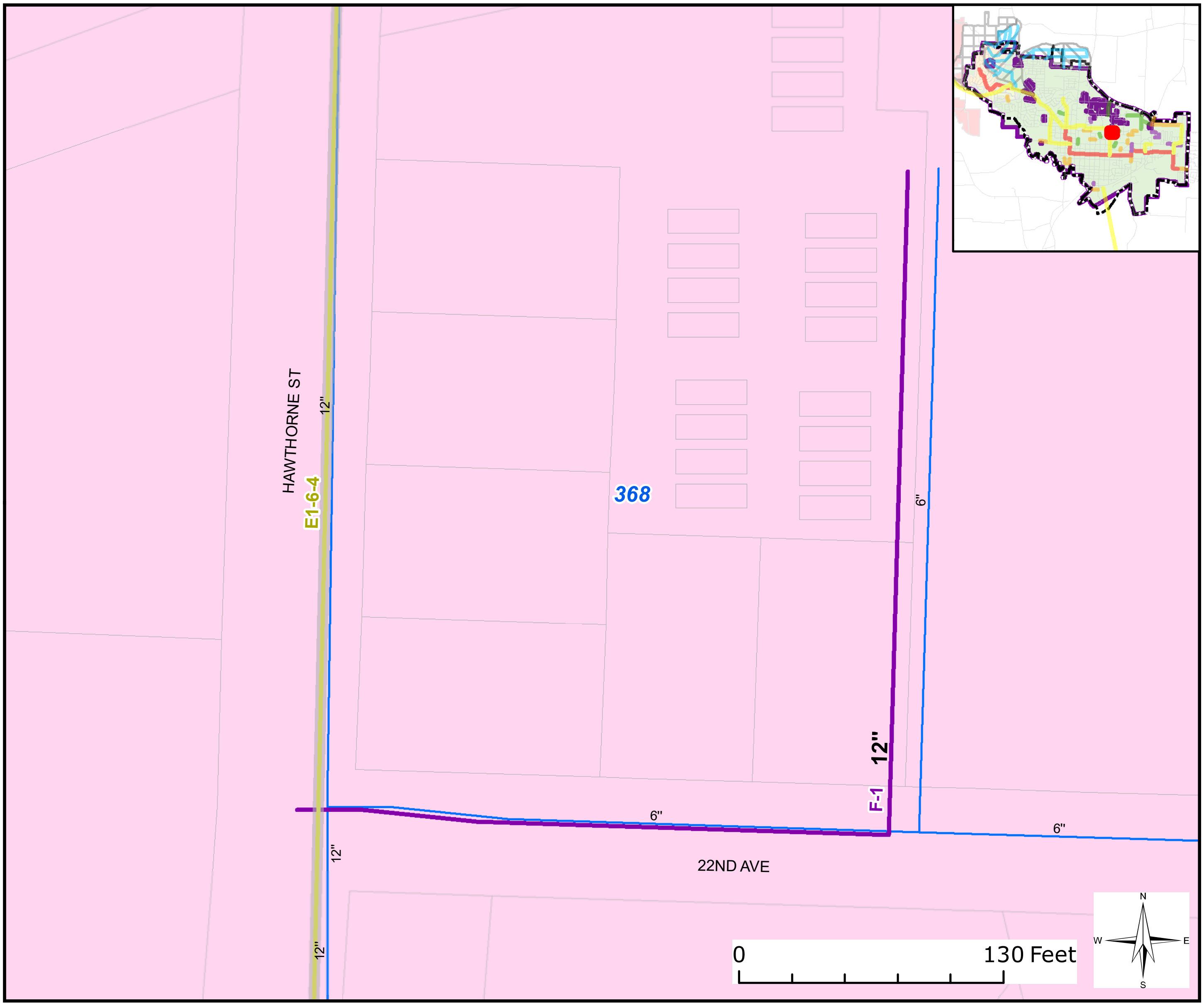
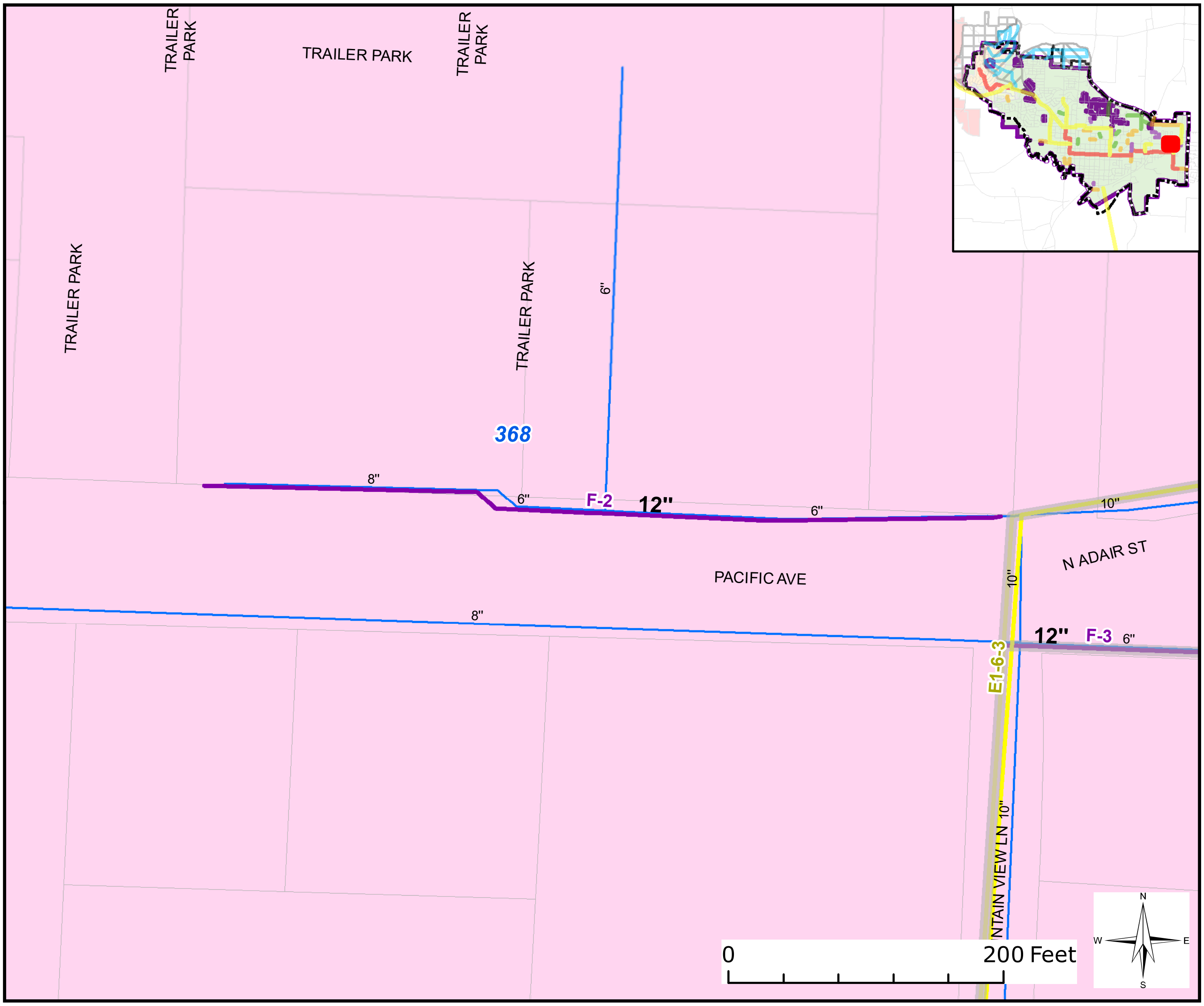


CIP Project F-1

Project Type: Fire Flow Improvement
Project Description: Multifamily Residential - 22nd Ave - Garden Grove Apartments - upsize to 12"
Project Need: Improve fire flow availability
Expected Timeframe: 11-20 Years
Priority: Medium
Project Cost: $260,000
Project Phasing: N/A

PumpStation
PRV
Tank
SRP Improvements
Fire Flow Improvements
368



CIP Project F-2

Project Type: Fire Flow Improvement
Project Description: Commercial - Pacific Ave - Best Western - upsize to 12"
Project Need: Improve fire flow availability
Expected Timeframe: 11-20 Years
Priority: Medium
Project Cost: $260,000
Project Phasing: N/A

PumpStation
PRV
Tank
SRP Improvements
Fire Flow Improvements
368

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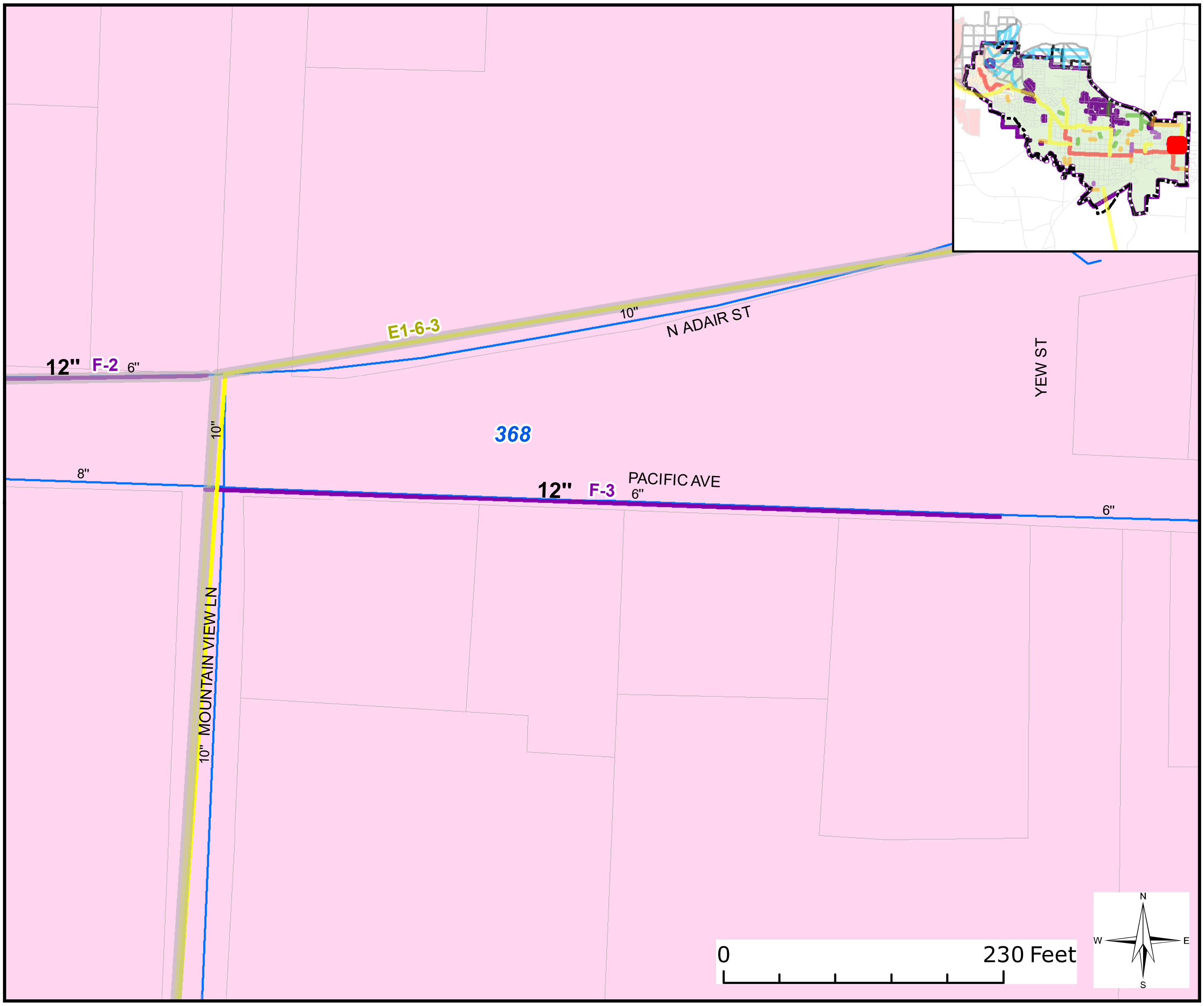

CIP Project F-3

Project Type: Fire Flow Improvement
Project Description: Commercial - Pacific Ave - Mountain View Ln to Yew St - upsize to 12"
Project Need: Improve fire flow availability
Expected Timeframe: 11-20 Years
Priority: Medium
Project Cost: $520,000
Project Phasing: N/A

PS PumpStation
PRV
Tank
SRP Improvements
Fire Flow Improvements
368

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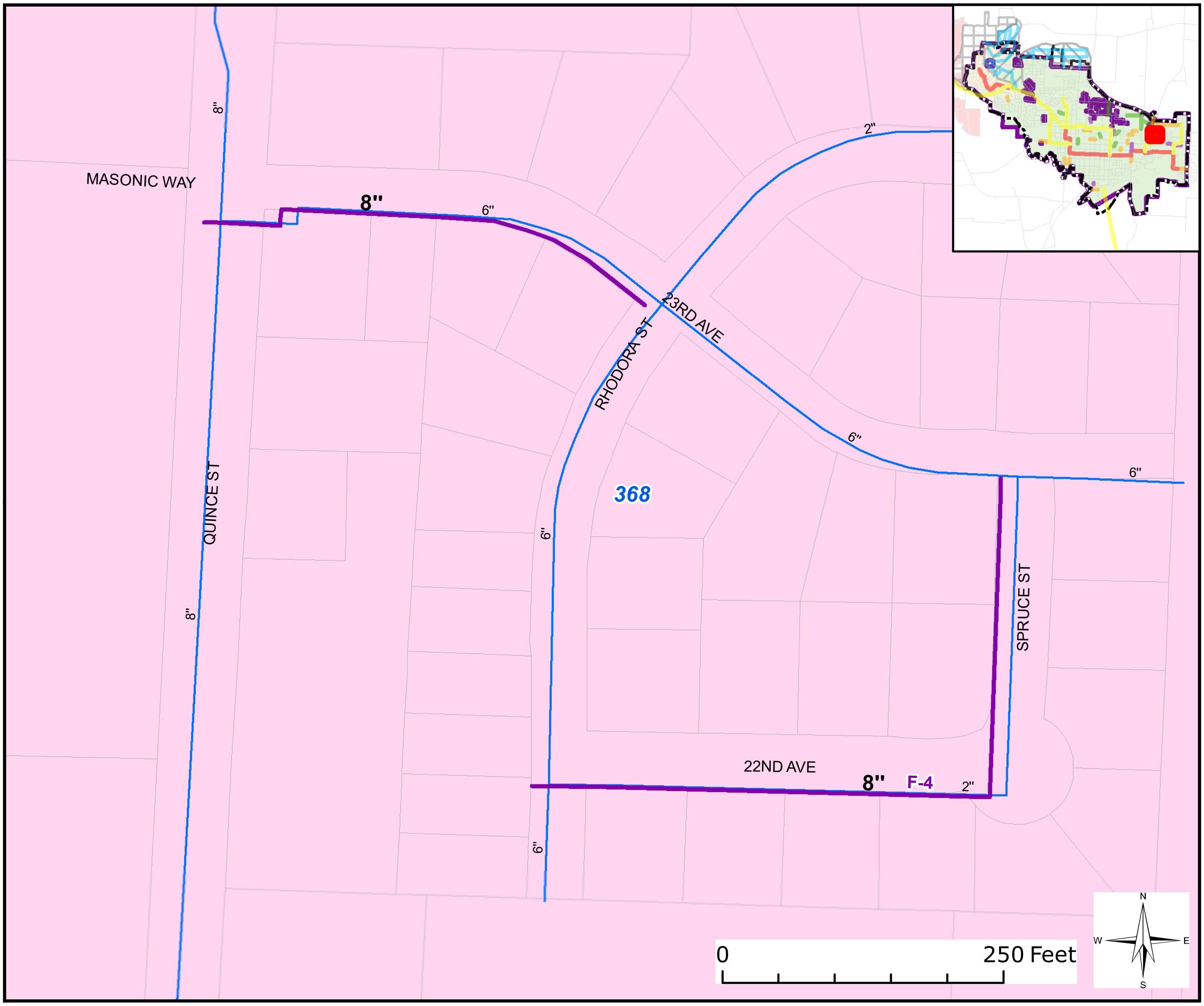

CIP Project F-4

Project Type: Fire Flow Improvement
Project Description: Residential – 23rd Ave - upsize to 8"
Project Need: Improve fire flow availability
Expected Timeframe: 11-20 Years
Priority: Medium
Project Cost: $350,000
Project Phasing: N/A

PumpStation
PRV
Tank
Fire Flow Improvements
368

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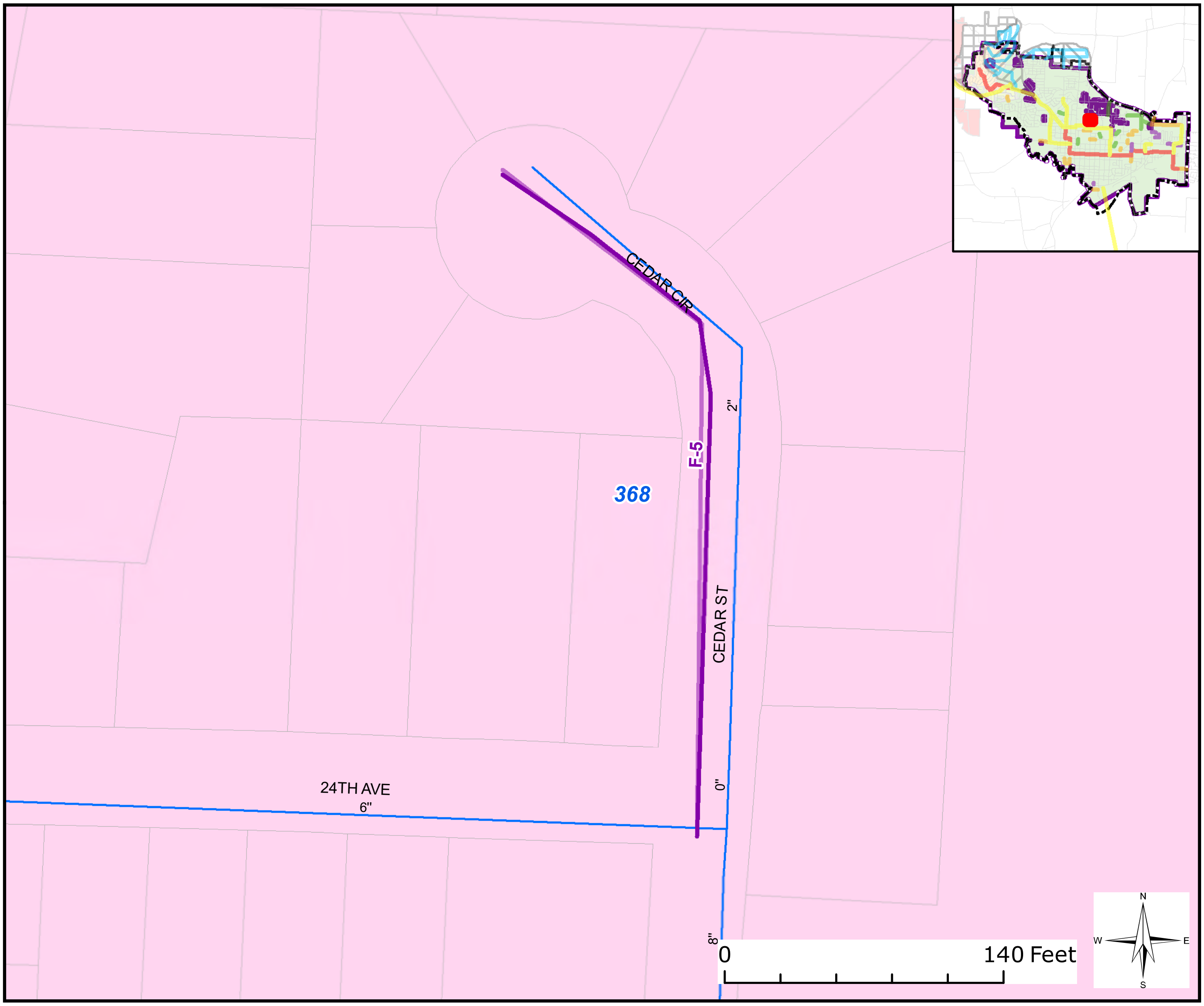

CIP Project F-5

Project Type: Fire Flow Improvement
Project Description: Residential - Cedar St - upsize to 6"
Project Need: Improve fire flow availability
Expected Timeframe: 11-20 Years
Priority: Medium
Project Cost: $90,000
Project Phasing: N/A

PumpStation
PRV
Tank
Fire Flow Improvements
368

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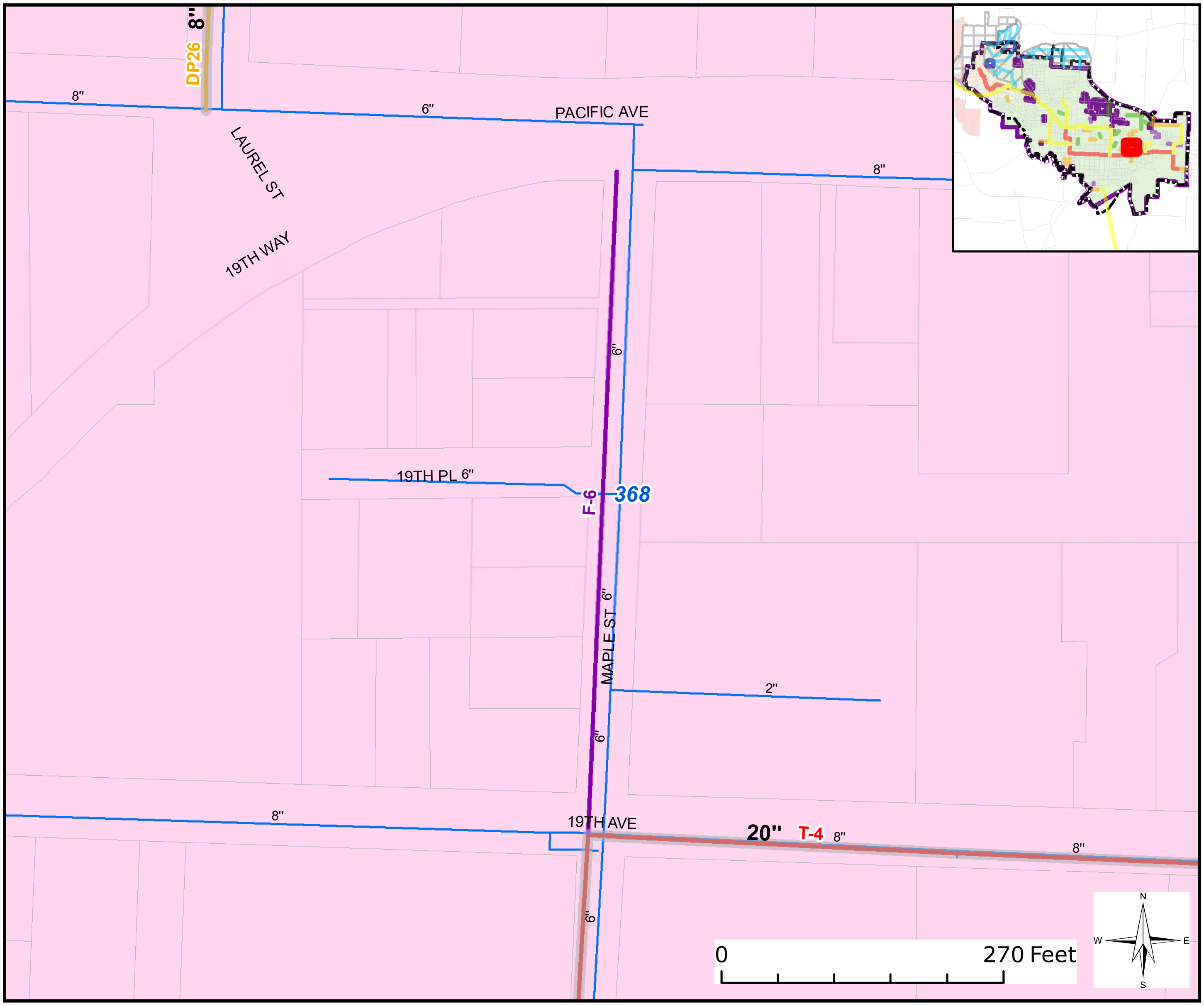

CIP Project F-6

Project Type: Fire Flow Improvement
Project Description: Industrial - Maple Street from 18th to 19th - upsize to 8"
Project Need: Improve fire flow availability
Expected Timeframe: 11-20 Years
Priority: Medium
Project Cost: $250,000
Project Phasing: N/A

- PumpStation
- PRV
- Tank
- Fire Flow Improvements
- Prior WMP Improvements, New Piping
- Transmission Improvements
- 368

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APPENDIX J
AVAILABLE FIRE FLOW MAPS

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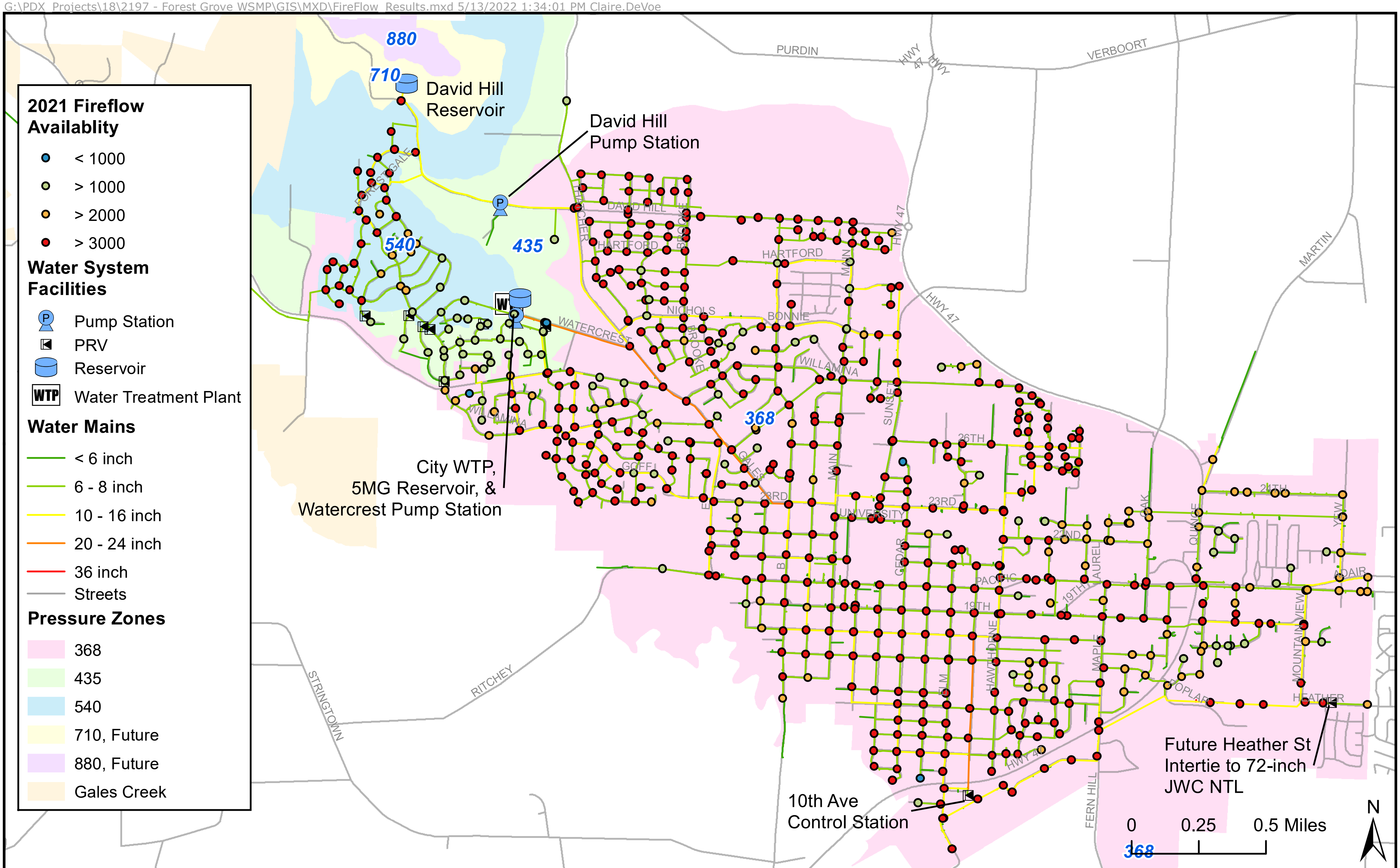

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City of Forest Grove
Water System Master Plan

Figure 1
2021 Available Fire Flow
No Improvements

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January 2022 18-2197

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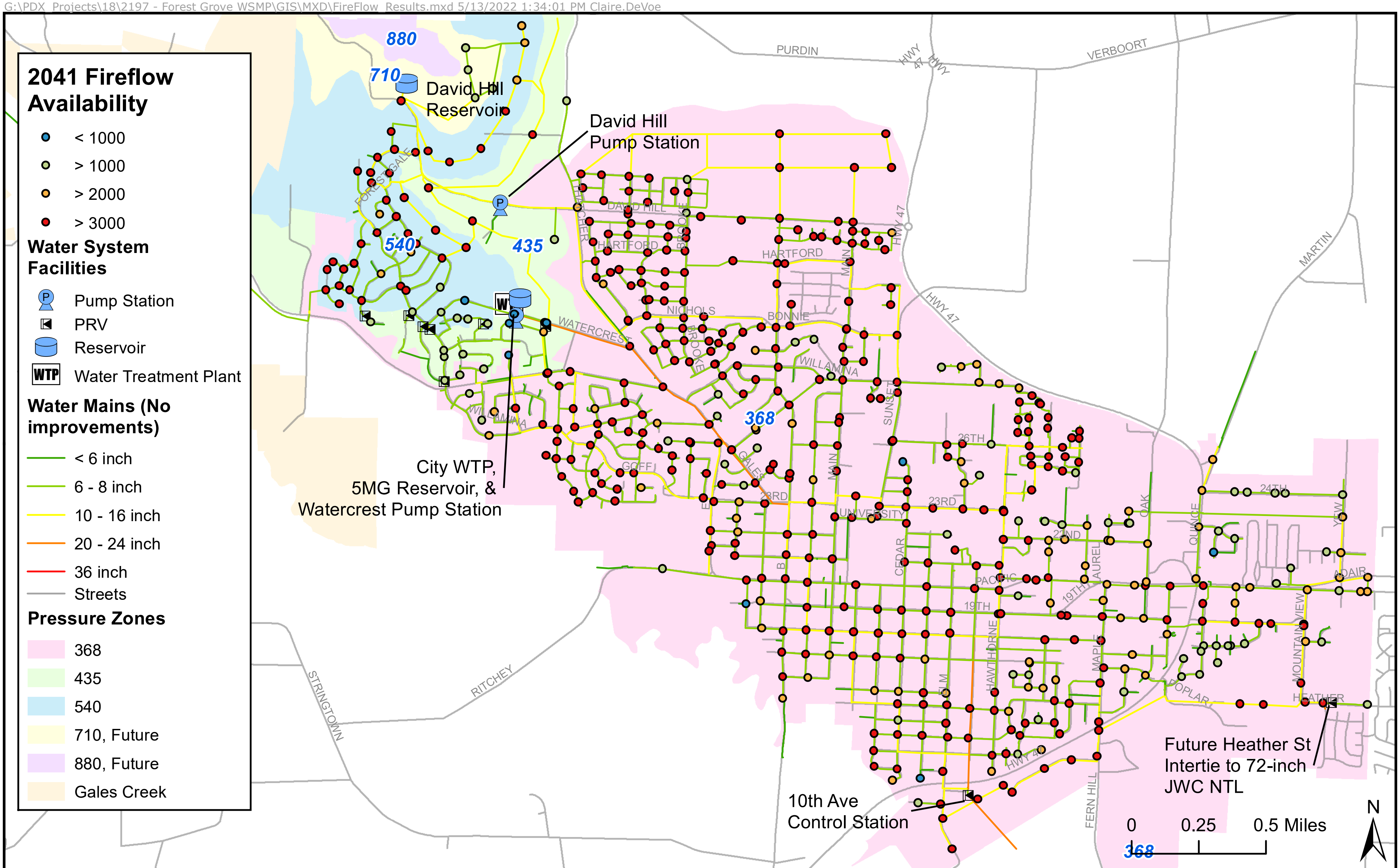

City of Forest Grove Water System Master Plan

Figure 2
2041 Available Fire Flow No Improvements

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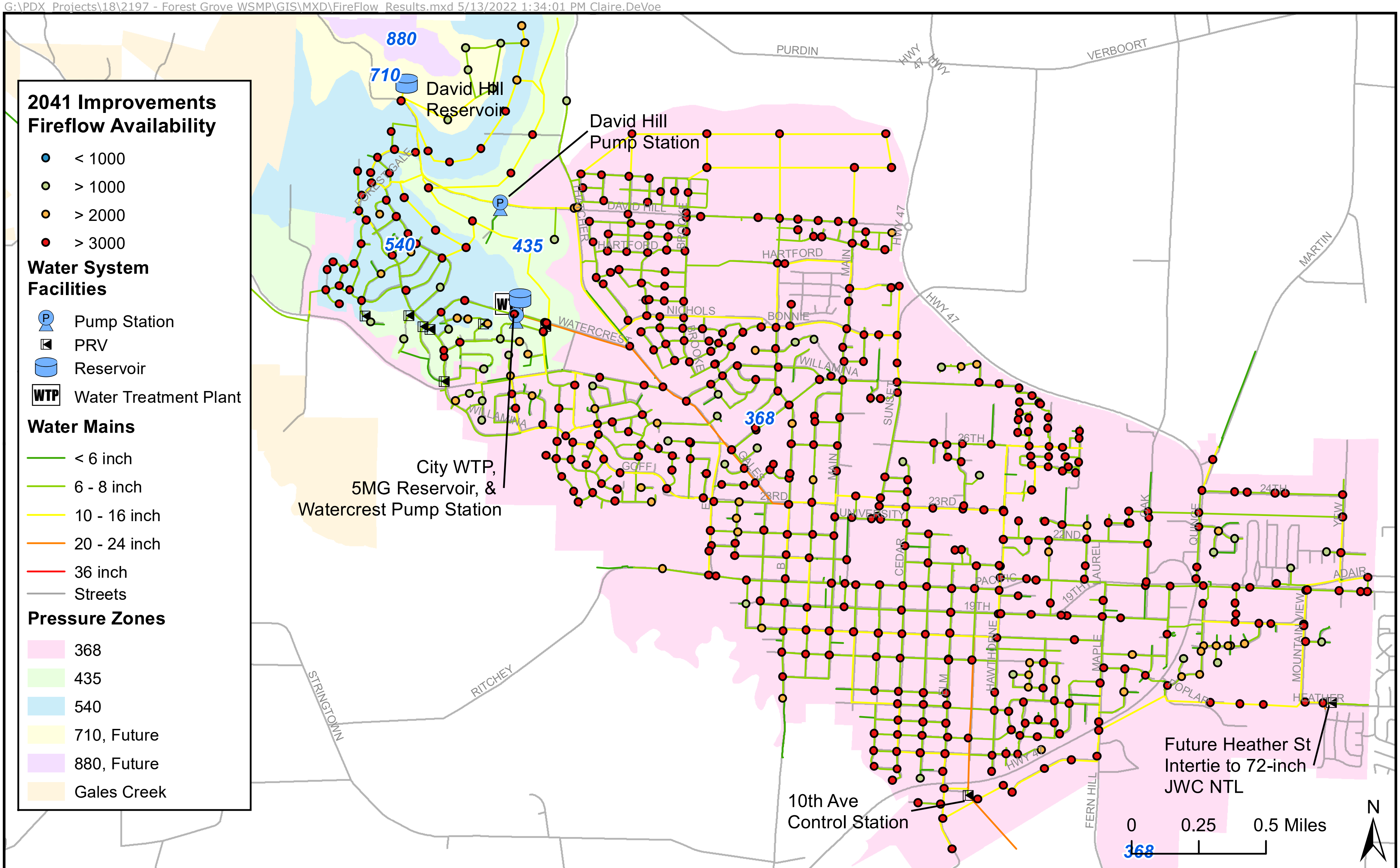

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City of Forest Grove
Water System Master Plan

Figure 3
2041 Available Fire Flow
With Improvements

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January 2022 18-2197

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APPENDIX K
SUPPLY FIGURE SPREADSHEETS

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Figure 4-1

Full Water Rights, Assuming No Seasonal Limitations

Year	2021	2026	2031	2041	2071
Maximum Month Demand (mgd)	5.32	5.73	6.55	7.59	8.66
Clear Creek Certificate (mgd)	1.81	1.81	1.81	1.81	1.81
Clear and Roaring Creek Certificate (mgd)	2.88	2.88	2.88	2.88	2.88
Gales Creek Certificate (mgd)	2.88	2.88	2.88	2.88	2.88
Barney Water Right (mgd)	0.98	0.98	0.98	0.98	0.98
Scoggins Water Right (mgd)	10.79	10.79	10.79	10.79	10.79
Barney Buy-Back (mgd)	1.57	1.57	1.57	1.57	1.57
Tualatin River (mgd)	21.3	21.3	21.3	21.3	21.3

Figure 4-2

Estimated Available Raw Water Supply during Peak Demands

Year	2021	2026	2031	2041	2071
Maximum Month Demand (mgd)	5.32	5.73	6.55	7.59	8.66
Clear Creek Certificate (mgd)	0.52	0.52	0.52	0.52	0.52
Barney Water Right (mgd)	0.98	0.98	0.98	0.98	0.98
Scoggins Water Right (mgd)	10.79	10.79	10.79	10.79	10.79
Barney Buy-Back (mgd)	1.57	1.57	1.57	1.57	1.57
Drought Reduced Stored Water Rights (mgd)	10.67	10.67	10.67	10.67	10.67

Figure 4-5

Finished Water Supply Capacity: Treatment Limitations

Year	2021	2026	2031	2041	2071
Maximum Day Demand (mgd)	6.17	6.64	7.59	8.80	10.03
FG WTP (3.7 mgd)	3.7	3.7	3.7	3.7	3.7
Full JWC Treatment Ownership, less North Plains Demand (mgd)	9.86	9.82	9.76	9.71	9.71

Figure 4-6

Finished Water Supply Capacity: Treatment, Transmission, and Raw Water Supply Limitations

Year	2021	2026	2031	2041	2071
Maximum Day Demand (mgd)	6.17	6.64	7.59	8.80	10.03
Clear Creek Certificate (mgd)	0.52	0.52	0.52	0.52	0.52
JWC 24" TL Capacity (mgd)	6.1	6.1	6.1	6.1	6.1
Additional Supply Assuming Access to Full JWC Treatment Ownership, less North Plains Demand (mgd)	3.76	3.72	3.66	3.61	3.61

Figure 4-3

Estimated Raw Water Availability, Regular Season Limitations

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2021 (mgd)	2.24	2.20	2.50	2.48	3.53	4.17	5.30	5.19	3.72	3.00	2.34	2.51
2026 (mgd)	2.41	2.37	2.69	2.68	3.81	4.50	5.71	5.59	4.01	3.24	2.53	2.70
2031 (mgd)	2.76	2.71	3.08	3.06	4.36	5.15	6.54	6.40	4.58	3.70	2.89	3.09
2041 (mgd)	3.21	3.15	3.58	3.56	5.06	5.98	7.60	7.44	5.33	4.30	3.36	3.59
2071 (mgd)	3.65	3.59	4.08	4.06	5.77	6.82	8.66	8.48	6.07	4.90	3.83	4.09
FG WTP Restricted Water Supply (mgd)	4.69	4.69	4.69	4.69	2.77	2.81	1.70	0.88	0.54	0.54	0.82	4.69
Barney Water Right (mgd)	0	0	0	0	0.16	0.54	0.87	0.98	0.62	0.46	0.47	0
Scoggins Water Right (mgd)	0	0	0	0	1.76	5.95	9.61	10.79	6.88	5.12	5.18	0
Barney Buy-Back (mgd)	0	0	0	0	0.26	0.86	1.40	1.57	1.00	0.74	0.75	0
Tualatin River Seasonally Restricted Supply (mgd)	21.3	21.3	21.3	21.3	10.65	0	0	0	0	0	10.65	21.3

Figure 4-4

Estimated Raw Water Availability, Seasonal and 20% Drought Limitations

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2021 (mgd)	2.24	2.20	2.50	2.48	3.53	4.17	5.30	5.19	3.72	3.00	2.34	2.51
2026 (mgd)	2.41	2.37	2.69	2.68	3.81	4.50	5.71	5.59	4.01	3.24	2.53	2.70
2031 (mgd)	2.76	2.71	3.08	3.06	4.36	5.15	6.54	6.40	4.58	3.70	2.89	3.09
2041 (mgd)	3.21	3.15	3.58	3.56	5.06	5.98	7.60	7.44	5.33	4.30	3.36	3.59
2071 (mgd)	3.65	3.59	4.08	4.06	5.77	6.82	8.66	8.48	6.07	4.90	3.83	4.09
Drought FG WTP Supply (mgd)	3.75	3.75	3.75	3.75	2.22	2.25	1.36	0.70	0.43	0.43	0.65	3.75
Tualatin River Supply (mgd)	17.04	17.04	17.04	17.04	8.52	0	0	0	0	0	8.52	17.04
Impoundments Supply (mgd)	0	0	0	0	1.74	5.89	9.50	10.67	6.80	5.06	5.12	0

APPENDIX L
JWC WATER MANAGEMENT AND CONSERVATION PLAN, GSI, 2021

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Water Management and Conservation Plan

Joint Water Commission

FEBRUARY 2021

Joint Water Commission

Hillsboro
•
Forest Grove
•
Beaverton
•
Tualatin Valley
Water District

Prepared by:
GSI Water Solutions, Inc.
1600 SW Western Boulevard, Suite 240,
Corvallis, OR 97333

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Oregon
Kate Brown, Governor

Water Resources Department
North Mall Office Building
725 Summer St NE, Ste A
Salem, OR 97301
Phone: 503-986-0900
Fax: 503-986-0904
www.Oregon.gov/OWRD

February 24, 2021

Joint Water Commission
Attn: Jessica Dorsey, Water Resources Manager
150 E. Main St. 3rd Floor
Hillsboro, OR 97123

Subject: Water Management and Conservation Plan

Dear Ms. Dorsey:

Enclosed; please find the final order approving your Water Management and Conservation Plan and authorizing the diversion of up to **44.0 cfs** of water under **Permit S-54737**.

The attached final order specifies that the Joint Water Commission's (JWC) plan shall remain in effect until **February 24, 2031**. Additionally, the JWC is required to submit a progress report to the Department by **February 24, 2026**, detailing progress made toward the implementation of conservation benchmarks scheduled in the plan. Finally, the JWC must submit an updated Water Management and Conservation Plan to the Department by **August 24, 2030**.

NOTE: *The deadline established in the attached final order for submittal of an updated water management and conservation plan (consistent with OAR Chapter 690, Division 086) shall not relieve the JWC from any existing or future requirement(s) for submittal of a water management and conservation plan at an earlier date as established through other final orders of the Department.*

We appreciate your cooperation in this effort. Please do not hesitate to contact me at 503-986-0919or *Kerri.H.Cope@oregon.gov* if you have any questions.

Sincerely,

Kerri H. Cope

Kerri Cope
Water Management and Conservation Analyst
Water Right Services Division

Enclosure

cc: WMCP File
Application #S-69637 (Permit #S-54737)
District 18 Watermaster, Jake Constans (via email)
GSI Water Solutions, Inc. Attn: Suzanne De Szoeke (via email)

BEFORE THE WATER RESOURCES DEPARTMENT
OF THE
STATE OF OREGON

In the Matter of the Proposed Water Management and Conservation Plan for Joint Water Commission, Washington County	)))	FINAL ORDER APPROVING A WATER MANAGEMENT AND CONSERVATION PLAN

Authority

OAR Chapter 690, Division 086, establishes the process and criteria for approving water management and conservation plans required under the conditions of permits, permit extensions and other orders of the Department. An approved water management and conservation plan may authorize the diversion and use of water under a permit extended pursuant to OAR Chapter 690, Division 315.

Findings of Fact

1. The Joint Water Commission (JWC) submitted a Water Management and Conservation Plan (plan) and required statutory fee for review of the plan to the Water Resources Department (Department) on September 11, 2020. The plan was required by a condition set forth under the JWC's previously approved plan (Sp. Or. Vol. 81, Pgs. 871 – 875) issued on September 14, 2010. The JWC is made up of four member agencies, which includes the Cities of Hillsboro, Forest Grove, and Beaverton, and Tualatin Valley Water District (TVWD).

2. The Department published notice of receipt of the plan on September 22, 2020, as required under OAR Chapter 690, Division 086. No public comments were received.

3. The Department provided written comments on the plan to the JWC on November 24, 2020. In response, the JWC submitted a revised plan on January 19, 2021.

4. The Department reviewed the revised plan and finds that it contains all of the elements required under OAR 690-086-0125 and OAR 690-086-0130.

5. The projections of future water needs in the plan demonstrate a need for an additional **18.0 cfs** of water (for a total of 44.0cfs) available under **Permit S-54737** (formerly S-50879) to help meet overall projected 20-year demands. These projections are reasonable and consistent with the JWC's land use plan.

This is a final order in other than a contested case. This order is subject to judicial review under ORS 183.484. Any petition for judicial review must be filed within the 60-day time period specified by ORS 183.484(2). Pursuant to ORS 536.075 and OAR 137-004-0080, you may petition for judicial review or petition the Director for reconsideration of this order. A petition for reconsideration may be granted or denied by the Director, and if no action is taken within 60 days following the date the petition was filed, the petition shall be deemed denied.

6. The **City of Hillsboro's** system is fully metered and the rate structure includes a base rate and volumetric charge. Water loss is estimated at 0.7%

7. The plan includes 5-year benchmarks for continuation and/or implementation of the following benchmarks specific to the **City of Hillsboro**:

    a. Annual Water Audits, and integration of an AWWA M36 water loss analysis into its water auditing practices; system-wide metering; a meter testing and maintenance program; a water rate structure based in part on the volume of water consumed to encourage conservation; leak detection surveys and inspections; budgeting specifically for replacement of high priority aging infrastructure; a public education program that focuses on water conservation; technical and financial assistance program; rebates to customers for replacement of high water use fixtures and/or devices and free water saving devices; actively seeking opportunities for water reuse and recycling; and continue membership in the Regional Water Providers Consortium, the Alliance for Water Efficiency, and the Conservation Committee of the Pacific Northwest Section of the AWWA.

8. The City of **Forest Grove's** system is fully metered and the rate structure includes a base rate and volumetric charge. Water loss is estimated at 15%

9. The plan includes 5-year benchmarks for continuation and/or implementation of programs specific to the **City of Forest Grove**:

    a. Annual Water Audits; replacement of two master meters; explore switching the City to an Advanced Metering Infrastructure (AMI) system; regular meter testing and maintenance program; a water rate structure based in part on the volume of water consumed to encourage conservation; a public education program; evaluate the expansion of the current home energy audit program to include more water conservation consultation; continue a rebate program for low-water-use washing machines, dishwashers, and toilets and explore the feasibility of implementing a rebate program for weather based irrigation controllers; and continue to recycle backwash water and seek non-potable water use opportunities.

    b. Because the City of Forest Grove's water loss is above 10%, they have set the following benchmarks:

        i. Within two years of approval of this WMCP, the City shall provide the Department a description and analysis identifying potential factors for the water loss and selected actions for remedy.

        ii. If the selected actions do not reduce water loss to less than 10 percent within five years of approval of the WMCP, the City will either develop and implement a regularly scheduled and systematic program to detect and repair leaks in the transmission and distribution system or develop and implement a water loss program consistent with AWWA standards.

10. The **City of Beaverton's** system is fully metered and the rate structure includes a base rate and volumetric charge. Water loss is estimated at 6.7%

11. The plan includes 5-year benchmarks for continuation and/or implementation of programs specific to the **City of Beaverton**:

    a. Annual Water Audits; system-wide metering, and conversion of all meters to an AMI system over the next seven years; a meter testing and maintenance program; a water rate structure based in part on the volume of water consumed to encourage conservation, and continued assessment of the City's water rate structure to adequately fund the operation and maintenance of the City's water system; leak detection surveys and inspections; budgeting specifically for replacement of high priority aging infrastructure; a public education program that focuses on water conservation; a technical and financial assistance program, and exploring the possibility of a free irrigation audit program for multi-family customers; a supplier financed rebate and incentive program to replace or retrofit inefficient fixtures; continued development and testing of a stormwater capture project and a purple pipe project; and continuing to be a member of the Regional Water Provider Consortium.

12. The **TVWD's** system is fully metered and the rate structure includes a base rate and volumetric charge. Water loss is estimated at 4.4%

13. The plan includes 5-year benchmarks for continuation and/or implementation of programs specific to the **TVWD**:

    a. Annual Water Audits; system-wide metering and installing Automatic Meter Reading in all new meter installations or as metering devices fail; continue to evaluate the use of AMI for consideration in the development of a long-term meter reading strategy; a meter testing and maintenance program; a rate structure based in part on the volume of water used that encourages conservation; regular leak detection surveys and inspections; a public education program; a technical and financial assistance program; a rebate program for replacement of inefficient fixtures, equipment, and processes; continued support for regional efforts in developing methods for water reuse; continue to facilitate and engage customer participation in water conservation efforts; continue to market the use of advanced irrigation technology in landscape irrigation and promote water efficient landscaping practices using the Water Efficient Demonstration Garden.

14. The plan identifies the surface water rights held by the JWC and its members from the Tualatin, Trask and Willamette River Basins. Ground water sources, including aquifer storage and recovery (ASR) wells, are also identified in the plan. The plan also accurately and completely describes, for each surface water source, the appropriate listed fish species and water quality limitations in the Tualatin, Trask and Willamette River Basins. It also accurately describes that several of the JWC member agency ground water rights are within the boundaries of a designated critical ground water area (CGWA), being the Cooper Mountain-Bull Mountain CGWA.

15. The water curtailment element included in the plan for the JWC and its member agencies satisfactorily promotes water curtailment practices. The water curtailment element also includes a list of four (4) stages of alert with concurrent curtailment actions for the JWC, City of Hillsboro In-Town System and City of Hillsboro Upper System, City of Forest Grove, and Tualatin Valley Water District, and a list of five (5) stages of alert with concurrent curtailment actions for the City of Beaverton.

16. The diversion of water under Permit S-54737 will be increased during the next 20 years and is consistent with OAR 690-086-0130(7), as follows:

    a. As evidenced by the 5-year benchmarks described in Findings of Fact #7 through #13, the revised plan includes a schedule for the continuation and/or implementation of conservation measures that would provide water at a cost that is equal to or lower than the cost of other identified sources;

    b. Considering that water savings alone from identified conservation measures cannot fully meet the JWC's water demand projections, and that the JWC's current water sources cannot adequately meet the JWC's water demand projections, access to increased diversion of water under existing Permit S-54737 is the most feasible and appropriate alternative available to the JWC.

    c. The JWC and its member agencies are not required to provide mitigation under Permit S-54737. There are, however, conditions in Permit S-54737 requiring the maintenance of seasonal bypass flows in Scoggins Creek from Scoggins Dam to the mouth.

Conclusion of Law

The Water Management and Conservation Plan submitted by the JWC is consistent with the criteria in OAR Chapter 690, Division 086.

Now, therefore, it is ORDERED:

Duration of Plan Approval:

1. The JWC Water Management and Conservation Plan is approved and shall remain in effect until **February 24, 2031** unless this approval is rescinded pursuant to OAR 690-086-0920.

Development Limitation:

2. The limitation of the diversion of water under **Permit S-54737** (formerly Permit S-50879) established by the extension of time approved on September 9, 2010 and the subsequent WMCP Final Order dated September 14, 2010, is modified and, subject to other limitations or conditions of the permit, the JWC is authorized to divert up to **44.0 cfs (*out of the total permitted 75.0 cfs*)** under **Permit S-54737**.
3. Failure to meet the conservation benchmarks listed below may result in the reduction of the quantity of water authorized for diversion under **Permit S-54737** during review of the JWC's next plan update.
    a. Water Loss Analysis (Finding of Fact # (9.b.i.))
    b. Water Loss Analysis (Finding of Fact # (9.b.ii.))

Plan Update Schedule:

4. The JWC shall submit an updated plan meeting the requirements of OAR Chapter 690, Division 086 (effective December 23, 2018) within **10 years** and no later than **August 24, 2030**.

Progress Report Schedule:

5. The JWC shall submit a progress report containing the information required under OAR 690-086-0120(4) by **February 24, 2026**.

Other Requirements for Plan Submittal:

6. The deadline established herein for the submittal of an updated Water Management and Conservation Plan (consistent with OAR Chapter 690, Division 086) shall not relieve the JWC from any existing or future requirement(s) for submittal of a Water Management and Conservation Plan at an earlier date as established through other final orders of the Department.

Dated at Salem, Oregon this day FEB 24 2021

Lisa J. Jaramillo, Transfer and Conservation Section Manager for
THOMAS M. BYLER, DIRECTOR
Oregon Water Resources

Mailing date: FEB 25 2021

Notice Regarding Service Members: Active duty service members have a right to stay these proceedings under the federal service members Civil Relief Act. For more information, contact the Oregon State Bar at 800-452-8260, the Oregon Military Department at 503-584-3571 or the nearest United States Armed Forces Legal Assistance Office through http://legalassistance.law.af.mil. The Oregon Military Department does not have a toll free telephone number.

Contents

Index of Exhibits

Appendices

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Executive Summary

The Joint Water Commission (JWC) is the primary drinking water supplier in Washington County, Oregon. The JWC consists of four member agencies (the Cities of Hillsboro, Forest Grove, and Beaverton, and Tualatin Valley Water District) that have varying levels of ownership in the JWC's water supply and water infrastructure, as well as manage their individually-owned water supply and water infrastructure. This Water Management and Conservation Plan (WMCP) describes how the JWC and JWC Member Agencies manage their water supplies and encourage water conservation, as well as how they plan to meet water supply needs in the future.

The drivers for developing this WMCP include:

- Complying with Oregon Water Resources Department (OWRD) Final Order (dated September 14, 2010) approving the JWC's WMCP and requiring submittal of an updated plan by September 14, 2020;
- Complying with the conditions in the extension of time for JWC's Permit S-54737;
- Requesting access from OWRD for up to 44 cfs under JWC's Permit S-54737 to meet projected demands within the next 20 years (referred to as seeking "greenlight water"); and
- Documenting and describing the JWC and JWC Member Agencies' water stewardship and planning activities.

Criteria outlined in administrative rules under OAR Chapter 690, Division 86 must be met to receive WMCP approval from OWRD. The JWC has met each of the criteria for approval in this WMCP as outlined below.

- The WMCP includes the requirements under OAR 690-086-0125.
    - Descriptions of the water supplier, water conservation measures and 5-year water conservation benchmarks, a water curtailment plan, and projected water supply needs.
    - A list of affected local governments to whom the JWC sent its draft WMCP, as well as any comments received by the affected local governments.
    - The JWC's proposed date for submitting an updated WMCP: within 10 years of the final order approving this WMCP. As required by OAR Chapter 690, Division 86, a progress report will be submitted to OWRD within 5 years of the final order.
    - A statement that the JWC is not requesting additional time to implement metering or a previous benchmark.
- The WMCP includes projections of future water needs.
    - The JWC water supply year has two seasons, the peak season (May-October) and the non-peak season (November-April), with different demands and available sources of supply during each season. Consequently, the JWC developed two

separate demand projections: maximum day demand (MDD) projections that represent the greatest demands anticipated in the peak season and average day demand (ADD) projections that represent typical demands anticipated in the non-peak season.

- Non-peak Season:
  - The JWC's projected ADD in 2040 is 178.79 cfs (115.57 mgd), which is based on the combination of the ADDs of the individual JWC Member Agencies and wholesale customers and several other factors described in Section 5 of the WMCP.
  - The JWC only has natural flow surface water rights available in the non-peak season that allow the use of up to 119.46 cfs. To meet projected non-peak season ADD in 2040, the JWC is seeking access to 44 cfs under Permit S-54737 (referred to as "greenlight water"), which is the difference between the estimated expanded JWC Water Treatment Plant capacity of 163 cfs and the 119.46 cfs of JWC natural flow surface water rights available in the non-peak season.
- Peak Season:
  - The JWC's projected MDD in 2040 is 237.94 cfs (153.8 mgd), which is the combined total of the MDDs of the individual JWC Member Agencies and wholesale customers.
  - The JWC has 248.8 cfs (160.8 mgd) of water rights and ASR limited license authorizations that can be used and developed to meet the projected MDD in 2040.
- The JWC's demand projections are reasonable and consistent with land use plans of affected local governments, and demonstrate the need for water to be diverted during the next 20 years under Permit S-54737.

- The WMCP describes the need for additional water supply under a permit ("greenlight water").
  - This WMCP describes the JWC's need for access to up to 44 cfs of water under Permit S-54737 in the non-peak season during the next 20 years.
  - The JWC determined that water savings from additional conservation measures cannot eliminate the JWC's need for additional water supply under Permit S-54737 to meet its future demands in the non-peak season within its entire service area. In addition, existing infrastructure is capable of diverting and distributing this additional supply; therefore, conservation measures would not provide water at a cost equal to or lower than the cost of using water under the permit.
  - The JWC has water supply agreements between multiple water supply systems, exemplifying regional cooperation. JWC Member Agencies are interconnected and have cooperative water management agreements that allow a given

Member Agency to make use of another Member Agency's unused water supply. Some JWC Member Agencies (City of Hillsboro, City of Beaverton, and Tualatin Valley Water District) are also investing in development of the Willamette River as a water supply source through a partnership under the Willamette Water Supply Program. However, the JWC focused on evaluating its ability to meet the needs of its member agencies in the event their individual water supplies are not available, and in that circumstance, the JWC's interconnections and water supply agreements cannot satisfy its projected water needs. As a result, the JWC would need to rely on Permit S-54737 to meet water demands.

- The WMCP correctly describes that the JWC currently is not required to take any mitigation actions to comply with legal requirements of the Endangered Species Act, Clean Water Act, and other applicable state or federal environmental regulations.

- The WMCP includes a summary of water management and conservation measures.
    - This WMCP describes the water management and conservation programs of JWC Member Agencies, each of which include water conservation measures required under OAR 690-086-0150(4 and 5), as well as 5-year benchmarks for implementation of conservation measures. A few examples of current programs/measures are highlighted below; the full descriptions can be found in Section 3 of the WMCP.
        - The JWC has an Events and Education Committee and is a member of the Regional Water Providers Consortium, both of which conduct water conservation outreach throughout the JWC service area.
        - JWC Member Agency customers can access an extensive amount of water conservation information through a JWC website, a Regional Water Providers Consortium website, and the websites of each JWC Member Agency.
        - Each JWC Member Agency has a rebate program that encourages customers to replace inefficient water fixtures.
        - The customer water rate structures of each JWC Member Agency are based, in part, on the quantity of water consumed. Several JWC Member Agencies also have a tiered water rate structure for some of their customer categories to provide an additional economic incentive to reduce water use.
        - In addition to being fully metered, JWC Member Agencies have installed meters that improve consumption tracking, leak detection, and meter maintenance efforts. Each JWC Member Agency is utilizing Automated Meter Reading or Automated Metering Infrastructure meters to some degree.

- The WMCP describes water quality and fish resource listings.
    - Based on the surface water sources used by JWC and JWC Member Agencies, the WMCP describes water quality listings and the fish species with state or federal protections in the Tualatin River watershed, Trask River watershed, and the Willamette River (at approximately River Mile 39).
    - The WMCP correctly identifies that the City of Beaverton and TVWD's native groundwater rights for municipal water supply are within the Cooper Mountain-Bull Mountain Critical Groundwater Area.
- The WMCP includes a curtailment plan with specific triggers and actions.
    - The JWC has a water curtailment plan that consists of four curtailment stages. For each stage, the JWC describes the potential triggers (i.e. initiating conditions) and its water use curtailment actions for each curtailment stage. The JWC requires that each JWC Member Agency and wholesale customers have a curtailment plan that meets the same requirements. The individual water curtailment plans of each JWC Member Agency are included in the Appendix.

1. Municipal Water Supplier Plan Elements

This section satisfies the requirements of OAR 690-086-0125.

This rule requires a list of affected local government to whom the plan was made available, and a proposed date for submittal of an updated plan.

1.1. Overview

The Joint Water Commission (JWC) is the primary drinking water supplier in Washington County, Oregon. The JWC is made up of four member agencies: the Cities of Hillsboro, Forest Grove, Beaverton, and the Tualatin Valley Water District (TVWD). Each member agency has individually-owned water facilities plus varying levels of ownership in the JWC and its water supply, water treatment plant, storage reservoirs, and transmission facilities.

Water supply: The JWC water supply comes from two surface water sources: the Tualatin River including its tributaries Sain Creek and Scoggins Creek, and the Middle Fork of the North Fork of the Trask River. In addition to diverting water directly from these sources ("direct diversion" or "natural flow"), in the summer months the JWC uses water from storage supplies in Barney Reservoir, on the Middle Fork of the North Fork of the Trask River, and Scoggins Reservoir (Hagg Lake) on Scoggins Creek, a tributary of the Tualatin River. JWC Member Agencies have their own water sources in addition to the JWC sources, which are described in this WMCP as well.

Treatment: The JWC diverts water from the Tualatin River through the Spring Hill Pumping Plant Intake south of Forest Grove. Water is treated at the JWC Water Treatment Plant (WTP) located at 4475 SW Fern Hill Road. Treatment at the plant consists of conventional media filtration with coagulation, flocculation, and sedimentation processes prior to filtration.

Storage: Finished water is stored in the Fern Hill Reservoirs, two 20-Million Gallon (MG) concrete reservoirs located approximately one-third mile east of the JWC Water Treatment Plant.

Transmission: After treatment, finished water is pumped from the JWC Water Treatment Plant to the Fern Hill Reservoirs or directly to the high-pressure transmission system. From the Fern Hill Reservoirs, water is conveyed via the south transmission line (STL) to the City of Hillsboro, the Tualatin Valley Water District, and the City of Beaverton. The north transmission line (NTL) provides service to the City of Hillsboro, City of North Plains, City of Cornelius, and the Tualatin Valley Water District. The NTL can be fed from the WTP's pump stations or Fern Hill Reservoirs. A third transmission main feeds the City of Forest Grove and the City of Hillsboro's Upper System from the WTP's pump stations.

The JWC is also committed to water conservation and water supply emergency preparedness.

Water Conservation*:* The JWC and its member agencies implement an array of water conservation activities aimed at minimizing system water loss and reducing use by water customers. Efforts to minimize water loss include conducting annual water audits, tracking meter reads for signs of leaks, and transmission and system line repairs or replacements to address leaks. Efforts to reduce customer demand include extensive public education and outreach, providing rebates on water saving fixtures, and implementing rate structures that encourage conservation.

Water Supply Emergency Preparedness: The JWC and its member agencies have water curtailment plans to address water supply emergencies. The curtailment plans identify triggers for different levels of curtailment, such as drought or infrastructure failures. For each curtailment level, the curtailment plans identify actions that could be taken by the water providers, such as curtailment of water consuming activities by water providers, customer outreach efforts, and voluntary or mandatory customers' actions.

The JWC is governed by a Board of Commissioners (three commissioners from each agency) and the City of Hillsboro's Water Department Director serves as the General Manager for the JWC. The JWC has been assigned the state and federal Public Water System Identification Number 4100379.

1.2. History of JWC Water Management and Conservation Plans

- 1993: A Conservation Plan was prepared and adopted by members of the JWC as part of the Barney Reservoir Expansion Project. The purpose of the plan was to address the role of conservation in the resource management and planning process.
- August 1998: The JWC submitted Phase I of a Water Management Plan to the Oregon Water Resources Department (OWRD) to fulfill OWRD's requirements for JWC's Permit S-50879 for diversion of water from Scoggins Creek.
- February 8, 1999: OWRD approved several sections of the 1998 JWC Water Management Plan and granted interim approval of Section 3, Water Conservation, and Section 5, Long Range Supply Plan. OWRD requested that these sections be updated by January 31, 2003.
- 2003: The JWC submitted to the OWRD a Water Management Plan Update that superseded the measures and actions originally described in 1998 plans.
- August 17, 2004: OWRD issued a Final Order accepting the WMCP and requiring an updated WMCP by August 16, 2009.
- August 13, 2009: The JWC submitted a draft WMCP update.

- September 9, 2010: OWRD approved an extension of time for Permit S-50879, which required a WMCP before diverting any water under the permit.
- September 14, 2010: OWRD issued a Final Order approving the JWC's WMCP. The Final Order authorized the diversion of up to 26 cfs under Permit S-50879 and included the requirement that the JWC submit a WMCP progress report by September 14, 2015 containing information required under OAR-086-0120(4) and an updated WMCP by September 14, 2020.
- December 15, 2011: OWRD issued a Final Order approving a change in point of diversion on Scoggins Creek, under Permit S-50879, to the Spring Hill Pumping Plant Intake and issued superseding Permit S-54737 to describe the approved change in point of diversion. Permit S-54737 restates the requirement to submit a WMCP progress report by September 14, 2015 and a WMCP update by September 14, 2020.
- October 26, 2015: OWRD issues a letter stating that the WMCP progress report submitted by the JWC was complete.

This Water Management and Conservation Plan, 2020 replaces all previously submitted plans.

1.3. Plan Requirement

The Final Order dated September 14, 2010 approving the JWC's WMCP and Permit S-54737 issued by OWRD on December 15, 2011 require the JWC to submit a WMCP by September 14, 2020.

This municipal Water Management and Conservation Plan (WMCP) fulfills the requirements of the Oregon Administrative Rules adopted by the Water Resources Commission in November

2002 (OAR Chapter 690, Division 86) and amended in December 2018. It describes water management, water conservation, and curtailment programs that guide the use and stewardship of JWC's water supply.

1.4. Plan Organization

This WMCP is organized into the following sections, each addressing specific sections of OAR Chapter 690, Division 86:

Section	**Requirement**
Section 1 – Water Supplier Plan Elements	OAR 690-086-0125
Section 2 - Water Supplier Description	OAR 690-086-0140
Section 3 - Water Conservation	OAR 690-086-0150
Section 4 - Water Curtailment	OAR 690-086-0160
Section 5 - Water Supply	OAR 690-086-0170

Section 2 is a self-evaluation of the JWC's water supply, water use, water rights, and water system. The information developed for Section 2 is the foundation for the sections that follow.

The later sections use this information to consider how the JWC and its member agencies can improve its water conservation and water supply planning efforts.

Section 3 reviews progress made on previous water conservation benchmarks, describes current water conservation program measures, and presents new 5-year water conservation benchmarks.

Section 4 contains the water curtailment plan of the JWC and its member agencies, which describe potential triggers of water supply shortages, levels of curtailment, and actions to be taken for each level of curtailment.

Section 5 describes the JWC's population projections, demand projections, and water supply strategy to meet those projected demands. It also considers alternative water sources.

The WMCP also includes appendices with supporting information.

1.5. Affected Local Governments

The following local governmental agencies are considered "affected local governments" under OWRD's WMCP administrative rules:

- City of Hillsboro
- City of Forest Grove
- City of Beaverton
- Metro
- Washington County
- Multnomah County
- City of Portland
- City of Wilsonville
- City of North Plains
- City of Gaston
- City of Cornelius
- City of Tigard
- City of Lake Oswego

Thirty days before submitting this WMCP to OWRD, the JWC made the draft WMCP available for review by each affected local government listed above, and included a request for comments relating to consistency with the local government's comprehensive land use plan. In addition, the JWC provided courtesy copies of the draft plan to: Tualatin Valley Water District, LA Water Cooperative, and the Willamette River Water Coalition. The letters requesting comments and documentation of any comments received are in Appendix A.

1.6. Plan Update Schedule

JWC anticipates submitting an update of this plan within 10 years of receiving the final order for this plan. As required by OAR Chapter 690, Division 86, a progress report will be submitted within 5 years of the final order.

1.7. Time Extension

The JWC is not requesting additional time to implement metering or a previous benchmark.

2. Water Supplier Description

This section satisfies the requirements of OAR 690-086-0140.

2.1. Service Area and Service Population Description

OAR 690-086-0140 (2)E

The JWC provided drinking water to a population of approximately 436,205 in 2019 through its four member agencies and two wholesale customers (City of North Plains and Westside Lutheran School), as shown in Exhibit 2-1. The JWC current and future water service areas and major water system features are shown in Exhibits 2-2. A detailed description of service area and service area population estimates for the JWC Member Agencies follows. The total population of the Wholesale Customers is based on the City of North Plains population estimate of 3,285 from Portland State University's Population Research Center and a population estimate of 230 from Westside Lutheran School.

Exhibit 2-1. Summary of Customer Connections and Total Population of JWC Member Agencies and Wholesale Customers, 2019

JWC Member Agencies and Wholesale Customers	Total Customer Connections (2019)	Total Population Served (2019)
Hillsboro	25,509	102,692
Forest Grove	6,659	25,303
Beaverton	22,501	89,978
TVWD	60,003	214,717
Wholesale Customers	3	3,515
Total	**114,675**	**436,205**

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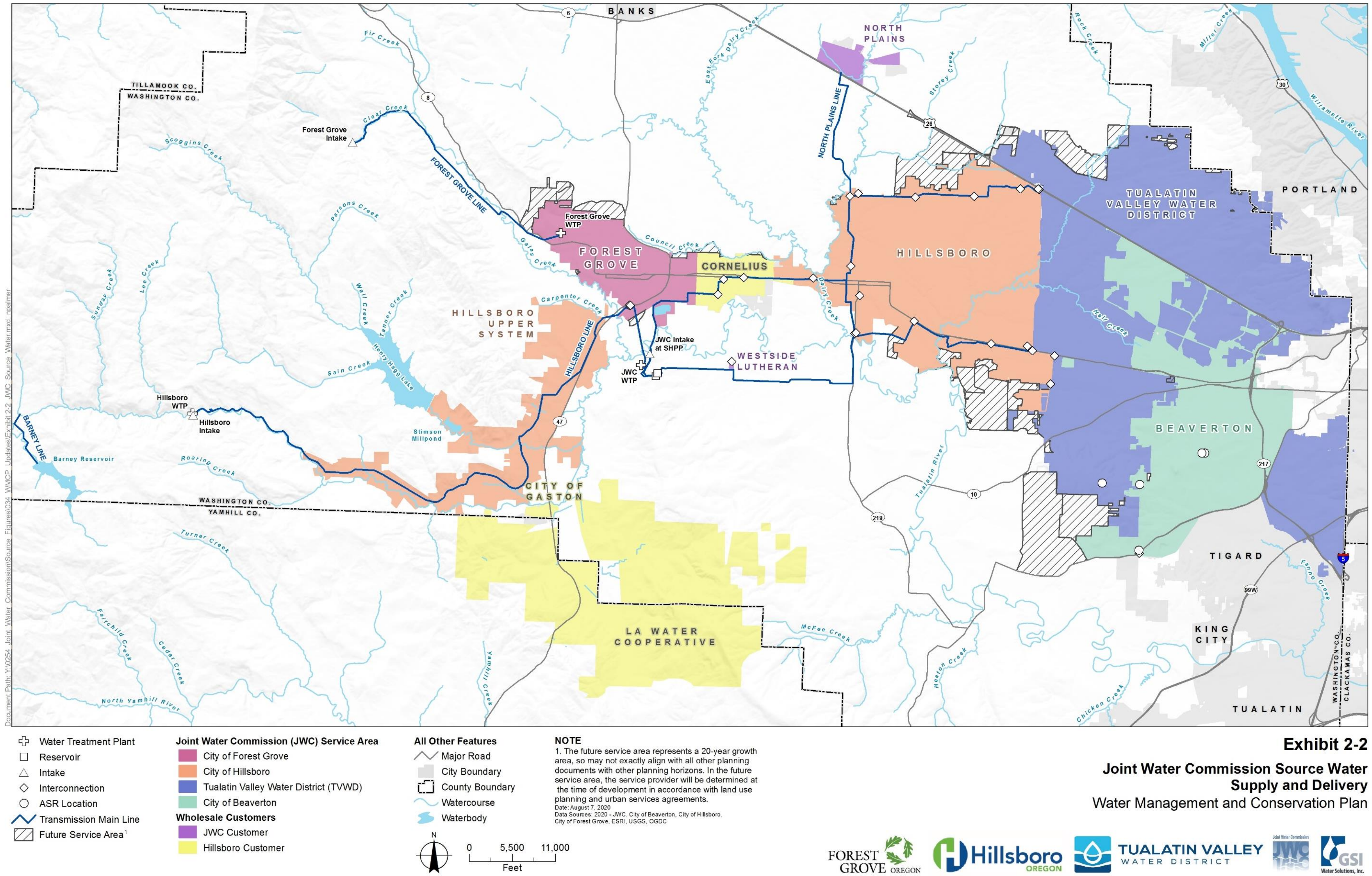
Exhibit 2-2. JWC Current and Future Service Areas and System Schematic



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2.1.1. Hillsboro

The City of Hillsboro's current retail water service area consists of two areas that are geographically separated: (1) the In-Town retail service area, which includes approximately 75% of the City of Hillsboro's urban boundary, and (2) the Upper System, which serves an unincorporated area to the southwest of the City of Forest Grove. The City of Hillsboro wholesales water to the City of Cornelius through interconnections near the In-Town area, and to the City of Gaston and LA Water Cooperative through interconnections in the Upper System. The City of Hillsboro serves its In-Town service area from the JWC WTP, and it's Upper System from both the JWC and Cherry Grove WTPs. The City of Hillsboro's remaining population, east of Cornelius Pass Road, is served by TVWD. Exhibit 2-2 shows the City of Hillsboro's existing service area.

The 2019 service area population in the City of Hillsboro's In-Town service area was approximately 87,929, plus 1,889 people in its Upper System (Portland State University Population Research Center). The City of Hillsboro wholesales to 2,500 people within LA Water Cooperative (as reported to the Oregon Health Authority by the LA Water Cooperative). The City of Hillsboro also wholesales water to the Cities of Cornelius and Gaston with 2019 populations of 9,719, and 655, respectively (Portland State University PRC). Summing the City of Hillsboro service and wholesale customer populations yields a total service population of 102,692. The City's service area populations are shown in Exhibit 2-3.

Exhibit 2-3. Hillsboro Water Service Areas and Service Area Populations, 2019

Water Service Area	Service Area Population
Hillsboro In-Town	87,929
Hillsboro Upper System	1,889
Cornelius	9,719
Gaston	655
LA Water Cooperative	2,500
Hillsboro & Wholesale	102,692

The City of Hillsboro has eight customer categories: single family residential, multi-family residential, commercial, industrial, public entity, non-profit, irrigation, and wholesale customer categories. These customer classes were established in October 2006. Exhibit 2-4 shows the number of accounts by customer category in 2019.

Exhibit 2-4. Hillsboro Accounts by Customer Category, 2019

Customer Category	Number of Accounts (2019)	Percent
Single Family	23,616	92.56%
Commercial	877	3.44%
Irrigation	460	1.80%
Multi-Family	271	1.06%
Public	119	0.47%
Industrial	84	0.33%
Non-Profit	82	0.32%
Wholesale	4	0.02%
Total	**25,513**	**100%**

2.1.2. Forest Grove

The City of Forest Grove, the smallest of the JWC member agencies, is home to Pacific University. Forest Grove's diverse economic base includes high tech, food and beverage processing, wood products, metalworking, education, and healthcare. The City of Forest Grove's service area is the area within its city limits plus 57 connections outside of the city limits in the Urban Growth Boundary along Gales Creek, Stringtown Road, and Oppenlander Lane, as depicted in Exhibit 2-2. The City of Forest Grove's estimated 2019 water service area population was 25,303, according to Portland State University's PRC. The City of Forest Grove has six customer categories: residential, commercial, school, multi-family, city, and industrial users. Exhibit 2-5 shows the number of customer connections for each of these six customer categories in 2019.

Exhibit 2-5. City of Forest Grove Water Connections by Customer Category, 2019

Customer Category	Number of Accounts (2019)	Percent
Residential	6,061	90.30%
Commercial	368	5.48%
School	42	0.63%
City	43	0.64%
Multi-Family	177	2.64%
Industrial	21	0.31%
Total	**6,712**	**100.00%**

2.1.3. Beaverton

The City of Beaverton's water service area is generally bounded on the east by Highway 217, on the north by the Oregon 8 Tualatin Valley Highway (TV Hwy), on the west by SW 160th Avenue, and on the south by SW Scholls Ferry Road, beyond which is the City of Tigard. The City of Beaverton's service area also includes the developing South Cooper Mountain area on the north side of SW Scholls Ferry Road from SW Loon Drive west to SW Tile Flat Road. The remaining portions of the City are served by neighboring water providers, including TVWD to the north, west, and east, and West Slope Water District and Raleigh Water District (RWD) to the northeast. Exhibit 2-2 depicts the City of Beaverton's existing service area.

The City of Beaverton's estimated 2019 water service area population was 89,743, according to Portland State University PRC. Only a portion of the City of Beaverton's population receives water provided by the City. The City of Beaverton has seven customer categories: apartment, commercial, fire line, irrigation, multi-family, public, and residential. The apartment category is defined as accounts that have greater than four units and the multi-family categories defined as accounts that have four units or fewer. Exhibit 2-6 shows the number of connections by customer category in Fiscal Year 2018/2019.

Exhibit 2-6. Beaverton Water Connections by Customer Category, Fiscal Year 2018/2019

Category	Number of Accounts	Percent
Residential	18,872	83.87%
Multi-Family	1,382	6.14%
Commercial	1,102	4.90%
Public Facility	98	0.44%
Irrigation and Fire	1,047	4.65%
Total	**22,501**	**100.00%**

2.1.4. Tualatin Valley Water District

TVWD provides services to an area of more than 45 square miles. TVWD serves portions of the cities of Beaverton, Hillsboro, Portland, and Tigard. TVWD also serves a portion of Washington County, including the unincorporated communities of Cedar Hills, Bethany, Rock Creek, Cooper Mountain, Progress, Metzger, and Aloha, as well as a small portion of Multnomah County. Exhibit 2-2 shows the TVWD's existing service area.

TVWD's water service area population was 214,717 in 2019, according to Portland State University PRC. TVWD has eight customer categories: single family residential, multi-family residential, commercial, industrial, public entity, irrigation, temporary irrigation (previously included within the irrigation category in the 2010 JWC WMCP), and wholesale customer categories. Exhibit 2-7 shows the number of accounts by customer category.

Exhibit 2-7. TVWD Water Accounts by Customer Category, 2019

Customer Category	Number of Accounts (2019)	Percent
Residential	55,682	92.80%
Multi-Family Residential	1,075	1.79%
Commercial	1,381	2.30%
Production	25	0.04%
Fireline	808	1.35%
Irrigation	975	1.62%
Temp Irrigation	40	0.07%
Wholesale	17	0.03%
Total	**60,003**	**100.00%**

2.2. Interconnections with Other Systems

OAR 690-086-0140(7)

As shown on Exhibits 2-3 through 2-7, multiple interconnections exist between JWC transmission lines and JWC member agencies, between JWC transmission lines and small water providers, between JWC member agencies themselves, and between JWC member agencies and neighboring communities. Exhibit 2-8 provides a summary of the interconnections between systems.

Exhibit 2-8. Summary of Interconnections for JWC Members and Wholesale Customers

Agency	Metered or Un-metered	Hillsboro	Forest Grove	Beaverton	TVWD	JWC	PWB	Cornelius	North Plains	West Side Lutheran	Other[2]	Total	Overall Total
Hillsboro[1]	M		0	0	0	17	0	4	0	0	3	24	33
	U		0	0	8	0	0	0	0	0	1	9	
Forest Grove	M	0		0	0	1	0	0	0	0	0	1	2
	U	0		0	0	0	0	1	0	0	0	1	
Beaverton	M	0	0		4	1	1	0	0	0	0	6	26
	U	0	0		17	0	0	0	0	0	3	20	
TVWD	M	0	0	4		0	4	0	0	0	4	12	55
	U	8	0	17		2	9	0	0	0	7	43	
JWC	M	17	1	1	2		0	4	1	1	0	27	27
	U	0	0	0	0		0	0	0	1	0	0	

Notes

[1]Total includes Hillsboro In-Town and Hillsboro Upper System Service Areas

[2]Connections to City of Tigard, City of Gaston, and LA Water Cooperative included in "Other" category

The Portland Water Bureau (PWB) provides reliable supplies to TVWD, and will have the ability to supply emergency water to JWC partners through the North Transmission Line (NTL). PWB obtains its water from the Bull Run Watershed, with a seasonal and emergency water supply from the Columbia South Shore Wellfield.

Wholesale customers only receive water from the JWC and JWC Member Agencies, so do not provide water supply.

2.2.1. JWC Interconnections

The JWC serves Hillsboro (Upper System and In-Town System), Forest Grove, Beaverton, TVWD, and wholesale customers through a total of 27 interconnections along JWC transmission lines. The City of Cornelius has 4 interconnections along the JWC transmission line, Westside Lutheran School has 2 interconnections, and the City of North Plains has one interconnection. All of these interconnections are metered except for one unmetered fire connection at Westside Lutheran School.

The JWC recently installed a connection with a new Willamette Water Supply Program (WWSP) transmission line, the South Transmission Line (STL), that is not yet in service. When the WWSP is fully operational, this intertie will allow for emergency supply provisions between the two agencies. A second of these connections is also planned.

2.2.2. Hillsboro Interconnections

The City of Hillsboro's Upper System transmission line has one metered interconnection with the City of Gaston, one metered interconnection with the LA Water Cooperative, and one metered interconnection with the JWC supply system. If the Cherry Grove WTP was impacted, a majority of the Upper System can be fed with adequate pressure by the JWC WTP. The Upper System's Cherry Grove WTP cannot currently serve the In-Town System.

The City of Hillsboro's In-Town System has interconnections with the JWC supply system and the TVWD service area. The City of Hillsboro has 17 master meter locations connecting to JWC transmission lines. The City of Hillsboro serves the City of Cornelius water via a JWC transmission line and currently water can only be conveyed one-way to the City of Cornelius. Eight unmetered emergency interties with TVWD are located on the boundary between the two systems. In the South Hillsboro development, one metered connection provides water from TVWD to Hillsboro and a second is planned. These connections are being established to serve the South Hillsboro development as the WWSP and Hillsboro distribution system improvements are completed. They will remain in place as emergency connections after those projects are complete.

2.2.3. Forest Grove Interconnections

Forest Grove maintains one metered connection from the transmission line from the JWC WTP, and has an emergency intertie with the City of Cornelius. Forest Grove's Clear Creek source and WTP do not supply or connect to other systems.

2.2.4. Beaverton Interconnections

Beaverton has distribution system interties with three adjacent water providers: TVWD, PWB, and City of Tigard.

The City is connected to PWB's Burlingame system at SW 60th Avenue; this connection is inactive. Beaverton has three emergency distribution system interties with the City of Tigard:

near SW Springwood Drive, SW 135th Avenue, and SW Barrows Road. The SW 135th Avenue connections can supply flow in either direction between the two cities. The SW Springwood Drive connection allows Tigard to supply water to Beaverton under emergency conditions. The intertie at SW Barrows Road can convey water to Tigard.

The City has several interties with TVWD, the majority of which are along the City's western water service area boundary where it adjoins TVWD's boundary. All current interties with TVWD are inactive.

2.2.5. TVWD Interconnections

TVWD has 55 interconnections, four of which provide the district with its primary water supply. TVWD has two interconnections with the JWC, which are located along the western boundary of its service area: the South Transmission Line entering near Tualatin Valley Highway and 75th Avenue, and the North Transmission Line entering near Cornelius Pass Road and Highway 26. TVWD has interconnections with PWB via the Washington County Supply Line (a transmission line that supplies several PWB wholesale customers in Washington County) and via an intertie with a transmission main that runs along Oleson Road and enters the distribution system at Florence Lane and 80th. Another connection (Garden Home) to the PWB system provides water supply to approximately 170 homes. TVWD has additional backup interconnections with PWB, and emergency interconnections with the Cities of Hillsboro, Beaverton, and Tigard, West Slope Water District, and Raleigh Water District.

2.3. Intergovernmental Agreements

OAR 690-086-0140(1)

A summary of all current intergovernmental agreements for JWC member agencies is contained in Appendix B. The summary includes agreements for wholesale water purchase, storage and diversion of water from the Barney and Scoggins Reservoirs, and the interagency agreements related to ownership, water rights, usage, maintenance, and financing of the JWC.

Under some of these agreements, the JWC member agency ownership shares of the 85 mgd capacity of the JWC WTP (this is the new capacity after the 10 mgd WTP expansion was completed in 2019) are currently as follows: City of Hillsboro 41.75 mgd (52.21 cfs), City of Beaverton 18.75 mgd (29.01 cfs), TVWD 14.5 mgd (19.34 cfs), and City of Forest Grove 10 mgd (15.47 cfs).

2.4. Water Sources

OAR 690-086-0140(1 & 2)

2.4.1. JWC Sources

The JWC water supply comes from two surface water sources: the Tualatin River including its tributaries Sain Creek and Scoggins Creek, and the Middle Fork of the North Fork of the Trask River. The JWC only diverts water directly from the “live” or natural flow of the Tualatin River during the non-peak season given that the JWC is regulated off most of its natural flow water right permits during the peak season by the Oregon Water Resources Department. (The JWC defines peak season as the six month period from May 1 through October 31 and non-peak season as the remaining six months of the year.) When this happens, JWC releases water from storage supplies in Barney Reservoir, on the Middle Fork of the North Fork of the Trask River, and Scoggins Reservoir (Hagg Lake) on Scoggins Creek, a tributary of the Tualatin River. The JWC also holds an Aquifer Storage and Recovery (ASR) Limited License (LL-019), but no wells have reached full production status to date.

Tualatin River

JWC’s main natural flow source is the Tualatin River and its tributaries. The JWC’s drinking water source area in the Tualatin River Basin encompasses approximately 220 square miles. The valley is surrounded to the north and east by the Tualatin Mountains, to the south by Chehalem and Parrett Mountains, and to the west by the Coast Range where the Tualatin River headwaters are located.

The JWC obtains water from the Tualatin River through the Spring Hill Intake and Pumping Plant (SHPP) at River Mile (RM) 56.3, south of Forest Grove. Water is treated at the JWC Water Treatment Plant (WTP) located at 4475 SW Fern Hill Road southwest of the intake. The JWC WTP has a rated peak capacity of 85 mgd and treatment consists of conventional media filtration with coagulation, flocculation, and sedimentation processes prior to filtration. Finished water from the JWC WTP is pumped via high pressure transmission lines directly to Forest Grove’s or Hillsboro’s distribution systems (The City of Beaverton and TVWD receive JWC water supply through interconnections with the JWC transmission line), or to the JWC-owned Fern Hill Reservoirs, two 20-million-gallon (MG) concrete reservoirs located on a hill approximately one-third mile east of the WTP. The first reservoir has been in operation since 1983, and the second came online in 2006. The location of the SHPP, JWC WTP, and two finished water reservoirs are shown on Exhibit 2-2.

The SHPP is shared with the Tualatin Valley Irrigation District and owned by the U.S. Bureau of Reclamation. The intake has traveling screens and strainers to prevent debris and wildlife from entering the pump well.

Barney Reservoir

The Trask River watershed is approximately 175 square miles. However, the sub-watershed from which JWC diverts and stores water, the Middle Fork of the North Fork of the Trask River, is approximately 13.2 square miles. As presented in Exhibit 2-9, Barney Reservoir is owned jointly by: TVWD (35 percent), City of Hillsboro (31 percent), City of Beaverton (21.5 percent), Clean Water Services (10 percent), and the City of Forest Grove (2.5 percent). These entities make up the Barney Reservoir Joint Ownership Commission with the City of Hillsboro serving as the managing agency. The Barney Reservoir is formed by the 120-ft, rock-fill, Eldon S. Mills Dam. Its storage capacity is 20,000 acre-feet. Of the annual storage or fill capacity, 15 percent is reserved by the Oregon Department of Fish and Wildlife for releases to the Trask River during the low flow (peak demand) season, 460 acre-feet remain in the dead pool, and the remainder of the storage is divided between owners by the ownership percentages presented above. During the storage release season, a 36-inch pipeline that is 6,500 feet in length diverts water across a narrow Coast Range divide from the Trask River Watershed into the headwaters of the Tualatin River at RM 78. Because of the travel time from Barney Reservoir to the SHPP Intake, water released from the reservoir is available for diversion at the intake in approximately 24 hours during the low flow (peak) season. The location of Barney Reservoir is shown on Exhibit 2-2.

Exhibit 2-9. Barney Reservoir Storage by Agency

Agency	Reservoir Ownership	Water Allocation	Storage at Full Capacity (ac-ft)
Hillsboro	31%	26%	5,127
Beaverton	21.5%	18%	3,556
TVWD	35%	29%	5,789
Forest Grove	2.5%	2%	414[1]
JWC Partner Sub-Total	**90%**	**75%**	**14,886**
Clean Water Services	10%	8%	1,654
ODFW	0%	15%	3,000
Dead Pool	-	2%	460
Total	**100%**	**100%**	**20,000**

Note

[1]Forest Grove also has an 800 acre-foot buy back option not reflected in this storage capacity

Scoggins Reservoir

Scoggins Reservoir (Henry Hagg Lake) was constructed between 1972 and 1975 for flood control, irrigation for agriculture, municipal and industrial uses, water quality control, and recreation. The 150-foot earthen dam is owned by the Bureau of Reclamation and operated by the Tualatin Valley Irrigation District. Approximately half of this reservoir's 56,000 acre-feet of water is contracted by the Tualatin Valley Irrigation District, but the JWC has water rights to use up to 13,500 acre-feet of impounded water when the reservoir fills to capacity. The Cities of Hillsboro, Forest Grove, and Beaverton have contracts with the Bureau of Reclamation for water volumes of 5,000, 4,500, and 4,000 acre-feet, respectively. Water is released from Scoggins Reservoir into Scoggins Creek (a tributary of the Tualatin River). The confluence of Scoggins Creek and the Tualatin River is located at RM 60 on the Tualatin River. Water released at Scoggins Dam takes approximately 12 hours to reach the SHPP Intake during the low flow (peak) season.

Aquifer Storage and Recovery

TVWD and the Cities of Hillsboro and Beaverton are parties to a JWC-held Aquifer Storage and Recovery (ASR) Limited License (LL-019), but no wells have reached full production status to date (ASR No. 6 and ASR No. 7 are also identified in LL-019). Each water provider has access to one-third the capacity of the JWC limited license. The City of Beaverton and TVWD currently have infrastructure to supply the Cooper Mountain area using ASR No. 6 and ASR No. 7, but the City of Hillsboro has not yet developed infrastructure for the use of ASR.

2.4.2. Non-JWC Water Sources

Each JWC member agency has at least one, non-JWC supply source as described below.

Hillsboro

The City of Hillsboro serves its Upper System, the City of Gaston, and LA Water Cooperative with water from the Tualatin River, which is diverted at the Haines Falls Intake located at RM 73.2. This water is treated at the Cherry Grove WTP, which is a slow sand filter plant with a maximum capacity of 3 mgd (4.6 cfs).

The City of Hillsboro recently acquired a 56 cfs portion of water use permit S-55045 from the City of Salem. This permit authorizes the use of water from the Willamette River for municipal purposes year-round. A water treatment plant, transmission lines, and associated infrastructure are currently under construction and scheduled for completion in 2026.

The City of Hillsboro also recently acquired ASR Limited License LL-0274 storage and recovery of water using up to three wells (Crandall Reservoir, Butternut Creek, and Wood Street), which are not yet constructed. The City of Hillsboro plans to use JWC supply in the winter months to recharge the ASR system and to withdraw the water in summer months. The City of Hillsboro may divert up to 3,825 gallons per minute and may store up to 900 MG. The maximum injection rate is 1,275 gallons per minute per well in the maximum recovery rate is 1,725 gallons per minute per well.

The City has numerous non-municipal water rights for use of water from such sources as the Tualatin River, McKay Creek and tributaries, Glencoe Swale, Beaverton Creek, Bronson Creek, Rock Creek and tributaries, Dairy Creek, a tributary to Jackson Slough, Sain Creek, a pond, wastewater effluent, and wells. The uses under these water rights include irrigation, supplemental irrigation, multi-purpose storage, wetlands creation enhancement, wildlife, hydroelectric production, nursery operations, fish culture, aesthetics, storage of wastewater, and instream use. These water rights are not used to meet the City's potable water supply needs; they are not withdrawn for treatment and are not put into the transmission or distribution systems.

Forest Grove

The City of Forest Grove supplements its JWC-supplied water with water from the City-owned Clear Creek Watershed. Forest Grove has intake facilities within the Clear Creek Watershed on Clear Creek, Roaring Creek, Thomas Creek, Deep Creek and Smith Creek. Forest Grove's water rights within this basin total 7.26 cfs (4.69 mgd). Water receives conventional, media-filtration treatment at the Forest Grove WTP located at Watercrest Road on Buxton Hill. During the summer, the supply is limited by the low flows in the creeks and can drop to as low as approximately 1.5 mgd, as measured by the raw water flow meter at the WTP.

Beaverton

The City of Beaverton owns and operates two native groundwater wells and two active ASR wells (ASR No. 2 and ASR No. 4), which store and recover water under the City of Beaverton and TVWD's jointly held ASR LL-02. Beaverton uses JWC supply in the winter months to recharge the ASR system, and this water is withdrawn in the summer months along with native groundwater to help meet peak demand.

ASR No. 2 is located at the Sorrento Water Works site and ASR No. 4 is located at SW Hanson Road and 135th across the street from the Sorrento Water Works site. The two ASR wells have a maximum combined capacity of approximately 5.0 mgd. They are generally operated daily during the summer season at a rate of approximately 700 gallons per minute (gpm) each, with a total daily supply contribution of approximately 2.0 mgd. The optimal operating point for the well pumps is 700 gpm (1.0 mgd) and the total 2.0 mgd output from this flow rate generally meets peak summer demands in excess of supply from JWC.

ASR No. 1 (referred to historically as "Well #2" or the "Hanson Road well") is located at the Sorrento Water Works site and recently was taken out of service and converted to a monitoring well. ASR No. 3 is located north of the intersection of SW Loon Drive and Scholls Ferry Road in the South Cooper Mountain (SCM) area and was taken out of service because of low yields and relatively high iron and manganese concentrations in the water.

Beaverton is scheduled to develop three new ASR wells (ASR No. 3A, ASR No. 5, and ASR No. 7) within the next five years. ASR No. 3 is located in South Cooper Mountain area and will be used primarily for irrigation demands to offset potable water demands. ASR No. 5 is located at the Sorrento Water Works site near ASR No. 1. Completion of this well along with new buildings and other improvements at the Sorrento site are currently in the design phase. ASR No. 7 is located at the Cooper Mountain Reservoir site west of the Beaverton's existing service area. ASR No. 6 is located in a residential area at 9460/9450 SW 166th Avenue, and is planned to be developed in the future by 2030. All of the ASR wells described above currently operate or would operate under the ASR limited license held by Beaverton and TVWD (LL-002).

Beaverton also owns a groundwater well (Well No. 1) located northeast of the Beaverton service area boundary within the limits of the West Slope Water District (WSWD). Well No. 1 was one of the original wells in the City's groundwater right, but it is currently inactive.

Finally, Beaverton is authorized to use up to 33.7cfs (21.8 mgd) of water from the Willamette River for municipal purposes under Permit S-54940.

TVWD

TVWD currently obtains water from one active ASR well (Grabhorn) under the City of Beaverton and TVWD's jointly held limited license, ASR LL-02, which is described in greater detail above. TVWD also purchases wholesale water from the City of Portland, as administered by the Portland Water Bureau (PWB).

The PWB source of supply comes from the Bull Run Watershed and the Columbia South Shore Well Field (CSSWF). TVWD receives water from the PWB by gravity primarily via the Washington County Supply Line (WCSL). TVWD owns approximately 42.3 million gallons per day (mgd) of capacity in the WCSL. The WCSL splits near the intersection of Beaverton-Hillsdale Highway and Scholls Ferry Road to serve two portions of its service area (metered at the main Portland-TVWD intertie and at the Florence Lane and 80th interconnection). In addition, two small portions of TVWD's service area are supplied water through interconnections from the PWB (Garden Home and Thompson meters) to provide water to a pressure zones that sits at a higher elevations than the surrounding areas and cannot be served by the existing hydraulic grade lines of the distribution system.

TVWD is also the managing agency and member of the Willamette River Water Coalition, which holds a water use permit for the use of water from the Willamette River for municipal and industrial purposes. TVWD intends to replace its PWB water supply with its Willamette River water supply in 2026, when construction of the Willamette Water Supply System in complete. TVWD is prepared to use its groundwater rights for emergency back-up water supply, as well.

2.5. System Description

OAR 690-086-0140(8)

2.5.1. JWC Facilities

As described in the Water Sources section above, the JWC has contracted water in Scoggins Reservoir, uses the SHPP, and owns the JWC WTP and two finished water reservoirs. These facilities are shown on Exhibit 2-2.

In addition, the JWC owns a transmission system that includes transmission lines, meters, and pressure reducing valves. Finished water is distributed to member agencies through the transmission lines shown on Exhibit 2-2, and described below:

- 36 and 42-inch lines from SHPP Intake to the JWC WTP (raw water)
- 24-inch line from the JWC WTP to Forest Grove and Hillsboro's Upper System
- 42- and 72-inch lines from the JWC WTP to Fern Hill Reservoirs
- 45-inch line from the Fern Hill Reservoirs to Hillsboro (South Transmission Line)
- 42-inch line from Hillsboro to Beaverton (South Transmission Line)
- 72-inch line from the JWC WTP to Hillsboro (North Transmission Line)
- 66-inch line from Hillsboro to TVWD (North Transmission Line)
- 42-inch line located near Hillsboro's western border (North-South Intertie)[1]

Exhibit 2-10 presents an inventory of JWC-owned transmission lines by diameter. The transmission system is primarily constructed with concrete cylinder pipe (95.9 percent), of diameters 42-inches and greater. The remainder of the system is ductile iron (3.8 percent) and cast iron (0.3 percent). Exhibit 2-11 summarizes the relative age of the transmission lines by pipe size. The JWC was established in 1976. The age of the system varies from approximately 30 years (46 percent) to less than 10 years (1.25 percent). Exhibit 2-12 is an inventory of JWC master meters and pressure reducing valves.

[1] The North-South Intertie is part of the North Transmission Line

Exhibit 2-10. JWC Transmission Line Inventory By Pipe Diameter

Diameter	Length (ft)	Length (mi)	Percentage
24-inch	10,843	2.10	7%
30-inch	103	0.02	0%
36-inch	2,510	0.48	2%
42-inch	34,488	6.50	22%
45-inch	37,543	7.10	24%
54-inch	1,103	0.20	1%
66-inch	25,239	4.80	16%
72-inch	47,709	9.00	30%
Total	**159,538**	**30.19**	**100%**

Exhibit 2-11. JWC Transmission System By Decade of Installation

Date Installed	Percentage of System
2010-2019	1.25%
2000-2009	22.24%
1990-1999	30.10%
1980-1989	0.00%
1970-1979	46.40%
Total	**100.00%**

Exhibit 2-12. JWC Master Meter and Pressure Reducing Valve Inventory

Meter Vault Locations	Customer	PRV Size (inch)	Meter Size (inch)	Meter Type
45"/42" South Transmission Line				
S 1st Ave & Maple	Hillsboro	8"	8"	Magnetic
TV Hwy & Minter Bridge	Hillsboro	8"	4” 8”	Magnetic
TV Hwy & Imlay (south vault)	Hillsboro	10"	10"	Magnetic
TV Hwy & Imlay (north vault)	Hillsboro	10"	10"	Magnetic
TV Hwy & 75th Ave	TVWD	4"	12"	Magnetic
TV Hwy & Cornelius Pass	Beaverton	N/A	36"	Magnetic
Jackson Bottom	Hillsboro	N/A	1.5”	AMR
Clean Water Services	Hillsboro	N/A	2”	AMR
TV Hwy & Cornelius Pass	WWSS			
72"/66" North Transmission Line				
10th & Heather	Cornelius	8"	8"	Magnetic
12th & Baseline	Cornelius	6"	6"	Magnetic
17th & Baseline	Cornelius	6"	6"	Magnetic
Valley View on TV Hwy	Hillsboro	3"	3"	Magnetic
	Cornelius	6"	6"	Magnetic
TV Hwy west of Dairy Creek	Cornelius Hillsboro	6"	3"	Magnetic
Connell & Jackson	Hillsboro	3"	3"	Magnetic
Crandall Reservoir	Hillsboro	10"	18"	Magnetic
Glencoe & Evergreen	Hillsboro	6"	12"	Magnetic
Glencoe & Evergreen	North Plains	N/A	10"	Magnetic
25th & Evergreen	Hillsboro		18”	Magnetic
Evergreen Reservoir	Hillsboro		12”	
Shute & Evergreen (aka Dawson Creek)	Hillsboro	6"	18"	Magnetic
229th & Bennet	Hillsboro	10"	24"	Magnetic
Cornelius Pass & Hwy 26	TVWD	N/A	10”	Magnetic
Cornelius Pass & Hwy 26	TVWD	N/A	20”	Magnetic
24" Dilley/Forest Grove Line				
Elm St. & Hwy 47 Bypass (aka Dilley)	Hillsboro	8"	8"	Magnetic
	Forest Grove	24"	24"	Sonic

2.5.2. Non-JWC Distribution System Facilities

In addition to the facilities described in the Non-JWC Water Sources section above, JWC member agencies have non-JWC finished water storage facilities and distribution systems. Exhibit 2-13 summarizes non-JWC finished water storage facilities.

Exhibit 2-13. Non-JWC Finished Water Storage Facilities

Agency	Number of Reservoirs	Total Reservoir Storage Capacity (MG)	Aquifer Storage Capacity (MG)
Hillsboro	4	31.9	0
Forest Grove	2	6	0
Beaverton	4	27.25	750
TVWD	23	67.35	750
Total	**31**	**132.5**	**1,500**

Exhibits 2-14 summarizes member agency distribution system inventories by length. The total length of the distribution systems in JWC's partner agencies is approximately 1,322 miles. TVWD accounts for approximately 48 percent of this length with 631 miles of pipeline. Forest Grove has the smallest distribution system of the JWC member agencies with 91 miles of pipeline.

Exhibit 2-14. Non-JWC Distribution System Inventory: Length By Diameter

JWC Member Agency	<=6 (in)	8 to 14 (in)	16 to 42 (in)	>42 (in)	Unknown	Total (ft)	Total (mi)
Hillsboro	464,218	963,547	242,035	7,920	106	1,677,826	305.5
Beaverton	483,648	882,288	119,328	0	0	1,485,264	281
Forest Grove	210,619	260,093	2,482	9,715	0	482,909	91
TVWD	1,409,760	2,048,640	443,520	63,360	0	3,970,560	752
					Total	**7,616,559**	**1,124**

2.6. Records of Water Use

OAR 690-086-0140(4) and (9)

2.6.1. Terminology

Demand (i.e., production) refers to the quantity of water delivered to a distribution system from a water treatment plant, wholesale supplier, native ground water well, or an ASR well. Water supplied to an ASR system is not included in demand given that counting water from an ASR system as demand and water delivered to an ASR system as demand results in counting the same water twice. Demand includes metered consumption (for example, residential, commercial, industrial, public, and irrigation customers[2]), un-metered public uses (firefighting, hydrant flushing, other), and water lost to leakage, reservoir overflow, and evaporation. Consumption is equal to the metered water use. Demand minus consumption equals water loss. Water loss is equal to the sum of un-metered uses (hydrant flushing, for example), leakage, overflows, evaporation, and inaccuracies of measurement at the production or customer meters. JWC defines its peak season as the six-month period from May through October. To evaluate seasonal use, summer season is defined as the four consecutive months of highest monthly demand or consumption. In general, this corresponds to the months of June through September for demand data, and July through October for billed consumption data. The offset in summer season for the two data sets results from differences in the timing of demand meter and customer meter reading.

Generally, demand and consumption in municipal systems are expressed in units of million gallons per day (mgd). They may also be expressed in cubic feet per second (cfs) or gallons per minute (gpm). One mgd is equivalent to 1.55 cfs or 694 gpm. For annual or monthly values, it is typical to refer to the total quantity of water in million gallons (MG). Water use per person (per capita use) is expressed in gallons per capita per day (gpcd). The following terms are used to describe specific values of demands:

- **Average day demand (ADD)** equals the total annual demand divided by 365 days.
- **Maximum day demand (MDD)** equals the highest demand that occurs on any single day during a calendar year. It is also called the one-day MDD or peak day demand. MDD for the JWC system is calculated using the system demand on the JWC water treatment plant and Fernhill Reservoirs. MDD for each water provider is estimated based on metered customer use, demand from all sources, and relevant peaking factors.
- **Monthly demand** refers to demand during a calendar month. This demand can be expressed as the total volume of water produced in a month, or as a daily demand value by dividing the total monthly volume by the number of days in the month.

[2] Each JWC member agency defines its own customer categories.

- **Maximum monthly demand (MMD)** equals the highest monthly demand during a calendar year.
- **Peaking factors** are the ratios of one demand value to another. The most common and important peaking factors are the ratio of the MDD to the ADD.

2.7. Historical Water Demands

The information presented in the following sections builds upon historical water demand information reported in the JWC's previous 2010 WMCP in order to provide better context and understanding of long-term trends. Data are provided through 2019 for the JWC and JWC Member Agencies except for the City of Beaverton, which has monthly data provided only through December 2018 and the following through Fiscal Year 2018/2019: ADD, MDD, and annual demand; this is the result of the City following a fiscal year data verification schedule.

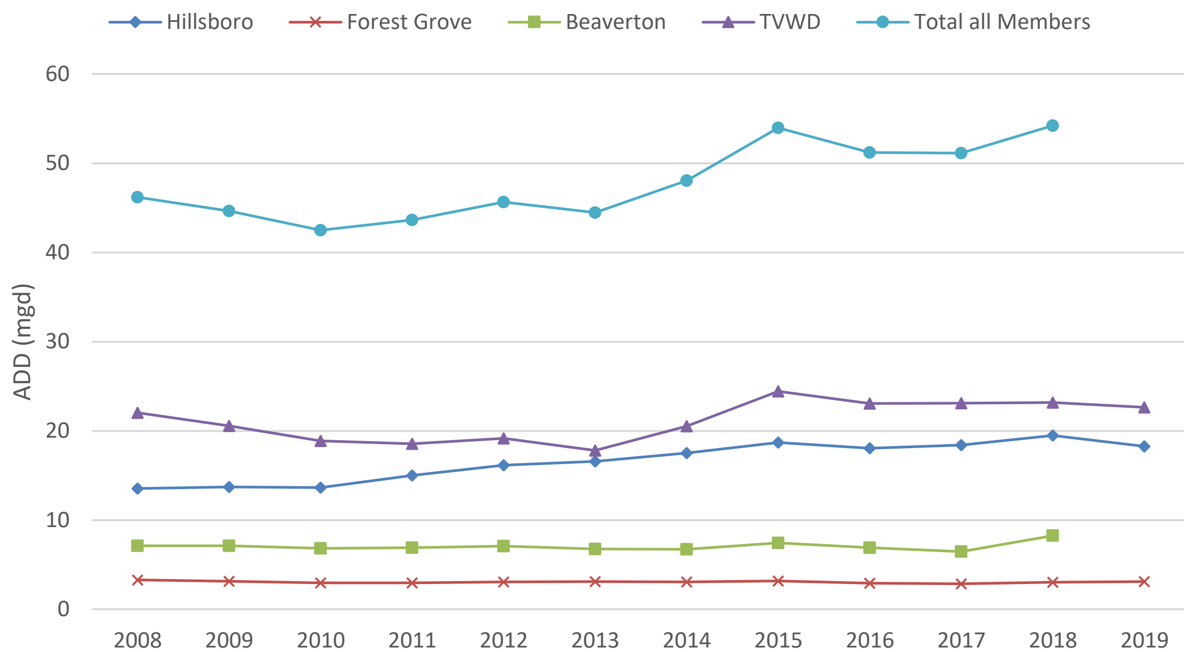
2.7.1. JWC Annual Demand

Exhibit 2-15 depicts ADD from all sources of water for all JWC Member Agencies and wholesale customers[3] from 2008 through 2019. ADD ranged from 42 mgd to 54 mgd and averaged 47 mgd from 2008 through 2018 for all JWC Member Agencies and wholesale customers. The water supplier with the greatest average ADD was TVWD (21 mgd), followed by the City of Hillsboro (17 mgd).

Exhibit 2-16 depicts ADD for JWC supplied water from 2008 through 2019. The JWC was able to provide 2019 data for the City of Beaverton. ADD for JWC supplied water ranged from 26 mgd to 36 mgd, with an average of 31 mgd for the 12 year period. Exhibit 2-17 depicts the 2017 ADD of JWC supplied water amongst JWC Member Agencies and wholesale customers.

[3] For simplicity, JWC wholesale customer demands are not shown individually, but are included in the total demand curve shown on Exhibits 2-, 16, 2-18, and 2-19. MDD values were not determined for these customers.

Exhibit 2-15. Average Day Demand From all Sources for JWC Members, 2008-2019[4]



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4 The City of Beaverton's fiscal year data are aligned with the calendar year in which the fiscal year began. FY 2019/2020 data for the City of Beaverton were not available.

Exhibit 2-16. Average Day Demand from JWC WTP for JWC Members, 2008-2019

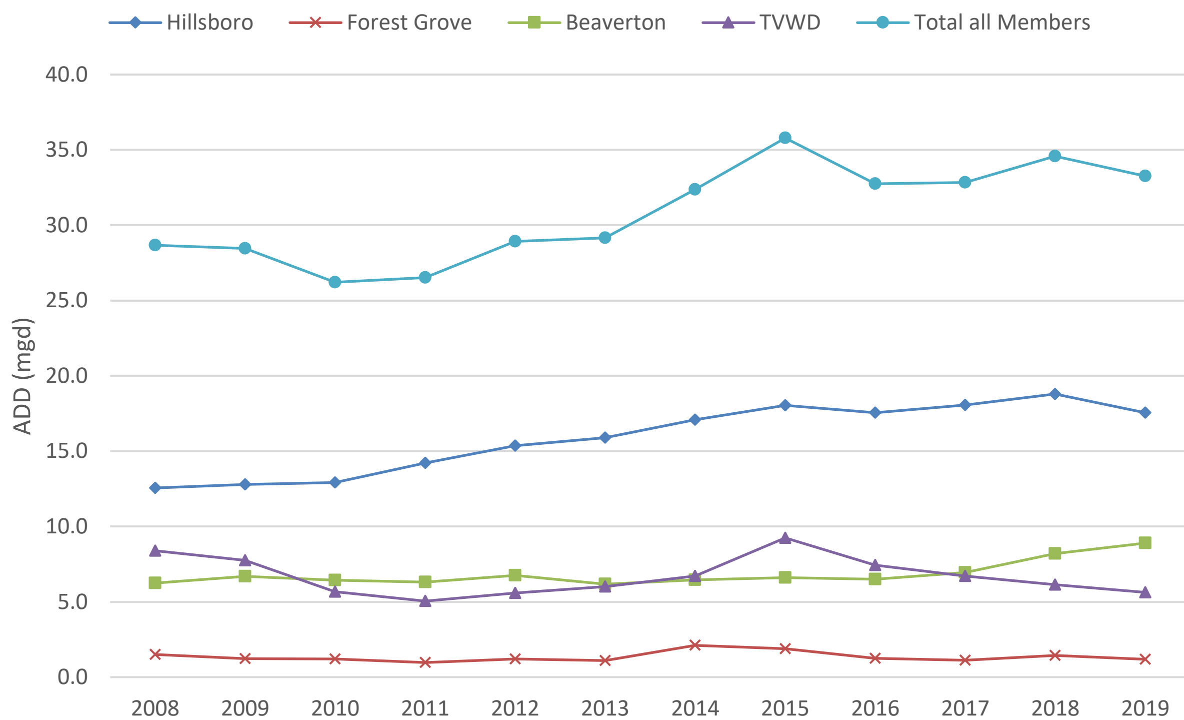


Exhibit 2-17. JWC Member Agency and Wholesale Customer Portions of JWC ADD (mgd) of JWC-supplied Water, 2019

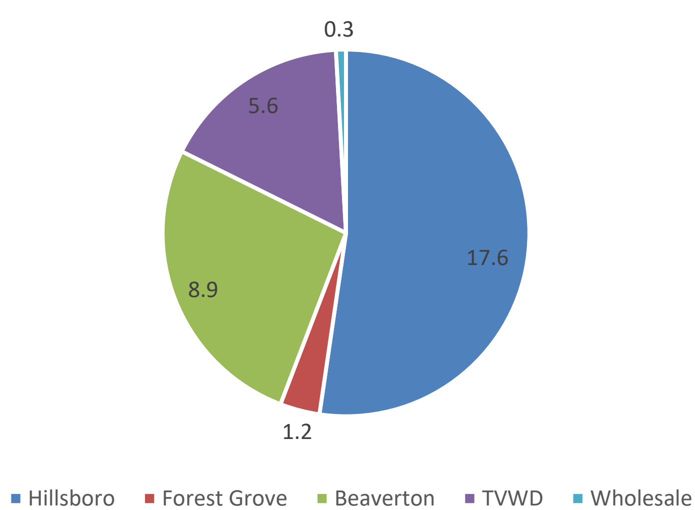
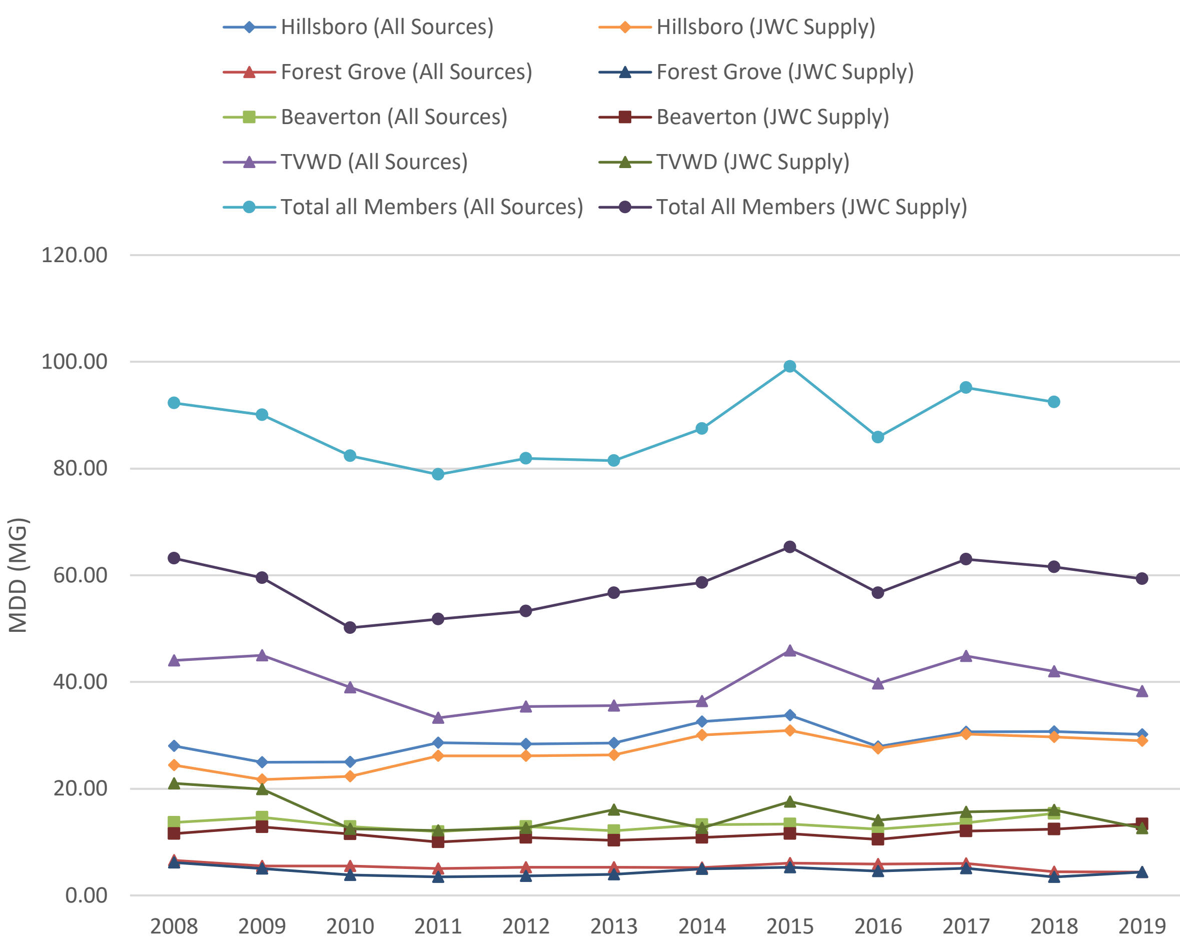


Exhibit 2-18 shows MDD values for all member agencies from 2008 through 2019. These values were calculated by each member agency.[5] TVWD had the greatest MDD values from 2008 through 2019, and MDD values remained relatively stable over time with the exception of TVWD, which had a drop in MDD from 2009 through 2011. MDD values tend to be more variable than ADD values. MDDs are generally more sensitive to fluctuations in weather patterns year to year, such as hot and dry weather that lead to increased outdoor water uses, such as irrigation.

Exhibit 2-18. Maximum Daily Demand from All Sources for JWC Members, 2008-2019[6]



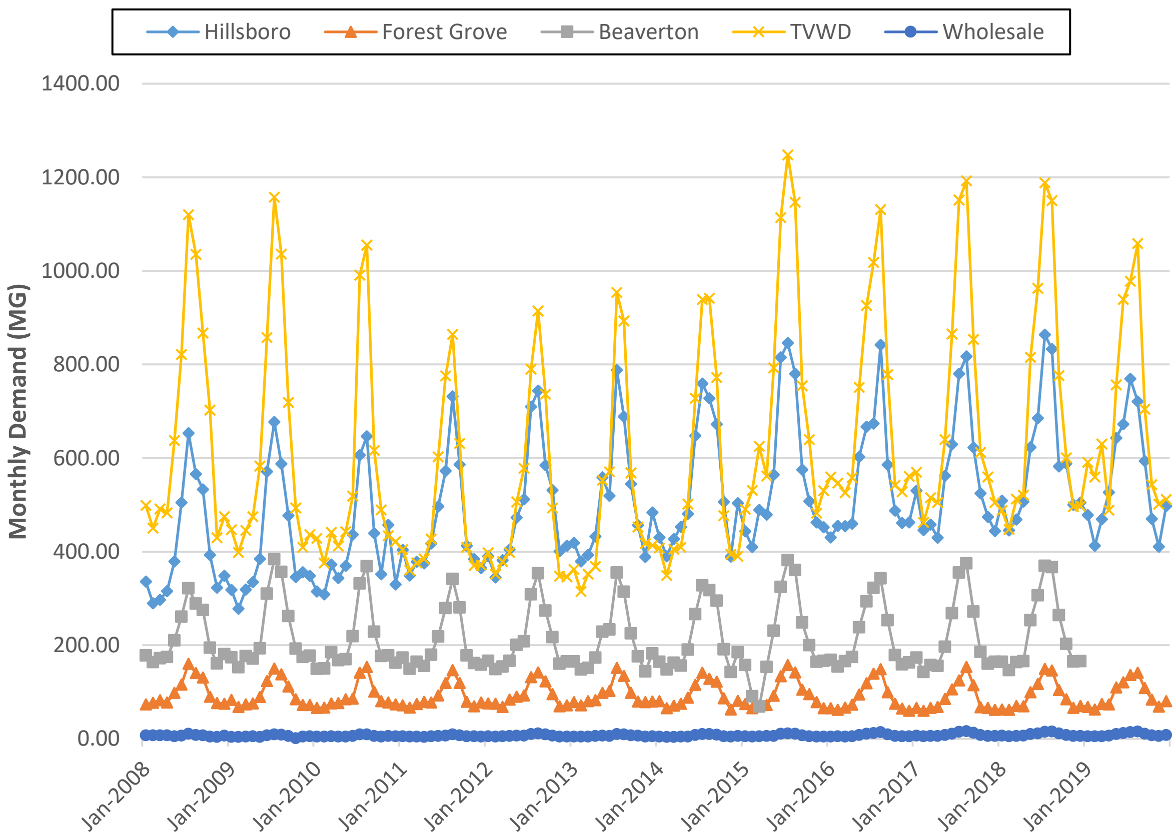
[5] Because individual systems experience maximum demand events at different times during the peak season, the sum of member agency MDDs in Exhibit 2-18 provides only an estimate of system-wide values. Wholesale customer MDDs were not determined.

[6] The City of Beaverton's fiscal year data are aligned with the calendar year in which the fiscal year began. FY 2018/2019 and FY 2019/2020 data for the City of Beaverton were not available.

2.7.2. JWC Monthly Demand

Exhibit 2-19 depicts monthly demand for all member agencies and wholesale customers from all sources from 2008 through 2019 and Exhibit 2-20 depicts monthly demand of JWC supplied water. Demands peak in summer when weather is hotter and drier, which results in increased outdoor water use. TVWD consistently had the highest peak month demand of all the member agencies throughout the eleven year period. However, because TVWD obtains a large amount of its peak season supply from non-JWC sources, TVWD's JWC supplied peak monthly demand is consistently lower than Hillsboro's JWC supplied peak monthly demand throughout the eleven year period. Forest Grove consistently had the lowest monthly demand of all the member agencies. It relies heavily on the JWC to meet its peak month supply needs.

Exhibit 2-19. Monthly Demand from all Sources for JWC Members and Wholesale Customers, 2008-2019[7]



[7] FY 2018/2019 and FY 2019/2020 data for the City of Beaverton were not available.

Exhibit 2-20. JWC-Supplied Monthly Demand for JWC Members and Wholesale Customers, 2008-2019

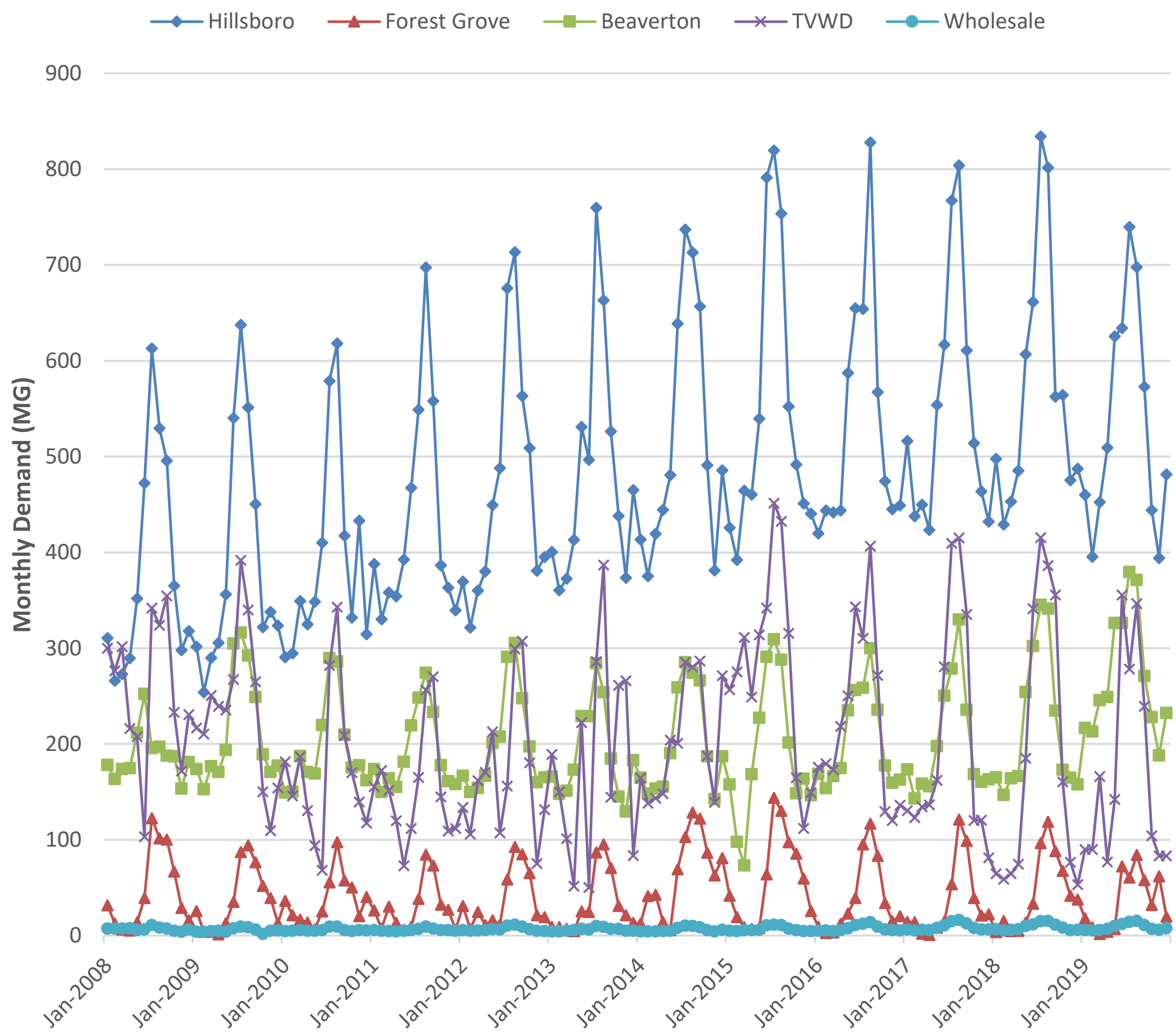
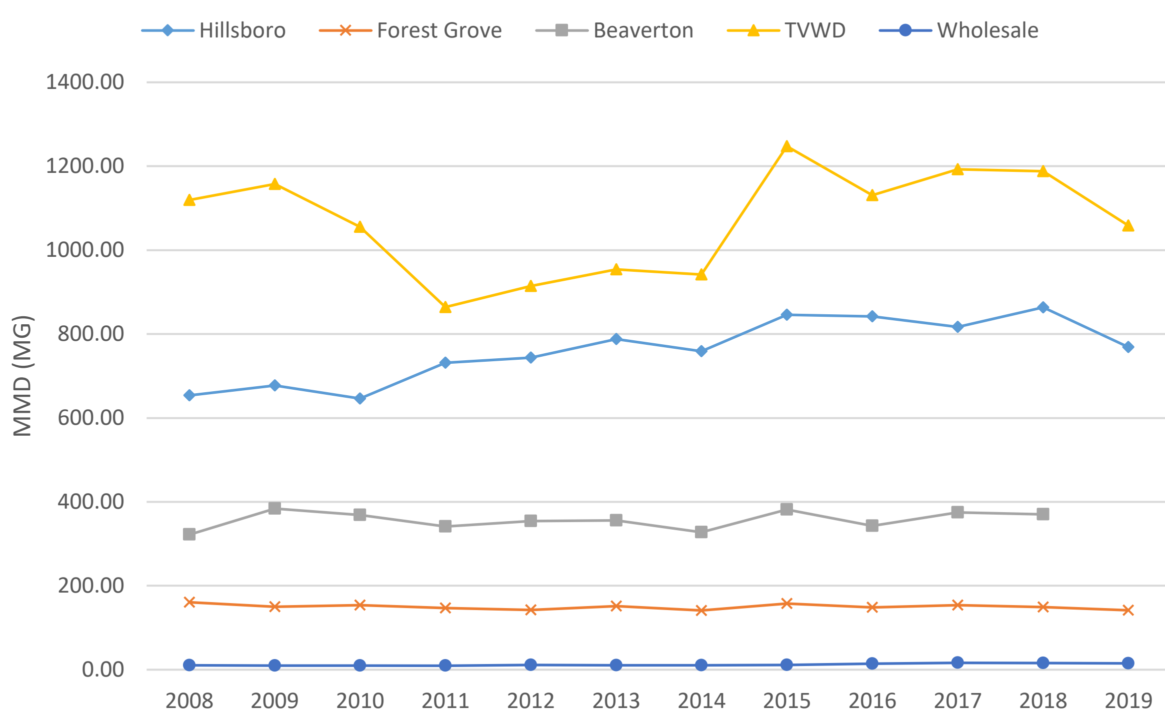


Exhibit 2-21 depicts the maximum monthly demand from all water sources for the JWC member agencies from 2008-2019. TVWD consistently had the highest maximum monthly demand, followed by Hillsboro, Beaverton, and Forest Grove, respectively. Like with MDD, MMD reflects weather patterns. Hot dry months in which people use water outdoors at a greater rate, are a large contributing factor to increased MMD.

Exhibit 2-21. Maximum Monthly Demand from All Sources for JWC Members, 2008-2019[8]



Exhibits 2-22 through 2-25 provide a tabular summary of water demands from all sources and JWC-supplied water demands for the JWC member agencies and JWC wholesale customers from 2008 through 2019. Data include: ADD, MDD, MMD, and MDD to ADD peaking factors for each member agency and wholesale customer. Exhibit 2-26 provides a summary of annual volume and ADD for JWC-supplied water for wholesale customers from 2008 through 2019.

[8] 2019 data for the City of Beaverton was not available.

Exhibit 2-22. Summary of ADD, MDD, MMD, and MDD/ADD peaking factor for total and JWC-supplied water for Hillsboro, 2008-2019

	All Sources					JWC-supplied		Percentage of annual supply from JWC
JWC Agency/Year	Annual Volume (MG)	Overall ADD (mgd)	Overall MDD (mgd)	MDD/ADD Peaking Factor	MMD (MG)	Annual Volume (MG)	ADD (mgd)	
Hillsboro								
2008	4,939.5	13.53	28.02	2.1	653.6	4,583.0	12.56	93%
2009	4,998.7	13.69	24.95	1.8	677.3	4,670.9	12.80	93%
2010	4,977.5	13.64	24.99	1.8	646.3	4,712.8	12.91	95%
2011	5,474.7	15.00	28.64	1.9	731.9	5,184.5	14.20	95%
2012	5,892.0	16.14	28.37	1.8	744.1	5,607.2	15.36	95%
2013	6,051.6	16.58	28.54	1.7	788.0	5,800.9	15.89	96%
2014	6,389.0	17.50	32.57	1.9	759.3	6,237.1	17.09	98%
2015	6,825.0	18.70	33.75	1.8	846.2	6,583.0	18.04	96%
2016	6,583.1	18.04	27.88	1.5	842.0	6,409.8	17.56	97%
2017	6,720.7	18.41	30.68	1.7	817.1	6,590.2	18.06	98%
2018	7,109.9	19.48	30.70	1.6	863.6	6,859.4	18.79	96%
2019	6,665.3	18.26	30.15	1.7	769.2	6,407.3	17.55	96%
Average 2008-2019	6,052.2	16.58	29.10	1.8	761.5	5,803.8	15.90	96%

Exhibit 2-23. Summary of ADD, MDD, MMD, and MDD/ADD peaking factor for total and JWC-supplied water for Forest Grove, 2008-2019

	All Sources					JWC-supplied		Percentage of annual supply from JWC
JWC Agency/Year	Annual Volume (MG)	Overall ADD (mgd)	Overall MDD (mgd)	MDD/ADD Peaking Factor	MMD (MG)	Annual Volume (MG)	ADD (mgd)	
Forest Grove								
2008	1,200.5	3.29	6.57	2.0	160.7	546.3	1.50	46%
2009	1,144.1	3.13	5.54	1.8	150.2	446.1	1.22	39%
2010	1,083.6	2.97	5.50	1.9	153.7	441.6	1.21	41%
2011	1,075.6	2.95	5.01	1.7	146.6	353.9	0.97	33%
2012	1,120.3	3.07	5.26	1.7	142.2	443.5	1.22	40%
2013	1,137.7	3.12	5.25	1.7	151.9	398.4	1.09	35%
2014	1,119.0	3.07	5.22	1.7	141.2	770.2	2.11	69%
2015	1,153.1	3.16	6.08	1.9	157.6	691.7	1.90	60%
2016	1,068.6	2.93	5.86	2.0	148.7	455.5	1.25	43%
2017	1,042.3	2.86	6.00	2.1	154.0	410.6	1.12	39%
2018	1,103.4	3.02	4.42	1.5	149.3	526.5	1.44	48%
2019	1,130.1	3.10	4.37	1.4	141.3	429.0	1.18	38%
Average 2008-2019	1,114.8	3.05	5.42	1.8	149.8	492.8	1.35	44%

Exhibit 2-24. Summary of ADD, MDD, MMD, and MDD/ADD peaking factor for total and JWC-supplied water for Beaverton, Fiscal Year 2008/2009-2018/2019[9]

	All Sources					JWC-supplied		Percentage of annual supply from JWC
JWC Agency/Year	Annual Volume (MG)	Overall ADD (mgd)	Overall MDD (mgd)	MDD/ADD Peaking Factor	MMD (MG)	Annual Volume (MG)	ADD (mgd)	
08/09	2,602.4	7.13	13.67	1.9	321.9	2,275.7	6.23	87%
09/10	2,590.7	7.10	14.62	2.1	384.0	2,441.6	6.69	94%
10/11	2,489.9	6.82	12.89	1.9	369.1	2,345.1	6.42	94%
11/12	2,525.0	6.92	11.96	1.7	341.5	2,300.4	6.30	91%
12/13	2,586.0	7.09	12.87	1.8	354.2	2,464.3	6.75	95%
13/14	2,471.0	6.77	12.14	1.8	355.4	2,252.4	6.17	91%
14/15	2,456.0	6.73	13.24	2.0	327.7	2,358.7	6.46	96%
15/16	2,719.0	7.45	13.38	1.8	412.8	2,412.6	6.61	89%
16/17	2,516.0	6.89	12.43	1.8	342.8	2,373.4	6.50	94%
17/18	2,715.0	6.46	13.61	2.1	374.8	2,535.7	6.95	93%
18/19	3,011.0	8.25	15.36	1.9	-	2,994.5	8.20	99%
Average 2008-2019	2,607.5	7.06	13.29	1.9	358.4	2,376.0	6.66	93%

[9] Monthly data were unavailable for the entire fiscal year 2018/2019.

Exhibit 2-25. Summary of ADD, MDD, MMD, and MDD/ADD peaking factor for total and JWC-supplied water for TVWD, 2008-2019

	All Sources					JWC-supplied		Percentage of annual supply from JWC
JWC Agency/Year	**Annual Volume (MG)**	**Overall ADD (mgd)**	**Overall MDD (mgd)**	**MDD/ADD Peaking Factor**	**MMD (MG)**	**Annual Volume (MG)**	**ADD (mgd)**	
2008	8,037.2	22.02	43.98	2.0	1,119.8	3,060.8	8.39	38%
2009	7,499.0	20.55	42.52	2.1	1,087.4	2,830.9	7.76	38%
2010	6,884.5	18.86	37.09	2.0	1,013.8	2,068.0	5.67	30%
2011	6,776.1	18.56	32.74	1.8	911.3	1,842.3	5.05	27%
2012	6,986.6	19.14	35.39	1.8	950.0	2,042.3	5.60	29%
2013	6,497.9	17.80	35.57	2.0	908.5	2,193.9	6.01	34%
2014	7,491.9	20.53	36.44	1.8	964.4	2,449.7	6.71	33%
2015	8,916.2	24.43	45.90	1.9	1,247.5	3,373.9	9.24	38%
2016	8,424.4	23.08	39.70	1.7	1,131.2	2,715.1	7.44	32%
2017	8,431.8	23.10	44.90	1.9	1,192.5	2,450.0	6.71	29%
2018	8,456.4	23.17	42.00	1.8	1,188.4	2,237.3	6.13	26%
2019	8,262.3	22.64	38.30	1.7	1,058.5	2,056.0	5.63	25%
Average 2008-2019	7,722.0	21.16	39.54	1.9	1,064.4	2,443.4	6.69	32%

Exhibit 2-26. Summary of Annual Volume and ADD for JWC-supplied water for wholesale customers, 2008-2019

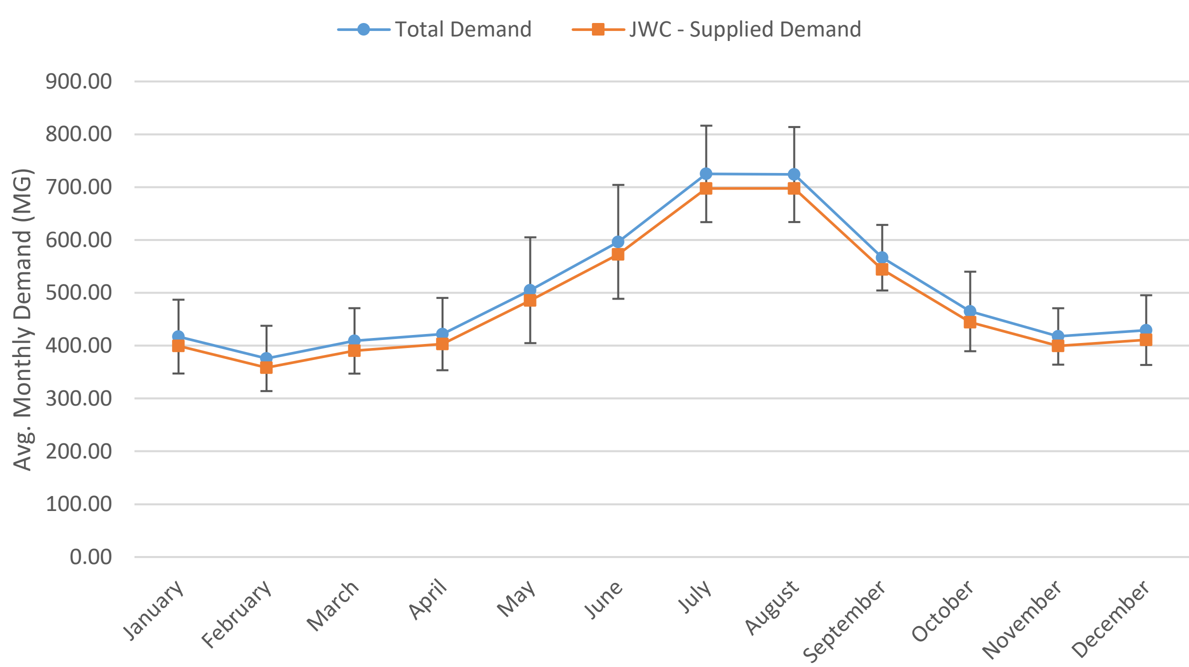
Year	Annual Volume (MG)	ADD (mgd)
2008	83.58	0.23
2009	66.14	0.18
2010	71.72	0.20
2011	70.69	0.19
2012	82.21	0.23
2013	76.69	0.21
2014	76.12	0.21
2015	83.20	0.23
2016	92.53	0.25
2017	106.92	0.29
2018	108.61	0.30
2019	107.52	0.29
Average 2008-2019	**85.49**	**0.23**

2.7.3. Hillsboro

Hillsboro's ADD from all sources ranged from 13.5 mgd to 19.48 mgd over the eleven year period, an increase of 69%. ADD increased between 0.4 mgd and 1.4 mgd each year, except for in 2009 and 2015 when ADD decreased by 0.06 mgd and 0.7 mgd respectively, and 2018 to 2019 when ADD decreased by 1.2 mgd. Hillsboro's MDD ranged from 24.95 mgd to 33.75 mgd, and the greatest MDD occurred in 2015. The MDD to ADD peaking factor averaged 1.8 for the eleven year period. The JWC supplied an average of 96% of Hillsboro's water demand from 2008 to 2019, with the remaining demand met by water from the Cherry Grove WTP.

Exhibit 2-27 depicts Hillsboro's average monthly demand from all sources and from JWC supplied sources for the eleven year period. Standard deviation is depicted for the total demand. On average, July and August were the months of highest demand, with the average maximum month demand occurring in August. The months June through September (one-third of the year) accounted for 43 percent of total average annual demand, with the remaining 57 percent of demand distributed over the remaining two thirds of the year.

Exhibit 2-27. City of Hillsboro Average Monthly Demand (Total and JWC-supplied), 2008-2019

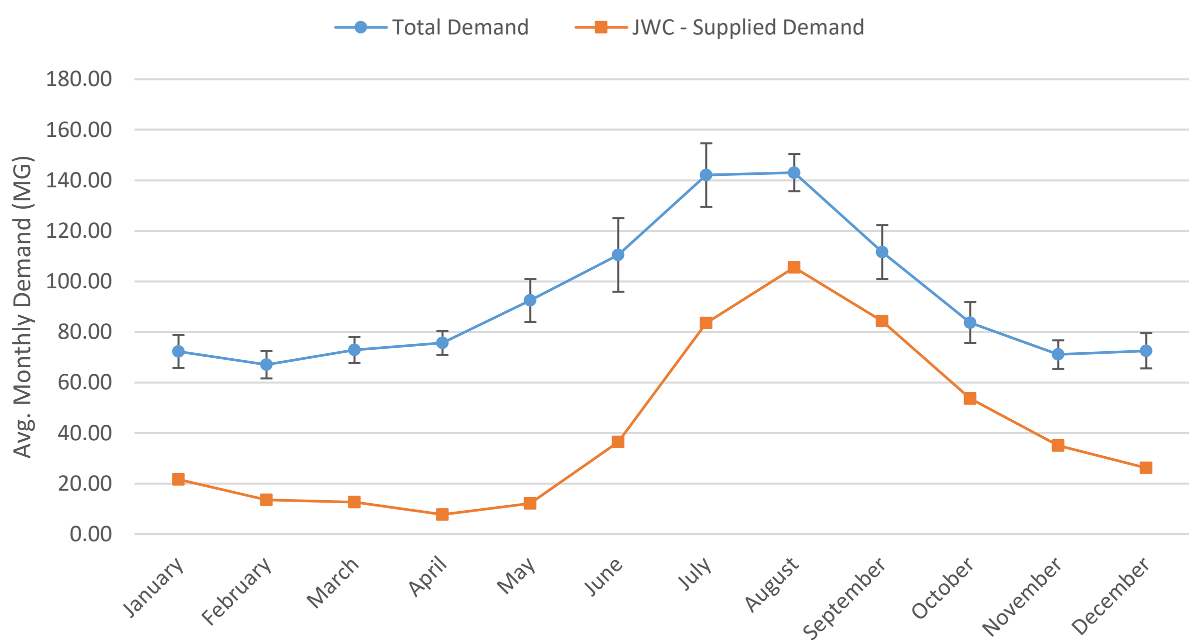


2.7.4. Forest Grove

From 2008 through 2019, Forest Grove's ADD ranged from 2.9 mgd to 3.3 mgd and averaged 3 mgd. The MDD ranged from 4.4 mgd to 6.6 mgd and averaged 5.4 mgd. The MDD to ADD peaking factor ranged from 1.4 to 2.1 during the eleven year period, and averaged 1.8. The JWC supplied an average of 44% of Forest Grove's water demand from 2008 to 2019, with the remaining demand met by water from the Forest Grove water treatment plant.

Exhibit 2-28 shows Forest Grove's average monthly demand from all sources and from the JWC. Standard deviation is shown for total demand. Throughout the eleven year period, the average maximum month demand occurred in August. The four month period of June through September accounted for an average of 63 percent of annual demand.

Exhibit 2-28. City of Forest Grove Average Monthly Demand (Total and JWC-supplied), 2008-2019

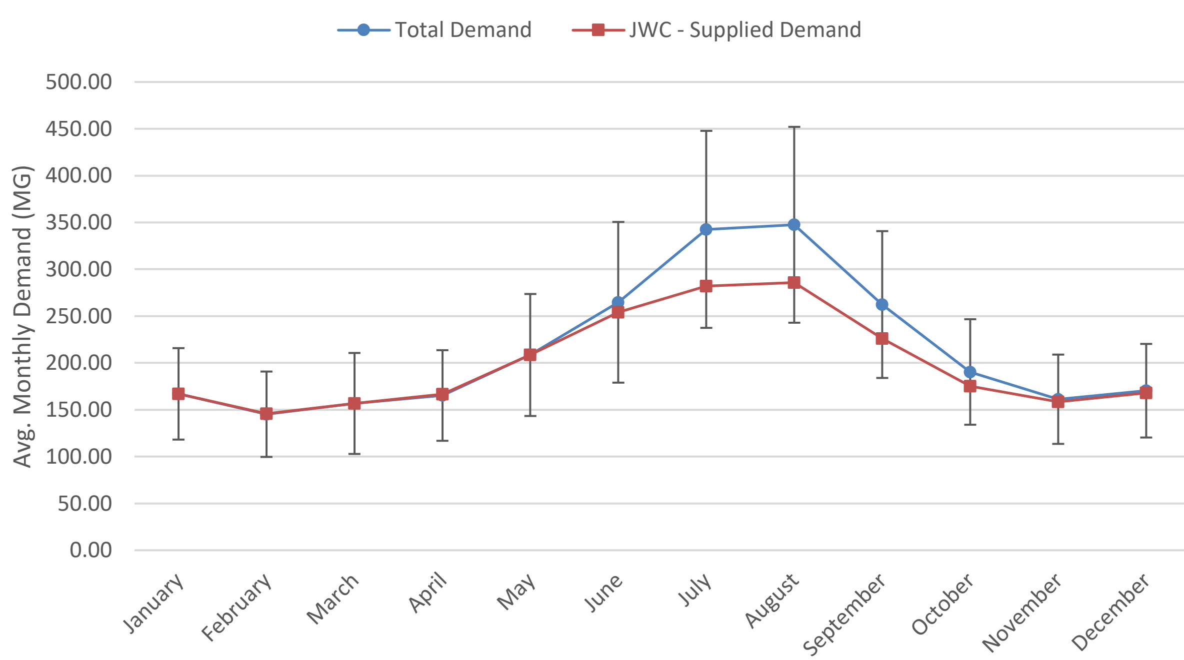


2.7.5. Beaverton

From Fiscal Year 2008/2009 through 2017/2018, Beaverton's ADD ranged from 6.5 mgd to 7.5 mgd and averaged 7.0 mgd. MDD ranged from 12.0 mgd to 15.4 mgd and averaged 13.3 mgd for the ten year period. The MDD to ADD peaking factor was fairly consistent from year to year, averaging 1.9. The JWC supplied an average of 93% of Beaverton's water demand from Fiscal Year 2008/2009 to 2017/2018, with the remaining demand met by ASR and native groundwater.

Exhibit 2-29 shows Beaverton's average monthly demand from all sources and from JWC supplied water. Standard deviation is shown for the total water demand. While the JWC is Beaverton's primary water supply source throughout the year, the difference between total and JWC supplied water, observed in July through September, reflects Beaverton's use of native groundwater wells. The four month period, June through September, accounted for 44 percent of the City's demand. The remaining supply was distributed throughout the remaining two-thirds of the year.

Exhibit 2-29. City of Beaverton Average Monthly Demand (Total and JWC-supplied), 2008-2018

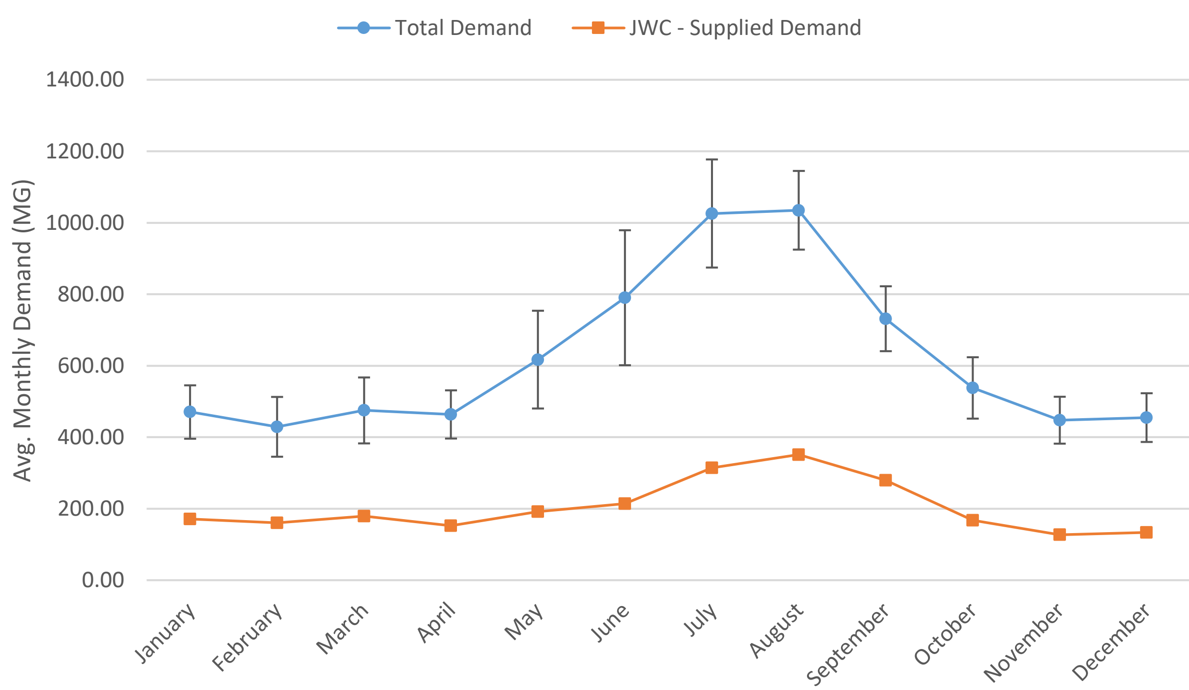


2.7.6. TVWD

From 2008 through 2019, TVWD's overall ADD ranged from 16.4 mgd to 24.5 mgd and averaged 20.4. The MDD ranged from 33.3 mgd to 45.9 mgd, and averaged 40 mgd. The MDD to ADD peaking factor for the period averaged 2.0. The JWC supplied an average of 33% of TVWD's water demand from 2008 to 2019, with the remaining demand met by PWB wholesale water and ASR.

Exhibit 2-30 shows the average monthly metered demand from all sources and from the JWC WTP for the 2008 through 2019. As shown, the JWC WTP supplied a base demand to TVWD throughout the year, with peak summer demands supplied by TVWD's other sources. August and September are typically the months of peak demand, with the average maximum month demand occurring in September. The four month period of June through September accounted for an average of 47% of annual demand.

Exhibit 2-30. TVWD Average Monthly Metered Demand (Total and JWC-supplied), 2008-2019



2.8. Annual Consumption and Water Loss

Consumption is equal to the metered or approved unmetered water use within the system. Some members estimate unmetered water used for firefighting, water main water quality flushing, main breaks, hydrant maintenance, and for construction. All customers served by JWC member agencies are metered.

For the purposes of this WMCP, water loss is equal to the difference between annual demand and annual metered consumption, and represents the sum of unmetered uses (e.g., hydrant flushing and distribution system flushing), system leakage, overflows, evaporation, and inaccuracies of measurement at demand (i.e., production) meters and customer meters. When this difference is divided by the demand value, water loss is expressed as a percentage of total demand. The OWRD administrative rules set a water loss goal of 10 percent or less.

Exhibits 2-31 through 2-34 present annual demand, metered consumption, and water loss values for 2008 through 2019 for Hillsboro, Forest Grove, Beaverton, and TVWD, respectively. A more detailed description of the methods that the JWC Member Agencies use to calculate water loss is provided in Section 3, along with descriptions of activities to minimize water loss and sources of any significant water loss.

Exhibit 2-31. Summary of Annual Demand, Metered Consumption, and Water Loss for Hillsboro, 2008-2019

Year	Total Demand (MG)	Metered Consumption (MG)	Water Loss (%)
2008	4,939.5	5,368.3	-8.7%
2009	4,998.7	5,495.1	-9.9%
2010	4,977.5	5,343.8	-7.4%
2011	5,474.7	5,191.2	5.2%
2012	5,892.0	5,566.5	5.5%
2013	6,051.6	5,598.8	7.5%
2014	6,389.0	6,017.2	5.8%
2015	6,825.0	6,398.6	6.2%
2016	6,583.1	6,236.1	5.3%
2017	6,720.7	6,338.2	5.7%
2018	7,109.9	6,719.8	5.5%
2019	6,665.3	6,619.6	0.7%

Exhibit 2-32. Summary of Annual Demand, Metered Consumption, and Water Loss for Forest Grove, 2008-2019

Year	Total Demand (MG)	Metered Consumption (MG)	Water Loss (%)
2008	1,200.5	964.6	19.7%
2009	1,144.1	950.1	17.0%
2010	1,083.6	872.8	19.5%
2011	1,075.6	871.2	19.0%
2012	1,120.3	912.4	18.6%
2013	1,137.7	913.4	19.7%
2014	1,119.0	967.9	13.5%
2015	1,153.1	992.3	13.9%
2016	1,068.6	965.1	9.7%
2017	1,042.3	948.6	9.0%
2018	1,103.4	972.4	11.9%
2019	1,130.1	960.1	15.0%

Exhibit 2-33. Summary of Annual Demand, Metered Consumption, and Water Loss for Beaverton, Fiscal Year 2008/2009-2018/2019

Fiscal Year	Total Demand (MG)	Metered Consumption (MG)	Water Loss (%)
08/09	2,602.4	2,515.0	3.4%
09/10	2,590.7	2,441.8	5.7%
10/11	2,489.9	2,270.8	8.8%
11/12	2,525.0	2,254.5	10.7%
12/13	2,586.0	2,314.9	10.5%
13/14	2,471.0	2,261.3	8.5%
14/15	2,456.0	2,360.8	3.9%
15/16	2,719.0	2,526.1	7.1%
16/17	2,516.0	2,307.9	8.3%
17/18	2,715.0	2,656.8	2.1%
18/19	3,011.0	2,808.5	6.7%

Exhibit 2-34. Summary of Annual Demand, Metered Consumption, and Water Loss for TVWD, 2008-2019

Calendar Year	Total Demand (MG)	Metered Consumption (MG)	Wheeled Water (MG)	Other (MG)	Total Water Consumption	Water Loss (%)
2008	8,037.2	7,626.0	26.22	22.9	7,675.1	4.5%
2009	7,499.0	7,601.2	24.93	19.5	7,645.6	-2.0%
2010	6,884.5	7,022.1	23.69	9.8	7,055.6	-2.5%
2011	6,776.1	7,030.7	19.53	11.4	7,061.6	-4.2%
2012	6,986.6	7,322.5	24.04	20.7	7,367.2	-5.4%
2013	6,497.9	7,437.5	22.70	21.5	7,481.7	-15.1%
Fiscal Year	**Total Demand (MG)**	**Metered Consumption (MG)**	**Wheeled Water (MG)**	**Other (MG)**	**Total Water Consumption**	**Water Loss (%)**
13/14	7,185.1	7,369.6	22.4	24.6	7,416.6	-3.2%
14/15	8,485.8	7,836.3	23.1	31.9	7,891.3	7.0%
15/16	8,455.8	8,206.4	23.1	36.7	8,266.2	2.2%
16/17	8,008.3	7,775.2	0.5	43.5	7,819.3	2.4%
17/18	8,523.7	8,064.7	22.4	34.4	8,121.6	4.7%
18/19	8,342.7	7,925.2	22.5	30.9	7,978.5	4.4%

Note: “Wheeled water” is water moved through TVWD’s water distribution system for PWB, City of Beaverton, and City of Hillsboro customers. “Other” consists of tracked, but unmetered authorized uses, such as hydrant use or pipeline flushing.

2.9. Customer Characteristics and Use Patterns

OAR 690-086-0140(6)

The JWC’s individual member agencies have unique customer bases and billing practices, and as a result, customer characteristics and use patterns are presented separately below. JWC Member agencies bill customers monthly and bi-monthly.

In addition to annual and monthly consumption, customer consumption characteristics are described as follows:

- Summer season: water consumption during the four months with the highest monthly consumption.

- Winter season: water consumption during the months of December through March. No irrigation was assumed to occur during the winter season months.
- Indoor: average winter monthly consumption applied to a twelve-month period, estimated for single family and multi-family residential customers only.
- Outdoor: difference between annual consumption and indoor consumption, estimated for single family and multi-family residential customers only.

Indoor and outdoor water consumption was not determined for commercial and industrial customers because seasonal changes in water use may be process related, and not necessarily because of irrigation. Water use by commercial and industrial water customers must be examined individually. All water from irrigation accounts was assigned to outdoor use regardless of when the accounts were billed.

Conservation measures targeting indoor water consumption by residential customers may provide year-round water savings, while measures targeting outdoor water consumption will reduce peak consumption during the summer. The benefit that a system can realize depends on the types of customers and water uses, and the proportion of indoor versus outdoor water uses.

2.9.1. Hillsboro

Hillsboro began billing all customers monthly in 2019, and in previous years billed some customers monthly and others bi-monthly. Exhibit 2-35 and Exhibit 2-36 depict annual metered consumption by customer category for the City of Hillsboro from 2008-2019. During these years, metered consumption averaged approximately 5,907 MG and just over half of this consumption went towards commercial and industrial uses, 34% was used residentially, and the remaining metered water use was divided between public and non-profit use, irrigation, and wholesale customers.

For comparison, the 2010 JWC WMCP showed five customer categories for the City of Hillsboro: residential, business/industrial, public and nonprofit, wholesale, and irrigation. Residential consumption was 1,949 MG in 2007, which is similar to the combined consumption of single family and multi-family residential customers in recent years. Similarly, consumption by public entities and nonprofit customers has remained steady since 2007. Irrigation consumption has decreased and returned to 2007 levels, and wholesale consumption has shown a decreasing trend since 2007. Meanwhile, industrial consumption has greatly increased from the 2,178 MG reported for business/industrial customers (which included commercial customers) in 2007.

Exhibit 2-35. Hillsboro Metered Consumption by Customer Category (MG), 2008-2019

Year	Metered Consumption by Sector (MG)								Total
	Single Family	Multi-Family	Commercial	Industrial	Public Entities	Non-profit	Irrigation	Wholesale	
2008	1,675	426	441	1,826	166	16	281	536	5,368
2009	1,651	435	396	1,998	182	15	271	549	5,495
2010	1,464	423	365	2,230	146	14	185	516	5,344
2011	1,474	423	369	2,065	130	13	219	498	5,191
2012	1,536	435	396	2,265	134	15	262	523	5,567
2013	1,503	412	377	2,378	144	14	246	524	5,599
2014	1,542	434	391	2,684	162	17	259	530	6,017
2015	1,573	458	418	2,961	169	16	283	521	6,399
2016	1,515	451	402	2,910	163	15	261	519	6,236
2017	1,552	469	408	2,991	155	13	234	516	6,338
2018	1,570	489	433	3,254	159	15	284	515	6,720
2019	1,484	469	400	3,321	145	31	251	519	6,620

Exhibit 2-36. Hillsboro Metered Consumption by Customer Category, 2008-2019

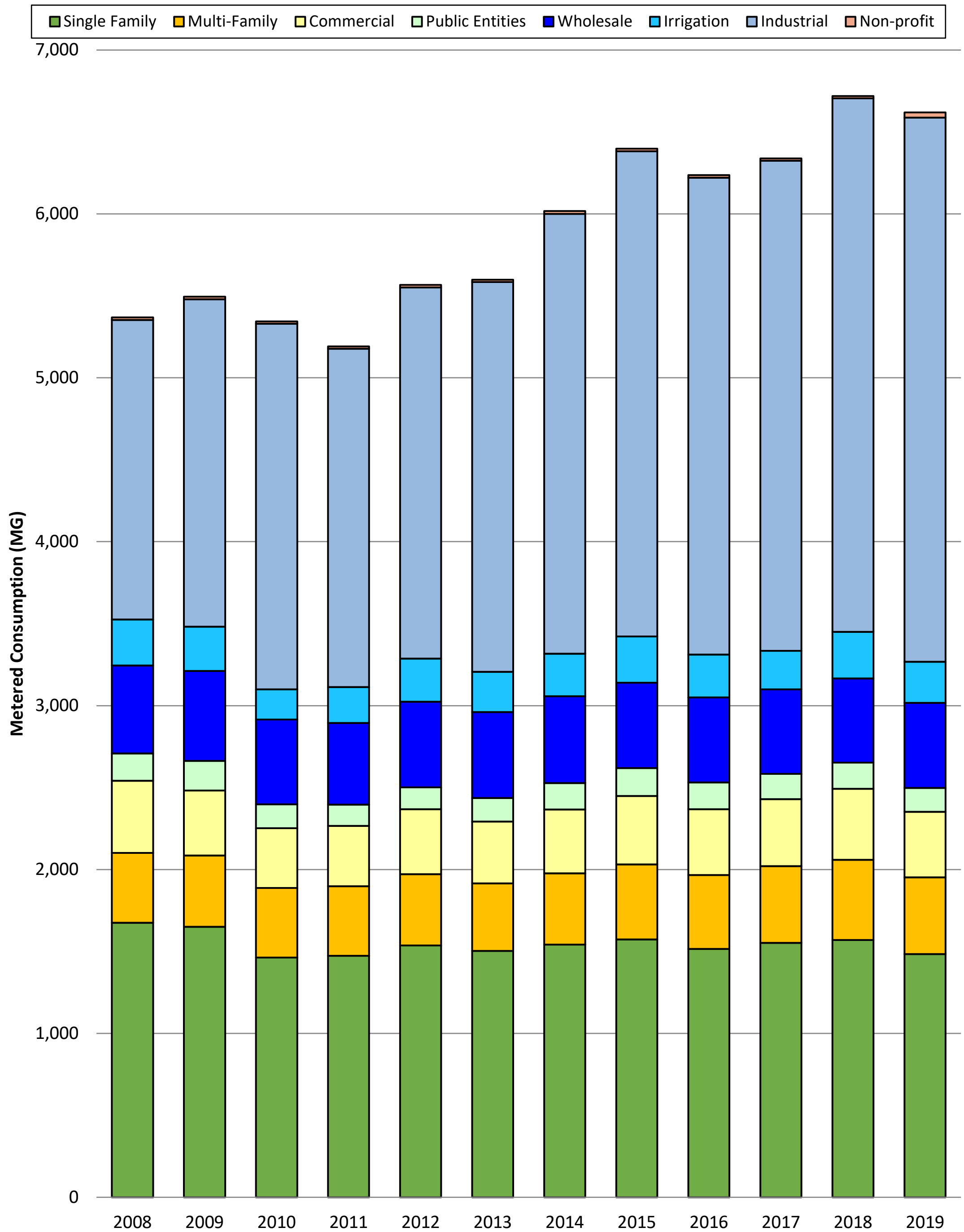


Exhibit 2-37 lists the City of Hillsboro's top ten water users, including wholesale customers, for 2019. The City of Hillsboro's system totals, including wholesale customers were 3,838 MG in 2019. The top ten water users accounted for 56.6 percent of total system use. The top three water users accounted for 47.4 percent of total system use.

Exhibit 2-37. Hillsboro Top 10 Water Users, 2019

Rank	Customer Class	Consumption (MG)
1	Industrial	2,828.1
2	Wholesale	383.4
3	Industrial	199.6
4	Wholesale	93.7
5	Industrial	88.8
6	Industrial	58.0
7	Public Entity	49.6
8	Industrial	46.3
9	Industrial	45.4
10	Wholesale	44.6
	Total	**3,838.09**

Exhibit 2-38 depicts average monthly billed consumption by customer category from 2008 through 2019. Consumption increases for all customer categories in the peak billing months July through September. Exhibit 2-39 shows the average monthly consumption for the summer season (July through October), winter season (December through March), and the annual average for 2008 through 2019.

Exhibit 2-38. Hillsboro Average Monthly Billed Consumption by Customer Category, 2008-2019

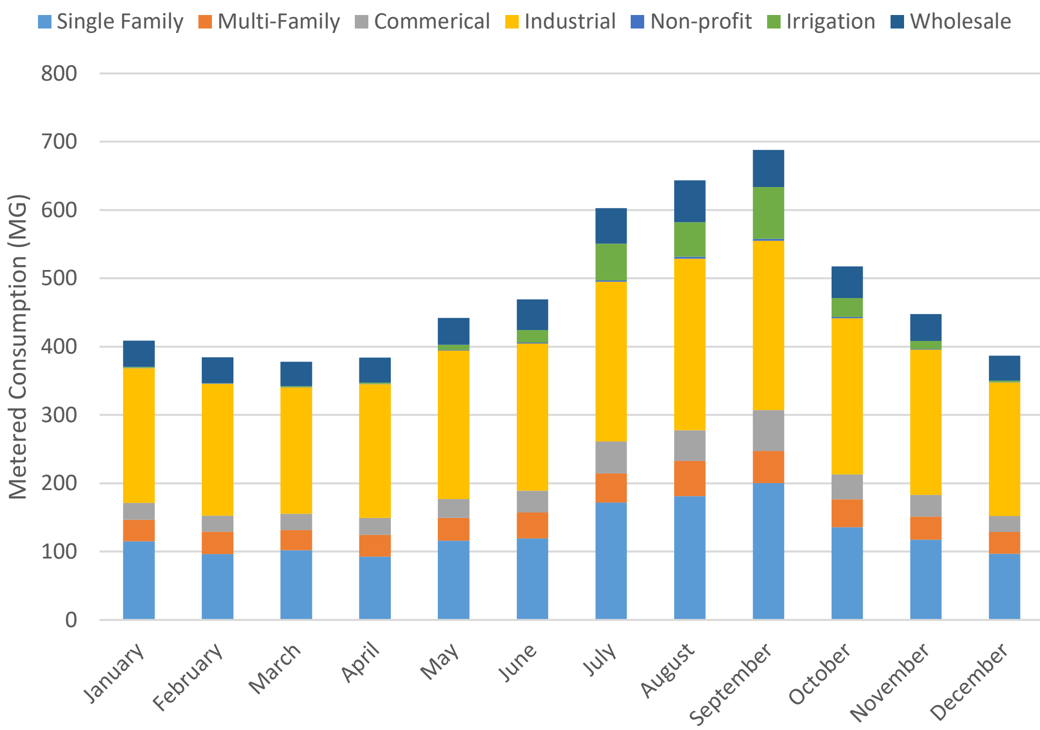


Exhibit 2-39. Hillsboro Average Monthly Consumption by Season and Customer Category, 2008-2019

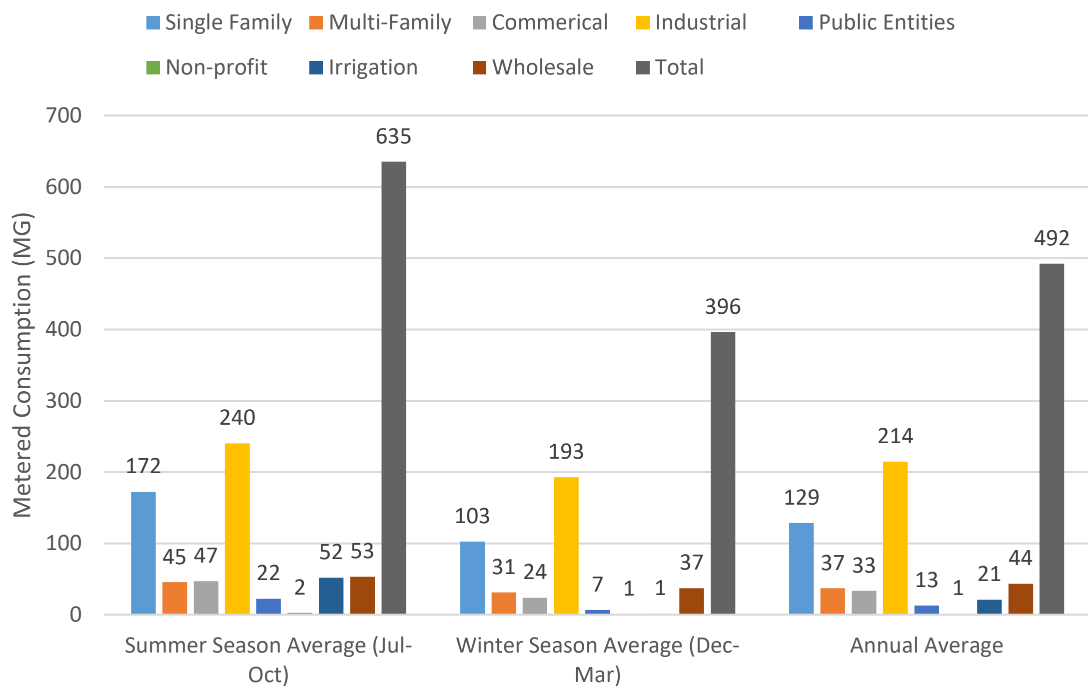
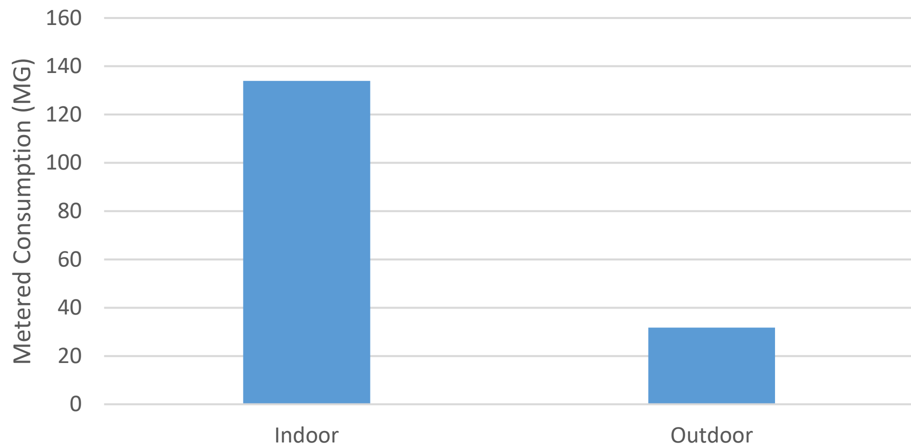


Exhibit 2-40 depicts estimated average indoor and outdoor water use from 2008-2019. Indoor water use was estimated by averaging winter water use (December through March) for all residential customers for the eleven year period. Winter water use was estimated by taking the difference of the annual average and subtracting the estimated winter indoor average, and then averaging for the eleven year period. Average indoor water use, over the eleven year period, was approximately four times greater.

Exhibit 2-40. Hillsboro Estimated Average Monthly Indoor and Outdoor Water Consumption for Residential Accounts, 2008-2019



2.9.2. Forest Grove

Forest Grove bills all customers monthly. Exhibit 2-41 and Exhibit 2-42 depict annual metered consumption by customer category for the City of Forest Grove from 2008 through 2019. Total metered consumption averaged approximately 941 MG over the eleven year period. Residential consumption averaged 62 percent of total metered consumption, with 46 percent attributed to single family customers and 16 percent attributed to multi-family customers. Commercial and industrial customers account for 30 percent of total metered consumption, and school and city customers account for the remaining 10 percent.

Consumption trends have varied among the customer categories since the 2010 JWC WMCP. Single family consumption has shown an increasing trend from the 403 MG reported in 2007 while industrial consumption has decreased from 210 MG in 2007 to 126 MG in 2019. Multi-family, commercial, school, and city consumption in 2019 remain close to 2007 consumption levels.

Exhibit 2-41. Forest Grove Metered Consumption by Customer Category (MG), 2008-2019

Year	Single Family	Multi-Family	Commercial	Industrial	School	City	Total
2008	405	150	137	185	59	28	965
2009	431	143	132	153	63	29	950
2010	400	136	119	143	43	31	873
2011	391	133	131	133	46	37	871
2012	412	134	144	145	42	36	912
2013	410	137	146	144	42	35	913
2014	447	141	152	139	52	36	968
2015	461	144	137	153	62	36	992
2016	453	141	130	139	66	35	965
2017	460	140	122	140	52	33	949
2018	468	138	149	127	57	34	972
2019	446	150	145	126	62	31	960
Average	**432**	**141**	**137**	**144**	**54**	**33**	**941**
Percentage of Use	**46%**	**15%**	**15%**	**15%**	**6%**	**4%**	**100%**

Exhibit 2-42. Forest Grove Annual Consumption by Customer Category (MG), 2008-2019

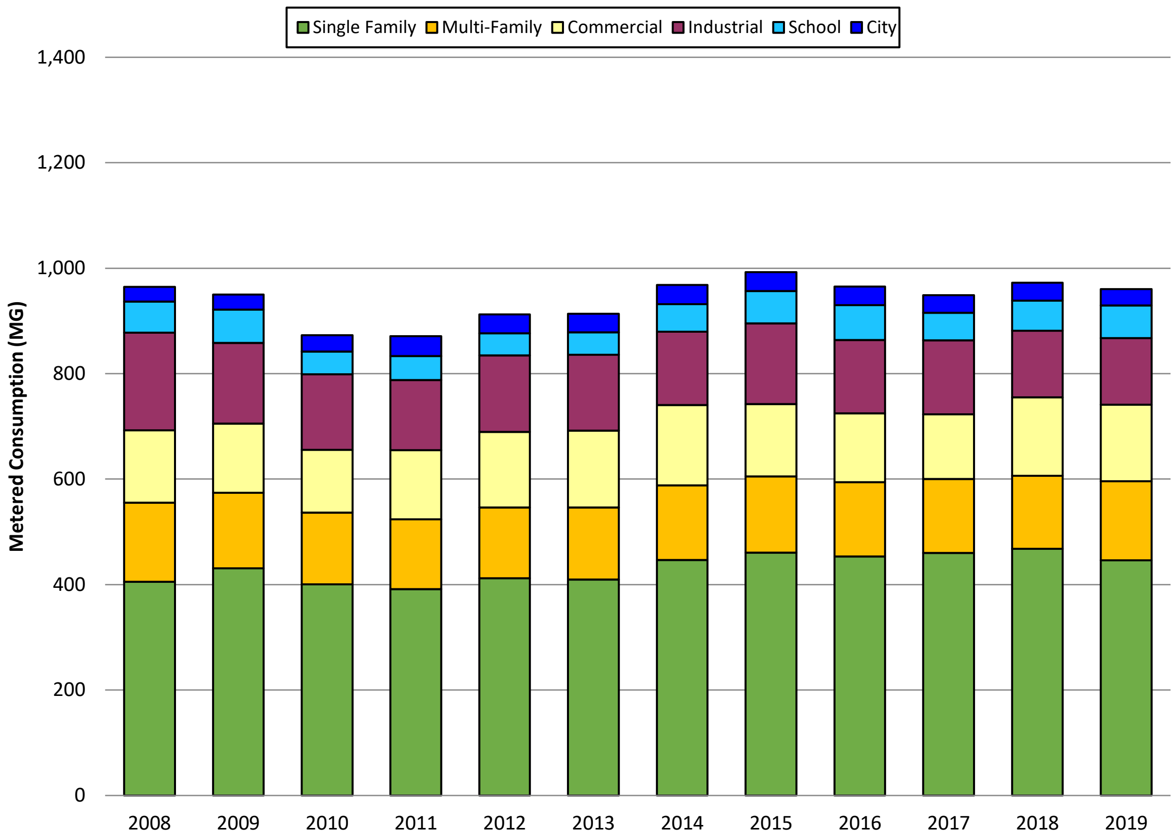


Exhibit 2-43 shows the ten customer accounts with the largest metered water consumption in 2019. The top industrial water user accounted for 4 percent of Forest Grove's total consumption. The top three water users accounted for 10 percent of total consumption.

Exhibit 2-43. Forest Grove Top 10 Water Users, 2019

Rank	Customer Class	Consumption (MG)
1	Industrial	41.1
2	Industrial	29.0
3	Commercial	26.3
4	Industrial	17.4
5	Multifamily	16.5
6	Multifamily	14.6
7	School (Elementary)	12.8
8	Multifamily	12.2
9	Commercial	9.6
10	School (University)	9.3
	Total	**188.8**

Exhibit 2-44 shows average monthly metered consumption by customer category from 2008 through 2019. August was on average the greatest month of consumption. Exhibit 2-45 shows the average overall monthly consumptions for the summer season, winter season, and for total annual consumption. The total summer season average was 109 MG, the total winter season average was 58 MG, and the total annual average was 78 MG.

Exhibit 2-44. Forest Grove Average Monthly Metered Consumption by Customer Category (MG), 2008-2019

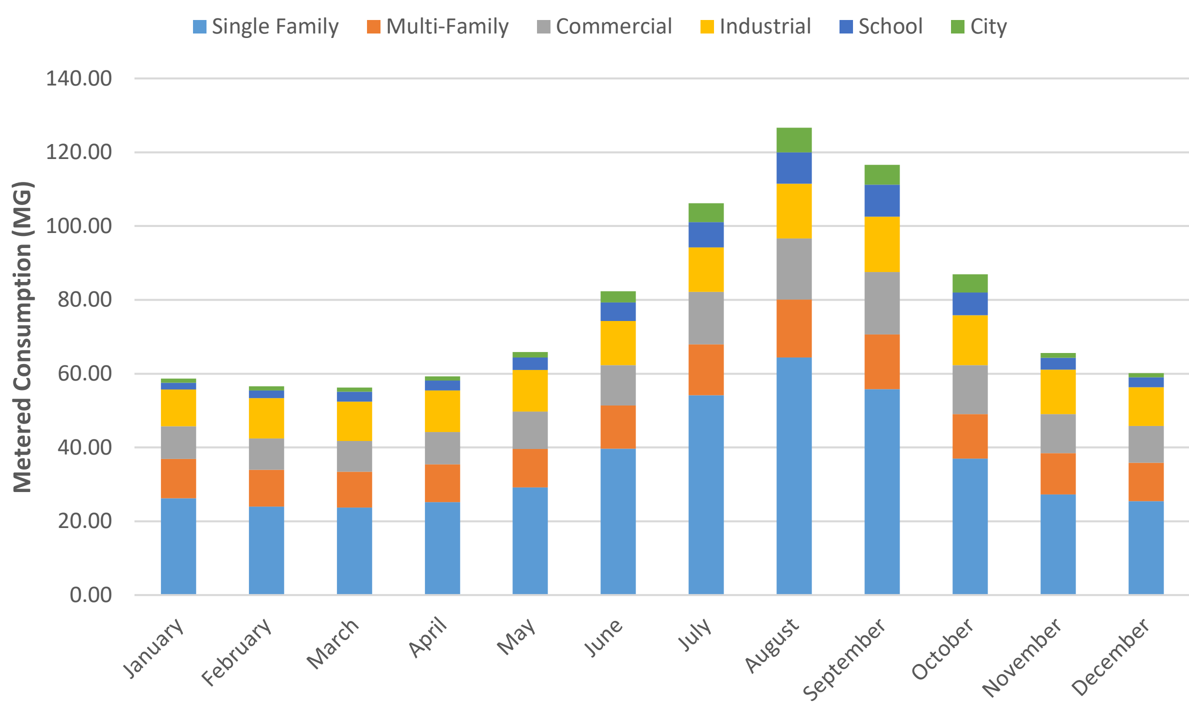


Exhibit 2-45. Forest Grove Average Monthly Consumption by Season and Customer Category (MG), 2008-2019

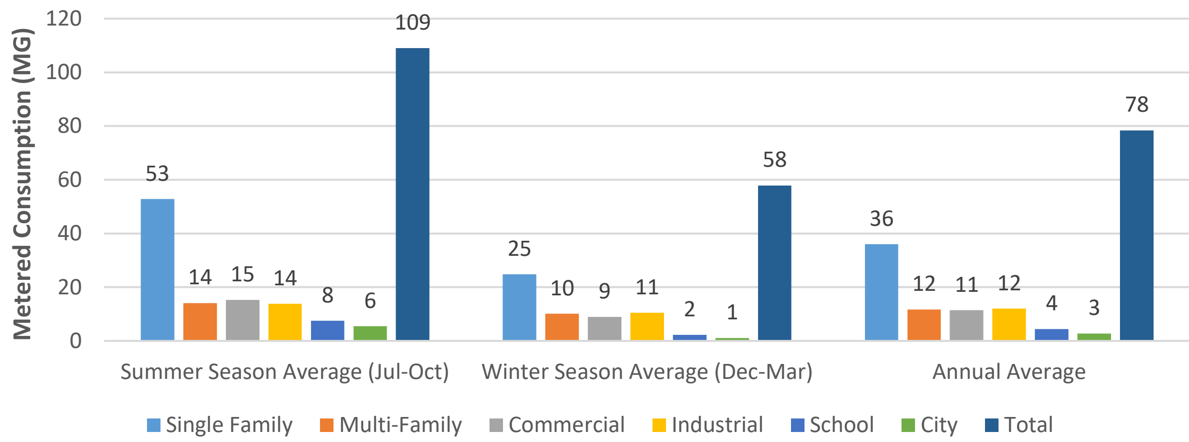
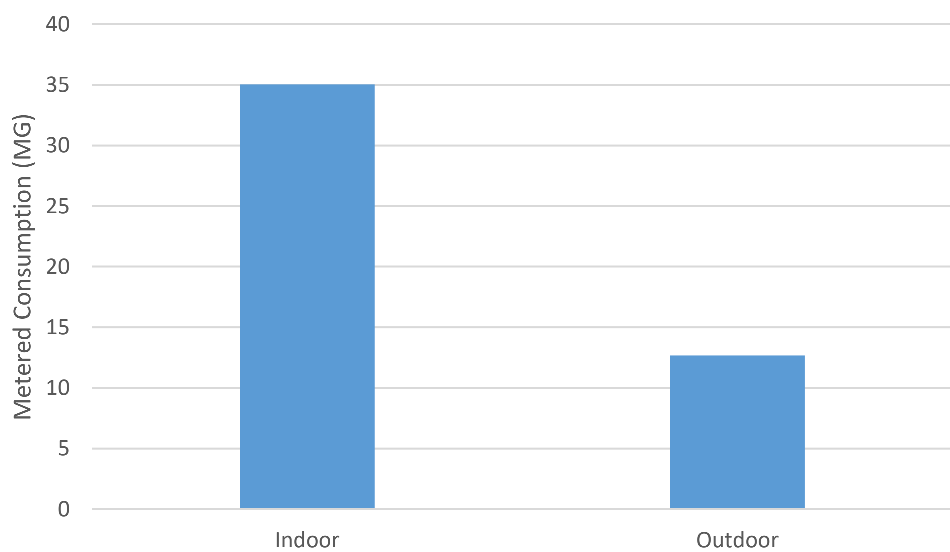


Exhibit 2-46 shows estimated average monthly indoor and outdoor water consumption amongst residential customers. Total average indoor water consumption is just over two and a half times greater than total average outdoor water consumption for the eleven year period.

Exhibit 2-46. Forest Grove estimated average monthly indoor and outdoor water consumption for residential accounts, 2008-2019



2.9.3. Beaverton

Beaverton began billing all customers monthly in 2013. Exhibit 2-47 and Exhibit 2-48 show the annual metered consumption by customer category for the City of Beaverton from fiscal year 2008/2009 through fiscal year 2018/2019.

When comparing recent consumption patterns to the 2010 JWC WMCP, different trends have emerged among the customer categories. Single family consumption has remained below the 2007 consumption of 1,077 MG and multi-family plus apartments consumption has consistently been lower than the multi-family consumption reported in 2007. Likewise, public facilities consumption has generally been lower than in 2007. Commercial consumption has fluctuated from the 537 MG reported in 2007, with a large increase in recent years. Irrigation consumption has similarly fluctuated from 210 MG in 2007 and then notably increased in the past two years.

Exhibit 2-47. Beaverton Metered Consumption by Customer Category (MG), FY 2008/2009 - 2018/2019

Fiscal Year	Single Family	Multi-Family	Apartments	Commercial/Industrial	Public Facilities	Irrigation	Fire	Total
08/09	1,054	95	596	520	29	221	1	2,515
09/10	1,019	95	592	499	27	209	0	2,442
10/11	950	89	581	463	25	164	0	2,271
11/12	944	89	567	471	19	164	0	2,254
12/13	983	90	547	470	21	205	0	2,315
13/14	931	86	584	470	26	165	0	2,262
14/15	979	93	568	498	22	201	0	2,361
15/16	1,053	88	591	523	23	249	0	2,527
16/17	960	83	573	479	21	192	0	2,308
17/18	1,005	82	568	686	60	255	0	2,657
18/19	1,052	81	616	748	0	312	0	2,808
Average	994	88	580	530	25	212	0	2,429
Percentage of Use	41%	4%	24%	22%	1%	9%	0%	100%

Exhibit 2-48. Beaverton Annual Consumption by Customer Category, FY 2008/2009 - 2018/2019

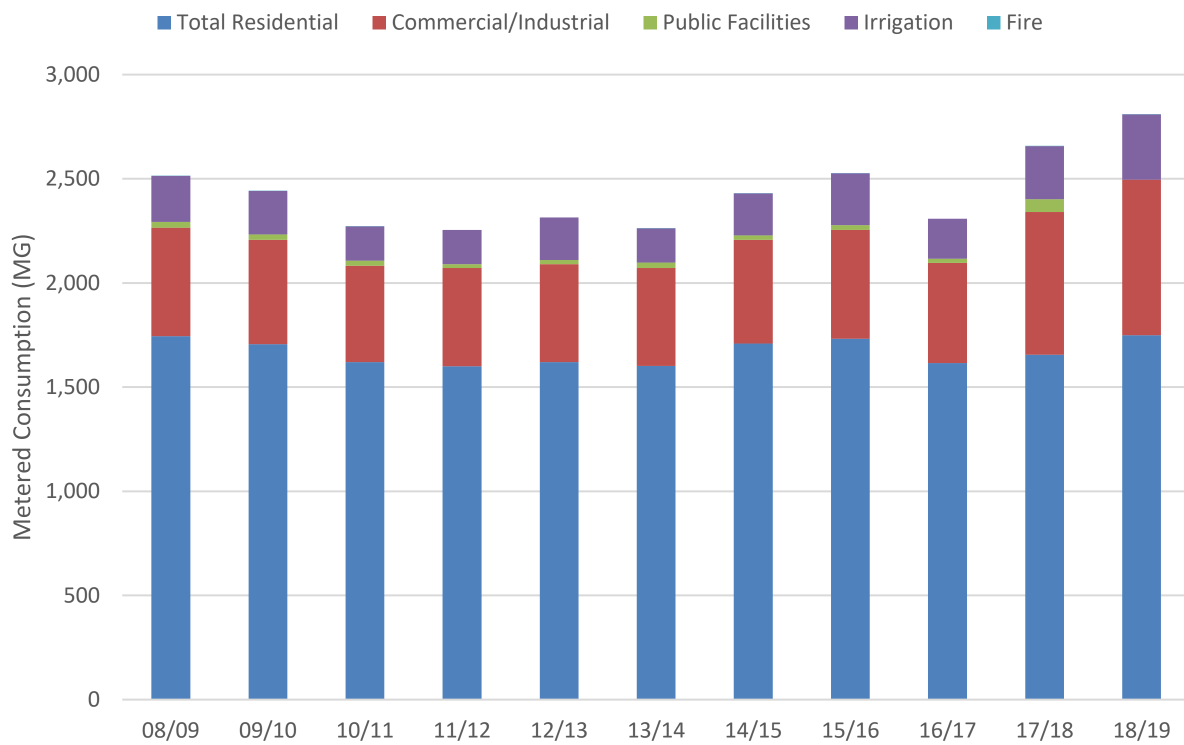


Exhibit 2-49 depicts Beaverton's top ten customer accounts with the largest metered water consumption in FY 2018/2019. The top water user accounted for over 1 percent of Beaverton's total consumption. The top three water users accounted for nearly 4 percent of total consumption.

Exhibit 2-49. Beaverton Top 10 Water Users, FY 2018/2019

Rank	Customer Class	Consumption (MG)
1	Public Facilities	36.0
2	Multi-Family	35.0
3	Single-Family	26.6
4	Commercial	22.4
5	Irrigation	22.4
6	Irrigation	22.2
7	Multi-Family	18.5
8	Multi-Family	16.2
9	Commercial	15.7
10	Single-Family	15.4
	Total	**216.4**

Exhibit 2-50 shows average monthly metered consumption from fiscal year 2008/2009 through fiscal year 2018/2019. The four month period from July through October represent the peak season, with August accounting for the highest average monthly consumption.

Exhibit 2-50. Beaverton Average Monthly Consumption by Customer Category, FY 2008/2009-2018/2019

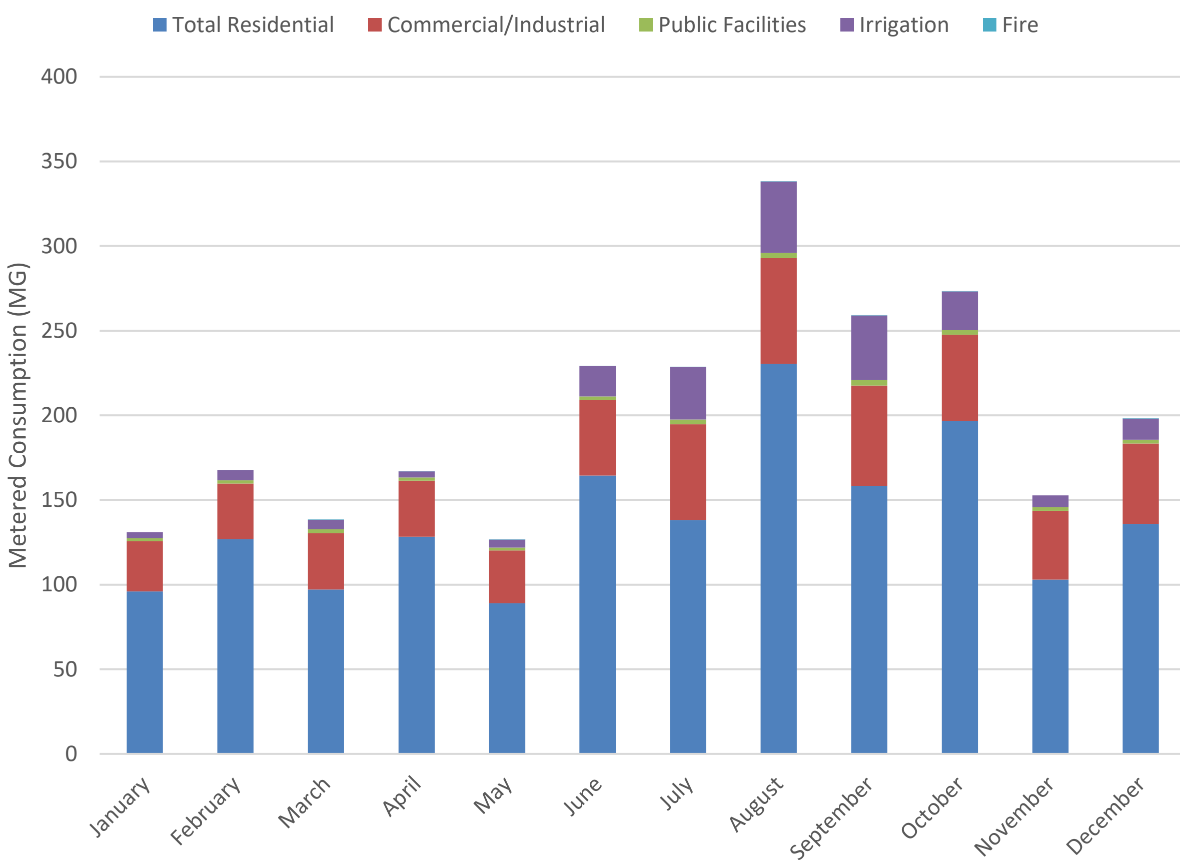


Exhibit 2-51 shows average monthly consumption for the summer season, winter season, and entire year. The total summer season average was approximately 293 MG, the total winter season average was approximately 164 MG, and the total annual average was approximately 203 MG.

Exhibit 2-51. Beaverton Average Monthly Consumption by Season and Customer Category, FY 2008/2009-2018/2019

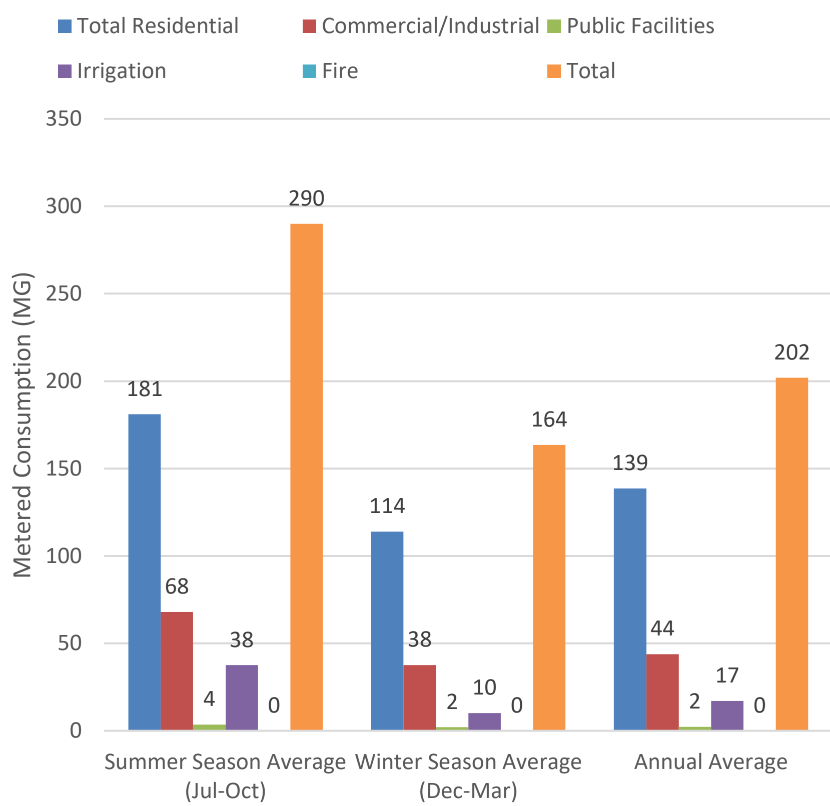
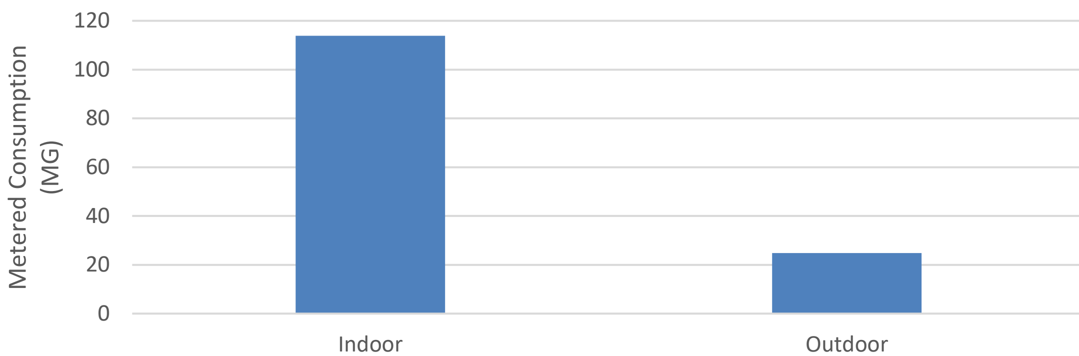


Exhibit 2-52 shows average monthly indoor and outdoor water consumption for residential accounts. Estimated average monthly indoor consumption was approximately 4.6 times greater than estimated average outdoor consumption.

Exhibit 2-52. Beaverton estimated average monthly indoor and outdoor water consumption for residential accounts, FY 2008/2009-2018/2019



2.9.4. TVWD

TVWD bills residential customer classes bi-monthly and commercial customer classes on a monthly basis. Exhibit 2-53 and Exhibit 2-54 depict annual metered consumption by customer category for TVWD from 2008 through 2019. For the eleven year period, average annual metered consumption averaged approximately 7,603 MG. Residential customers accounted for approximately 70 percent of all metered consumption. Commercial use accounted for another 16 percent. The remaining 14 percent was divided between production (8.5 percent), irrigation (5.7 percent), fire line (0.02 percent), wholesale (0.3 percent), and temporary irrigation customers (0.06 percent).

Consumption trends by TVWD’s customer categories have been mixed since the 2010 JWC WMCP. Single family consumption has remained below the 2007 consumption of 4,089 MG, commercial consumption remained below the 2007 consumption of 1,321 MG except for two years, and wholesale consumption has decreased considerably since 2007. However, multi-family consumption fluctuated around levels reported from 2002 through 2007, production consumption (formally called Industrial) increased from 505 MG in 2007 to more than 700 MG in recent years, and irrigation consumption has fluctuated around the 2007 level of 422 MG.

Exhibit 2-53. TVWD Annual Consumption by Customer Category (MG), 2008-2019

Year	Single Family	Multi-Family	Commercial	Production	Irrigation	Fireline	Wholesale	Temporary Irrigation	Total
2008	3,939	1,416	1,202	600	423	3	43	0	7,626
2009	4,022	1,399	1,180	527	445	1	28	0	7,601
2010	3,648	1,363	1,055	592	336	1	28	0	7,022
2011	3,572	1,402	1,038	637	360	1	20	0	7,031
2012	3,738	1,432	1,123	588	418	1	22	0	7,322
2013	3,730	1,452	1,208	614	388	2	41	3	7,437
2014	3,797	1,567	1,271	704	438	2	53	6	7,837
2015	4,009	1,595	1,361	695	525	1	8	10	8,204
2016	3,805	1,570	1,273	692	466	2	1	10	7,818
2017	3,895	1,628	1,297	709	461	2	0	11	8,003
2018	3,927	1,644	1,364	723	506	1	5	10	8,181
2019	3,454	1,477	1,107	680	400	1	30	8	7,157
Average	**3,795**	**1,495**	**1,207**	**647**	**431**	**1**	**23**	**5**	**7,603**
Percent of Use	**49.91%**	**19.67%**	**15.87%**	**8.51%**	**5.66%**	**0.02%**	**0.31%**	**0.06%**	**100.00%**

Exhibit 2-54. TVWD Annual Consumption by Customer Category, 2008-2019

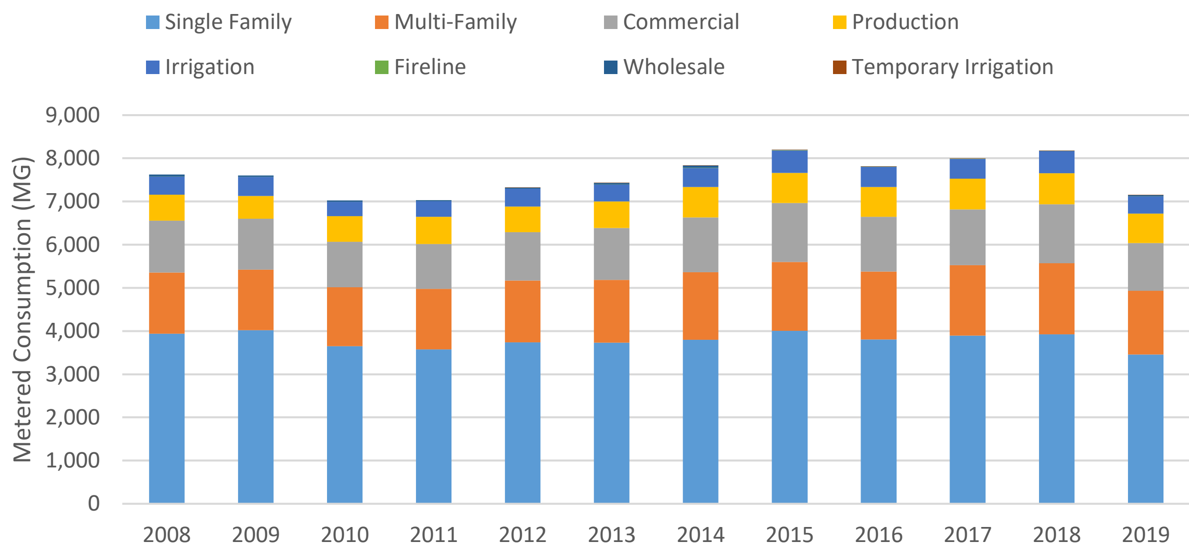


Exhibit 2-55 presents TVWD's top ten largest water consumers from 2019. These top water users accounted for approximately 13 percent of TVWD's total consumption for the year 2019. The top three water users accounted for approximately 8 percent of total consumption.

Exhibit 2-55. TVWD's Top 10 Largest Water Consumers, 2019

Customer Class	Total Consumption (MG)
Commercial	231.8
Commercial	227.9
Commercial	96.5
Commercial	91.0
Commercial	56.4
Multi-Family	45.4
Commercial	41.7
Multi-Family	40.7
Irrigation	40.5
Multi-Family	38.2

Exhibit 2-56 shows average monthly consumption from 2008 through 2019. The months of peak consumption were July through October. As shown in Exhibit 2-57, the total summer season average monthly consumption was approximately 903 MG, the total winter season average was 469 MG, and the annual average was 634 MG.

Exhibit 2-56. TVWD Average Monthly Metered Consumption by Customer Category, 2008-2019

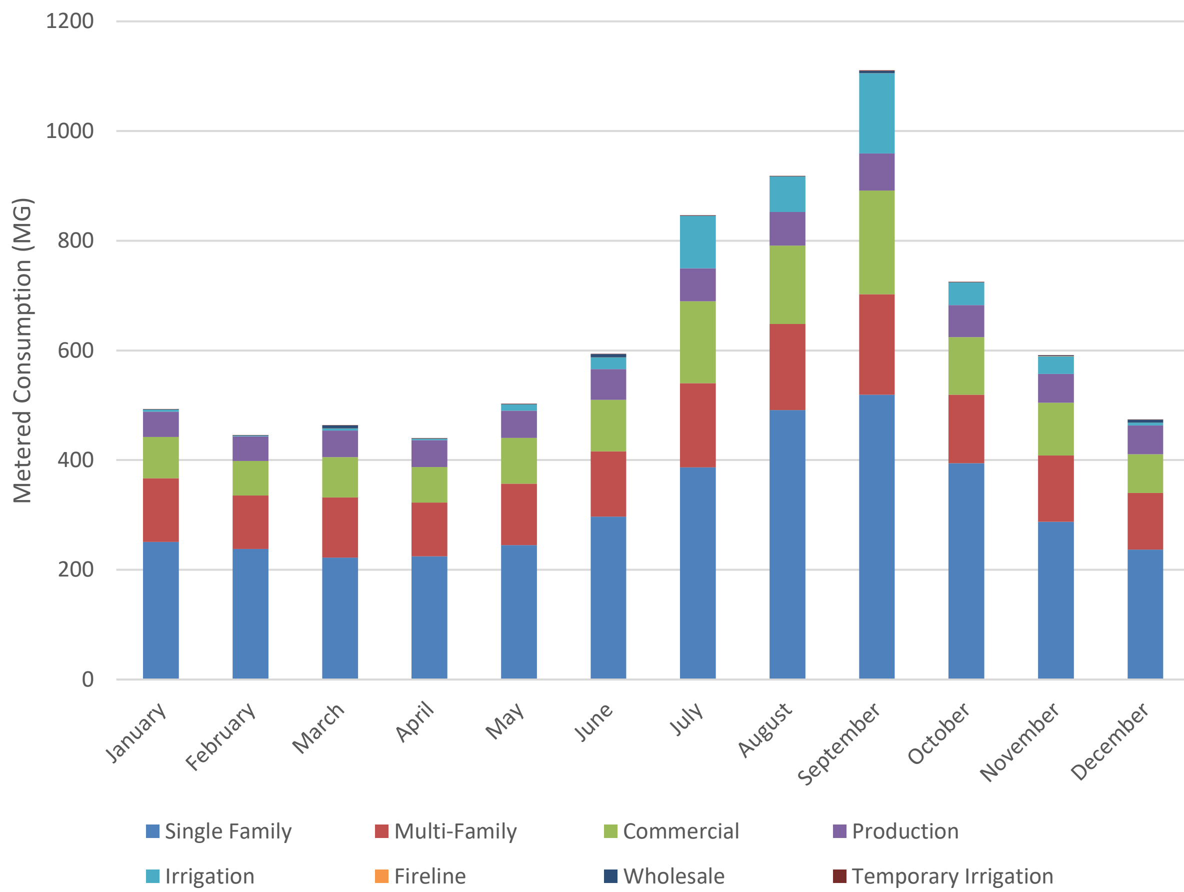


Exhibit 2-57. TVWD Average Monthly Consumption by Season and Customer Category, 2008-2019

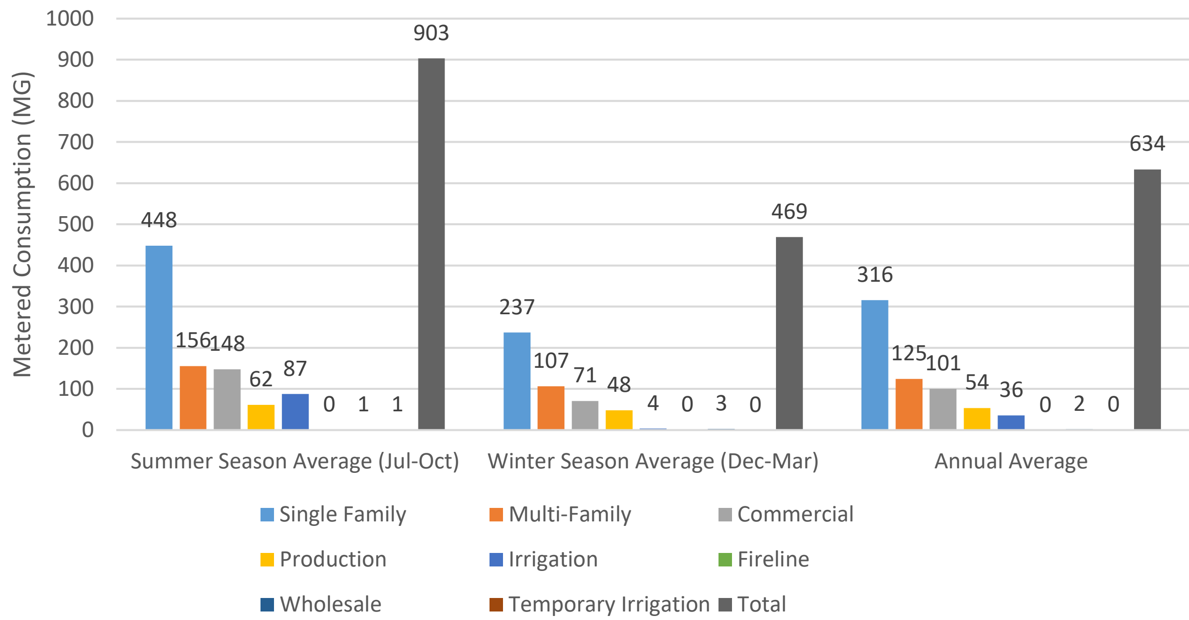
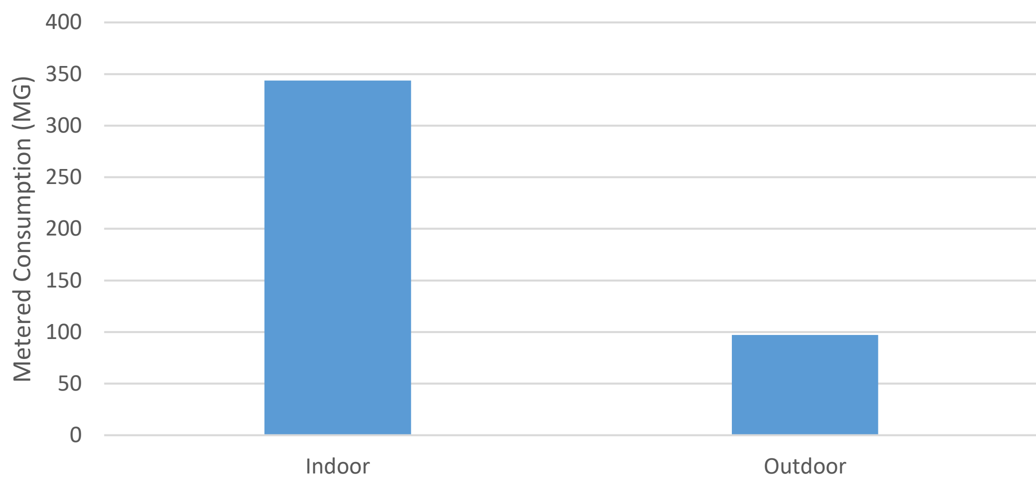


Exhibit 2-58 shows average estimated indoor and outdoor water use from 2008-2019. Indoor water use was estimated by averaging winter water use (December through March) for all residential customers for the eleven year period. Outdoor water use was estimated by taking the difference of the annual average and subtracting the estimated winter indoor average, and then averaging for the eleven year period. Indoor water use was approximately three and a half times greater than outdoor water use over the eleven year period.

Exhibit 2-58. TVWD Average Annual Indoor and Outdoor Metered Consumption, 2008-2019



2.10. Per Capita Demand

Exhibit 2-59 presents the overall system, and residential per capita demands for the JWC members. Demand from all sources and total population data from 2019 were used to estimate overall system average day per capita demand. Residential per capita demand was estimated based on the proportion of residential water use within each system. Overall system per capita average and maximum day demands ranged from 91.7 to 177.8 gallons and 170.7 to 293.6, respectively. Larger overall system per capita demands can result from greater proportions of commercial and industrial water uses. The residential per capita average day demands, including both single-family and multi-family residences, ranged from 52.6 gallons to 76.0 gallons.

Exhibit 2-59. 2019 Per Capita Demand for JWC Member Agencies

JWC Member	ADD (MG)	MDD (MG)	MDD/ADD Peaking Factor	2019 Population	ADD per capita (gal)	MDD per capita (gal)	Residential Percentage of Total Use	Residential ADD per capita (gal)
Hillsboro	18.3	30.2	1.7	102,692	177.8	293.6	30%	52.5
Forest Grove	3.1	4.4	1.4	25,303	122.4	172.7	62%	76.0
Beaverton	8.3	15.4	1.9	89,978	91.7	170.7	62%	57.1
TVWD	22.6	38.3	1.7	214,717	105.4	178.4	69%	72.6

2.11. Water Rights

OAR 690-086-0140(5)

The JWC's use of water is authorized by numerous water rights, including rights for the use of natural flow, storage rights, secondary rights to use stored water, and Aquifer Storage and Recovery (ASR) rights. These water rights authorize the use of water for municipal purposes, with the exception of two water rights for pollution abatement. Some water rights are held by the JWC, some are held by the Barney Reservoir Joint Ownership Commission, and some are held by the individual member agencies. Exhibit 2-60 provides a summary of JWC water rights and further description is provided below.

In addition to the water rights used by the JWC, the individual member agencies hold surface water and groundwater rights for use outside of the JWC system, but within the individual member agencies municipal water supply systems. These water rights are also for municipal use. Exhibit 2-61 provides a summary of water rights held by member agencies that supply water for their individual municipal water supply systems and further description is provided below.

Some JWC member agencies hold additional water rights that are not part of their municipal water supply systems, such as water rights for irrigation and wildlife, which are summarized in Appendix C.

Exhibit 2-60. JWC Water Rights

Source	Priority Date	Application	Permit	Certificate/ Transfer	Entity name on water right	Type of Beneficial Use	Authorized Rate (cfs)	Authorized Volume	Maximum Rate of Withdrawal To Date		Average Daily Diversion (mgd)		Average Monthly Diversion (MG)		Authorized Date of Completion
									Instantaneous (cfs)	Annual (MG)	2019	5-year (2014-2019)	2019	5-year (2014-2019)	
JWC Water Rights															
Sain Creek	1/22/1912	S-2016	S-1136	81026	City of Hillsboro	Municipal	3	n/a	3						n/a
Sain Creek	5/1/1915	S-4250	S-2443	81027	City of Hillsboro	Municipal	2	n/a	2						n/a
Gales Creek	2/14/1947	S-22251	S-17549	~~85113~~ T-11677	City of Forest Grove	Municipal	4.46	n/a	4.46						10/1/2035
Tualatin River	8/15/1930	S-13681	S-10408	67891	City of Hillsboro	Municipal	9	n/a	9						n/a
Tualatin River	2/6/1974	S-51643	S-46423	85913	City of Hillsboro	Municipal	43	n/a	43						n/a
Tualatin River	7/15/1980	S-60357	S-45455	85914	City of Beaverton	Municipal	25	n/a	25						n/a
Tualatin River	4/28/1976	S-54203	S-40615	85916	City of Forest Grove	Municipal	33	n/a	33						n/a
Tualatin River	1/31/2018	S-88506			Joint Water Commission	Municipal	44	n/a	0						
Scoggins Creek	6/9/1988	S-69637	S-54737		City of Hillsboro, City of Forest Grove, City of Beaverton, Tualatin Valley Water District, Joint Water Commission	Municipal	75[1]	n/a	0						10/1/2071
Middle Fork of the North Fork Trask River (Barney Reservoir)	6/26/1958 & 12/10/1965	R-32420	R-4890	81024	City of Hillsboro	Municipal	n/a	12,600 AF & 7,400 AF	n/a	12,600 AF & 7,400 AF	21.60	27.04	657.03	822.5	n/a
Middle Fork of the North Fork Trask River and Barney Reservoir	6/26/1958	S-32421	S-32139	81020	City of Hillsboro	Municipal	38.7	n/a	38.7						n/a
Barney Reservoir	6/24/1971	S-48359	S-37837	81022	City of Forest Grove	Municipal	n/a	500 AF	n/a	500 AF					n/a
Middle Fork of the North Fork Trask River (in Barney Reservoir)	12/23/1971	R-48907	R-5773	81023	City of Hillsboro	Pollution Abatement	n/a	2,000 AF	n/a	2,000 AF					n/a
Barney Reservoir	7/8/1971	S-48420	S-35782	81021	City of Hillsboro	Pollution Abatement	30	n/a	30						n/a
Barney Reservoir	12/26/2017	S-88492	S-55219		Barney Reservoir Joint Ownership Commission	Municipal	30	8,734	0						7/26/2039
Scoggins Creek	2/20/1963	R-38449	R-5777	81149	Bureau of Reclamation	Irrigation, Supplemental Irrigation, Municipal, Water Quality Control, and Fish and Recreation	n/a	60,000 AF (13,500 AF for Municipal Use by JWC Member Agencies)	n/a	60,000 AF					n/a

Source	Priority Date	Application	Permit	Certificate/ Transfer	Entity name on water right	Type of Beneficial Use	Authorized Rate (cfs)	Authorized Volume	Maximum Rate of Withdrawal To Date		Average Daily Diversion (mgd)		Average Monthly Diversion (MG)		Authorized Date of Completion
									Instantaneous (cfs)	Annual (MG)	2019	5-year (2014-2019)	2019	5-year (2014-2019)	
JWC Water Rights, continued															
Scoggins Reservoir/Henry Hagg Lake	2/20/1963	S-38447	S-35792	87304	Bureau of Reclamation	Municipal	70.0	13,000	70.0						n/a
Scoggins Reservoir/Henry Hagg Lake	2/20/1963	S-38447	S-35792	93873	Bureau of Reclamation	Municipal	n/a	500 AF	n/a	500 AF	n/a	n/a	n/a	n/a	n/a
Sain Creek, Tualatin River, Scoggins Creek and the Bull Run River, tributaries of Scoggins Creek, the Willamette River, the Tualatin River, and the Sandy River.			ASR LL-019		Joint Water Commission	Aquifer Storage and Recovery (ASR)	Recovery: up to 28,000 gpm (40.3 mgd) total (2000 gpm, 2.9 mgd) from each of 14 wells	2.1 billion gallons	0	0	0	0	0	0	9/27/2021

[1]Diversion of water under Permit S-54737 is currently limited to 26.0 cfs due to the development limitations in the extension of time dated September 9, 2010 and the subsequent WMCP Final Order dated September 14, 2010.

Notes

AF = acre-feet
ASR = aquifer storage and recovery
cfs = cubic feet per second
gpm = gallons per minute
JWC = Joint Water Commission
LL = limited license
MG = million gallons
mgd = million gallons per day
N/A = not applicable
TVWD = Tualatin Valley Water District

Exhibit 2-61. Non-JWC Water Rights Held by JWC Member Agencies

Source	Priority Date	Application	Permit	Certificate/ Transfer/Claim	Entity name on water right	Type of Beneficial Use	Authorized Rate (cfs)	Authorized Volume	Maximum Rate of Withdrawal To Date		Average Daily Diversion (mgd)		Average Monthly Diversion (MG)		Authorized Date of Completion
									Instantaneous (cfs)	Annual (MG)	2019	5-year (2015-2019)	2019	5-year (2015-2019)	
Non-JWC Water Rights Held By Member Agencies															
City of Hillsboro															
Willamette River	12/6/1976	S-55010	S-55045 (Permit amendment T-12512)		City of Salem, City of Hillsboro	Municipal	200 (56 cfs of which is the City of Hillsboro's portion)[1]	n/a	0	0	0	0	0	0	10/1/2086
Crandall Reservoir ASR Well Butternut Creek ASR Well Wood Street ASR Well			ASR LL-027		City of Hillsboro	Aquifer Storage and Recovery (ASR)	Recovery: up to 1725 gpm per well for up to three wells	900 MG	0	0	0	0	0	0	1/21/2025
City of Forest Grove															
Branches of Clear Creek	3/29/1917	S-5460	S-3318	2194	City of Forest Grove	Municipal	0.80	n/a	0.80		1.92	1.52	58.42	46.28	
Four Branches of Clear Creek	4/16/1935	S-15790	S-12034	13471	City of Forest Grove	Municipal	1.00	n/a	1.00						
Branches of Clear Creek	7/27/1939	S-18298	S-13944	13797	City of Forest Grove	Municipal	1.00	n/a	1.00						
Roaring Creek, a tributary of Clear Creek, and Clear Creek, a tributary to Gales Creek	4/28/1976	S-54203	S-40615	92949	City of Forest Grove	Municipal	4.46, being 2.43 cfs from Roaring Creek and 2.83 from Clear Creek	n/a	4.46, being 2.43 cfs from Roaring Creek and 2.83 from Clear Creek						
City of Beaverton															
Native Groundwater • Well #1 Golf Cr. Basin • Well #2 Fanno Cr. Basin ASR 2 ASR 3 ASR 4 Rubber Reservoir Well Dernbach Well ASR 5 ASR 6 ASR 7	1932 (Well #1) 1945 (Well #2)	--	--	GR modification T-10990; GR 343	City of Beaverton	Municipal	3.01 (1,350 gpm) Note: Original authorized appropriation for Well #1 is 400 gpm (0.89 cfs) and Well #2 is 950 gpm (2.12 cfs).	NA	3.01	N/A	0.12 (ASR) + 0.47 (native ground-water) = 0.58[2]	0.17 (ASR) + 0.43 (native ground-water) = 0.59[2]	3.58 (ASR) + 14.21 (native ground-water) = 17.78[2]	5.08 (ASR) + 13.00 (native ground-water) = 18.08[2]	N/A

Source	Priority Date	Application	Permit	Certificate/ Transfer/Claim	Entity name on water right	Type of Beneficial Use	Authorized Rate (cfs)	Authorized Volume	Maximum Rate of Withdrawal To Date		Average Daily Diversion (mgd)		Average Monthly Diversion (MG)		Authorized Date of Completion
									Instantaneous (cfs)	Annual (MG)	2019	5-year (2015-2019)	2019	5-year (2015-2019)	
City of Beaverton, continued															
Willamette River	3/11/2014	S-87964	S-54940	--	City of Beaverton	Municipal	33.7	N/A	0	N/A	0	0	0	0	05/4/2035
Tualatin River and Bull Run	N/A	--	ASR LL-002	--	City of Beaverton and TVWD	ASR	Recovery: up to 14.4 mgd from 13 wells	Storage: up to 1.5 billion gallons	Recovery: up to 9 mgd from 4 wells	Storage: up to 1.15 billion gallons	2.0 (Beaverton's use)	2.0 (Beaverton's use, 2014-2019)	45.5 (Beaverton's use)	1.7 (Beaverton's use, 2014-2019)	12/20/2023 Limited License renewable every 5 years
Tualatin Valley Water District															
Groundwater, tributary to Beaverdam Creek	1/21/1959	G-1351	G-1229	~~86081~~ Transfer T-11612	TVWD and Aloha Huber Water District	Municipal	0.58[3]	116 acre-feet Season of use limited to: May 1 - Sept. 30	0.58		0	0	0	0	10/1/2035; Transfer added five points of appropriation
Groundwater, a tributary to Beaverton Creek	5/2/1957	G-637	G-588	~~36440~~ Transfer T-11612	Aloha Huber Water District	Municipal	1.10	N/A	1.10		0	0	0	0	10/1/2035; Transfer added five points of appropriation
Groundwater, a tributary to Butternut Creek	2/23/1962	G-2242	G-2064	~~36441~~ Transfer T-11612	Aloha Huber Water District	Municipal	2.2	N/A	2.2		0	0	0	0	10/1/2035; Transfer added five points of appropriation
Willamette River	6/19/1973	S-50693	S-49240	Permit amendment T-10477	Willamette River Water Coalition	Municipal and Industrial	202[4]	N/A	0[5]	0	0	0	0	0	10/1/2047
Tualatin River and Bull Run	N/A	--	ASR LL-002	--	City of Beaverton and TVWD	ASR	Recovery: up to 14.4 mgd from 13 wells	Storage: up to 1.5 billion gallons	Recovery 4.45 cfs (2.9 mgd)	211.1	0.51	0.45	15.4	13.54	12/20/2023 Limited License renewable every 5 years

[1] The City of Salem assigned the City of Hillsboro a 56 cfs portion of the total permitted rate of 200 cfs in August 2016 and retained the remaining 144 cfs. Diversion of water under Permit S-55045 is currently limited to 30.94 cfs for the City of Hillsboro due to the development limitations in the extension of time dated July 31, 2015 and the subsequent Final Order approving the City of Hillsboro's WMCP dated August 28, 2017.
[2] Due to rounding, the parts do not exactly equal the total.
[3] Total diversion, in combination with the remaining irrigation right (Certificate 44119), is limited to 1.31 cfs.
[4] Diversion of water under Permit S-49240 is currently limited to 80.1 cfs for TVWD due to the development limitations in the extension of time dated June 26, 2007 and the subsequent Final Order approving TVWD's WMCP dated January 16, 2015.
[5] Although the City of Sherwood has used water under the WRWC Permit S-49240, TVWD has not diverted any water under this permit to date.

Notes

AF = acre-feet
ASR = aquifer storage and recovery
cfs = cubic feet per second
gpm = gallons per minute
JWC = Joint Water Commission
LL = limited license
MG = million gallons
mgd = million gallons per day
N/A = not applicable
TVWD = Tualatin Valley Water District

2.11.1. JWC Water Rights

Overview

The JWC's current water supply sources are the Tualatin River and its tributaries, which include a combination of natural flow and stored water released from Hagg Lake, and Barney Reservoir in the Trask River watershed. The JWC, along with its member agencies and the Barney Reservoir Joint Ownership Commission (BRJOC), have several water rights granting access to these water supply sources. The intergovernmental agreements previously described in Section 2 clarify how and when these water rights are pooled together.

The JWC also holds a limited license (ASR LL-019) for an aquifer storage and recovery (ASR) program. TVWD, the City of Hillsboro, and the City of Beaverton each has access up to one-third of the capacity of the JWC limited license.

Direct Diversion (Natural Flow) Water Rights

The JWC manages water rights for the use of natural flow from:

- the Tualatin River with authorized points of diversion at the Haines Falls Intake and at the Spring Hill Pumping Plant (SHPP);
- Sain Creek, which flows into Scoggins Creek at Hagg Lake, with points of diversion on Sain Creek and at the Scoggins Dam outlet, with re-diversion authorized at the SHPP;
- Scoggins Creek; and
- Gales Creek, with an authorized additional point of diversion at the SHPP.

These water rights for natural flow consist of six certificates, one water right in transfer status, one permit, and one permit application.

The two most senior natural flow JWC managed water rights are in the name of the City of Hillsboro. Certificate 81026 with a priority date of January 22, 1912, authorizes diversion of up to 3.0 cfs, and Certificate 81027 with a priority date of May 1, 1915, authorizes diversion of up to 2.0 cfs. The source for both rights is Sain Creek, which flows into Scoggins Creek at Hagg Lake. The certificates authorize the use of water for municipal purposes. The points of diversion for these rights are now on Sain Creek and at the Scoggins Dam outlet, with re-diversion authorized at the Spring Hill Pumping Plant (SHPP) Intake.

The JWC manages the following four certificated water rights for natural flow from the Tualatin River for municipal purposes:

- Certificate 67891, in the name of the City of Hillsboro, has a priority date of August 15, 1930 and authorizes diversion of up to 9.0 cfs (the authorized points of diversion are at the Haines Falls Intake and at the SHPP Intake);
- Certificate 85913, in the name of the City of Hillsboro, has a priority date of February 6, 1974 and authorizes diversion of up to 43.0 cfs;
- Certificate 85916, in the name of the City of Forest Grove, has a priority date of April 28, 1976 and authorizes the use of up to 33.0 cfs; and
- Certificate 85914, in the name of the City of Beaverton, has a priority date of July 15, 1980, and authorizes the use of up to 25.0 cfs.

The JWC manages Transfer T-11677, which added a point of diversion to enable the JWC to divert up to 4.46 cfs of water from Gales Creek at the SHPP Intake. However, water can only be diverted at the additional point of diversion (POD) from June 1 through September 30 if a streamflow gaging station with telemetry is installed at or near the original POD on Gales Creek and streamflow measurements are taken using a protocol and following a frequency stated in the Final Order approving Transfer T-11677. Transfer T-11677 has a priority date of February 14, 1947, and a development deadline of October, 1, 2035.

The JWC holds Permit S-54737, which allows up to 75.0 cfs to be diverted from Scoggins Creek for municipal purposes from October 1 through May 31. Diversion of water under Permit S-54737 is currently limited to 26.0 cfs due to the development limitations in the extension of time dated September 9, 2010 and the subsequent WMCP Final Order dated September 14, 2010. The priority date of this permit is June 9, 1988, which makes it a junior water right in the Tualatin River Basin. This right is subordinate to the fill schedule of Scoggins Reservoir, and requires bypass of 20 cfs from October 1 through November 30 and 15 cfs from December 1 through May 31.

The JWC has Application S-88506 pending at OWRD requesting a water right for municipal use of up to 44 cfs from the Tualatin River. The requested permit is intended to increase the reliability of the JWC's water supply during a portion of the non-peak season (December 1 through April 30). The permit would not, however, provide additional water supply, because use of water under the requested permit, in combination with use of the 75 cfs authorized by Permit S-54737, will be limited to a total of 75 cfs. The priority date of the water right would be January 31, 2018.

Storage Rights and Secondary Rights to Use Stored Water

In addition to using direct diversion or "natural flow" water rights, the JWC uses water rights to store water and secondary water rights to use the stored water in order to meet the existing water demands within its system. These water rights are associated with Barney Reservoir and Scoggins Reservoir (Hagg Lake).

Barney Reservoir

The storage and secondary rights associated with Barney Reservoir are: Certificates 81020, 81021, 81023, and 81024 in the name of the City of Hillsboro; 81022 in the name of the City of Forest Grove; and Permit S-55219 in the name of Barney Reservoir Joint Ownership Commission (BRJOC). The stored water in the reservoir is currently allocated among JWC members by agreements through the BRJOC, and some of the water is also released for Clean Water Services and ODFW.

- Certificates 81023 and 81024, combined, authorize storage of up to 20,000 acre-feet of water from the Middle Fork of the North Fork Trask River in Barney Reservoir.
  - Certificate 81023 has a priority date of December 23, 1971, and authorizes the storage of water for pollution abatement. Clean Water Services manages releases of this stored water for pollution abatement in the Tualatin River.
  - Certificate 81024 has priority dates of June 26, 1958, and December 10, 1965, and authorizes storage for municipal purposes.
- Certificates 81020, 81021, and 81022 and Permit S-55219 authorize the use of the water stored in Barney Reservoir.
  - Certificate 81020 has a priority date of June 26, 1958, and authorizes the use of up to 38.70 cfs for municipal purposes.
  - Certificate 81021 has a priority date of July 8, 1971, and authorizes the use of up to 30.0 cfs for pollution abatement.
  - Certificate 81022 has a priority date of June 24, 1971, and authorizes the use of up to 500 acre-feet of stored water for municipal purposes.
  - Permit S-55219 has a priority date of December 26, 2017, and authorizes the use of up to 30 cfs (limited to 8,734 AF) for municipal purposes.

Scoggins Reservoir

The Bureau of Reclamation holds Certificate 81149, which authorizes storage of up to 60,000 acre feet from Scoggins Creek in Scoggins Reservoir/Henry Hagg Lake for irrigation, municipal, water quality, fish, and recreation purposes. The Bureau of Reclamation has contracts with JWC member agencies (Hillsboro, Forest Grove, and Beaverton) to provide up to 13,500 acre-feet of stored water from the reservoir for municipal purposes under two secondary water rights. Certificate 87304 authorizes the use of up to 70 cfs (and up to 13,000 acre-feet) from Scoggins Reservoir. Certificate 93873 authorizes use of up to 500 acre-feet of water stored from Scoggins Reservoir during the irrigation season of each year.

Reservoir Storage and Release Management

The JWC actively participates in the Tualatin River Flow Management Technical Committee. This committee provides a mechanism for the coordination and management of flow in the Tualatin

River. The members of the committee are technical staff who possess detailed knowledge of specific flow and water quality characteristics of the Tualatin River and represent several stakeholders in the basin including the following agencies:

- Oregon Water Resources Department – Watermaster District 18
- Clean Water Services
- Joint Water Commission
- City of Hillsboro
- City of Forest Grove
- Tualatin Valley Irrigation District
- Lake Oswego Corporation
- Washington County - Emergency Management System

Since its inception in 1987, the Tualatin River Flow Management Technical Committee has prepared annual reports documenting the flow management of the Tualatin River. In addition to detailing reservoir releases and river withdrawals for each agency, these reports also highlight overall basin characteristics, such as precipitation patterns, water quality, and improvement projects. The communication and coordination among various Tualatin River users that comes from this committee is invaluable to the JWC. The annual flow reports can be viewed on the Washington County Watermaster's website (District 18) at http://www.co.washington.or.us/Watermaster/index.cfm

JWC ASR Program

The JWC (on behalf of the City of Hillsboro, City of Beaverton, and TVWD) holds ASR Limited License #019 (LL-019) to assess the feasibility of developing a regional ASR project in the Cooper Mountain vicinity. Each partner has access to one-third of the capacity of the Limited License.

OWRD most recently granted the JWC a five-year time renewal for ASR LL-019, from September 27, 2016 to September 27, 2021. ASR LL-019 was issued in the name of the JWC to authorize ASR pilot testing. It authorizes the storage of up to 2.1 billion gallons, which can be injected using up to 14 wells. Water can be injected at a maximum rate of 8,100 gpm (11.7 mgd). The JWC ASR limited license authorizes recovery of the stored water at a combined rate of up to 28,000 gpm (40.3 mgd). Recovery is limited to 2,000 gpm (2.9 mgd) at each of the 14 recovery wells, which are also the injection wells.

Thus far, development under ASR LL-019 has included development of ASR wells and test wells. No ASR pilot testing activities have occurred to date.

Non-JWC Water Rights Held By Member Agencies

City of Hillsboro

The City holds a 56 cfs portion of Permit S-55045, which authorizes the use of water from the Willamette River year-round for municipal purposes. The City of Salem assigned the City of Hillsboro a 56 cfs portion of the total permitted rate of 200 cfs in August 2016 and retained the remaining 144 cfs. Diversion of water under Permit S-55045 is currently limited to 30.94 cfs for the City of Hillsboro due to the development limitations in the extension of time dated July 31, 2015 and the subsequent Final Order approving the City of Hillsboro's WMCP dated August 28, 2017 (The City of Salem is currently not authorized to divert any water under Permit S-55045). The priority date of this permit is December 6, 1976. The current development timeline for this permit is October 1, 2086. Permit amendment T-12512 changed the authorized point of diversion for the City's 56 cfs portion of the permit to the Willamette River Intake near the City of Wilsonville. In addition, the City holds ASR Limited License LL-0274, which authorizes recovery of up to 1,725 gpm per well for up to three wells and storage of up to 900 MG.

As shown in Appendix C, the City has numerous non-municipal water rights for purposes other than potable water supply. The sources of these water rights include the Tualatin River, Barney Reservoir, McKay Creek and tributaries, Glencoe Swale, Beaverton Creek, Bronson Creek, Rock Creek and tributaries, Dairy Creek, a tributary to Jackson Slough, Sain Creek, a pond, wastewater effluent, and wells. The uses under these water rights include pollution abatement, irrigation, supplemental irrigation, multi-purpose storage, wetlands creation enhancement, wildlife, hydroelectric production, nursery operations, fish culture, aesthetics, storage of wastewater, and instream. Many of these water rights have been acquired through land acquisitions. The City's efforts identifying and tracking water rights acquired through land acquisitions are described in the City's 2017 WMCP.

City of Forest Grove

The City of Forest Grove has its own water treatment facility and holds a number of non-JWC natural flow water rights that can be used in conjunction with its JWC water supply. Forest Grove holds three certificates authorizing use of natural flow of up to 2.80 cfs from branches of Clear Creek, a tributary of Gales Creek, for municipal purposes. Certificate 2194 for the use of up to 0.8 cfs has a priority date of March 29, 1917, Certificate 13471 for the use of up to 1.0 cfs has a priority date of April 16, 1935, and Certificate 13797 for the use of up to 1.0 cfs has a priority date of July 27, 1939. Additionally, Forest Grove holds Certificate 92949 for the use of up to 4.46 cfs, being 2.43 cfs from Roaring Creek, and 2.83 cfs from Clear Creek for municipal purposes. Certificate 92949 has a priority date of April 28, 1976.

City of Beaverton

The City holds three non-JWC water rights: a surface water right for use of the Willamette River, a groundwater right (groundwater registration), and a limited license for the use of water for ASR.

The City's one groundwater registration (i.e. a claim to a groundwater right that pre-dates Oregon's Ground Water Act of 1955), GR-343, claims the right to use up to 1,350 gpm (3.01 cfs) for municipal purposes. The registration originally included two wells, with claimed priority dates of 1932 and 1945. The City amended GR-343 under GR modification T-10990 (approved September 3, 2014) to add six additional wells (ASR wells numbers two through seven) as authorized points of appropriation and to change the authorized place of use. The City amended GR-343 again under GR modification T-13012 (approved April 9, 2020) to add five points of appropriation (ASR 5, ASR 6K, ASR 3-IW1, ASR 3-IW2, and ASR 3-IW3).

The City and TVWD were issued ASR Limited License #002 (LL-002) in 1998, which authorized ASR pilot testing for 5 years (until 2003). OWRD subsequently renewed ASR LL-002 four times (2003, 2009, 2013, 2018). Most recently, OWRD extended ASR LL-002 to December 20, 2023. ASR LL-002 authorizes the storage of up to 1.5 billion gallons, which can be injected using up to 13 wells. The project's water sources are the Tualatin River, as authorized under the City's existing municipal water right Certificate 85914 (further described above), and the Bull Run River, as authorized by ORS 538.420. Water can be diverted from these sources for ASR purposes at a combined rate of 12.5 mgd, with diversion from the Bull Run River limited to 2 mgd. ASR LL-002 authorizes the recovery of the stored water for municipal use at a rate of up to 14.4 mgd, and specifies recovery rates of 1.5 mgd or 3.0 mgd for each of the 13 recovery wells, which also serve as the injection wells. To date, up to 954 MG has been stored in a single year and up to 6 mgd has been recovered from three wells.

The City also holds Permit S-54940, which authorizes the use of up to 33.7 cfs of water from the Willamette River year-round for municipal purposes and has a priority date of March 11, 2014. The current development timeline for this permit is May 4, 2035.

TVWD

TVWD holds five non-JWC water rights: a surface water right for use of the Willamette River, three groundwater rights, and a joint limited license for the use of water for ASR.

TVWD is the managing agency and a member of the Willamette River Water Coalition (WRWC), which holds Permit S-49240 modified by Permit Amendment T-10477. The WRWC also includes the Cities of Tigard, Tualatin, and Sherwood. This permit authorizes use of up to 202 cfs from the Willamette River year-round for municipal and industrial purposes and it has a priority date of June 19, 1973. Diversion of water under Permit S-49240 is currently limited to 80.1 cfs for TVWD due to the development limitations in the extension of time dated June 26, 2007 and the subsequent Final Order approving TVWD's WMCP dated January 16, 2015 (The City of Sherwood's diversion of water under Permit S-49240 is currently limited to 9.04 cfs as a result of the Final Order approving the City of Sherwood's WMCP dated December 20, 2018). To date, the cities of Tigard and Tualatin have not sought access to any water under Permit S-49240. The current development timeline for this permit is October 1, 2047. Currently, the City of Sherwood is the only WRWC member that is appropriating water under Permit S-49240.

TVWD holds three water rights for the use of groundwater for municipal purposes, all under Transfer T-11612 that added five points of appropriation to former Certificates 86081, 36440, and 36441. The water rights previously evidenced by Certificates 36440 and 36441 authorized the use of up to 1.1 cfs and 2.2 cfs of groundwater year-round, respectively. The water right evidenced by Certificate 86081 authorized the use of up to 0.58 cfs of groundwater from one well. This water right originally authorized the use of groundwater for irrigation use. As a result, it has a period of use limited to May 1 through September 30 and an annual volume limitation of 116 acre-feet.

As described above, TVWD and the City of Beaverton jointly hold ASR Limited License #002 (LL-002).

2.12. Aquatic Resources Concerns

OAR 690-086-140(5)

OAR 690-086-140(5) requires municipal water suppliers to identify the following for each of its water sources: (1) any listing of the source as water quality limited (and the water quality parameters for which the source was listed), (2) any streamflow-dependent species listed by a state or federal agency as sensitive, threatened, or endangered that are present in the source, and (3) any designation of the source as being in a state-designated Critical Groundwater Area.

2.12.1. Water Quality

The JWC's water rights authorize diversions on the Tualatin River and tributary creeks, and the Middle Fork of the North Fork Trask River. The Tualatin River and many of its tributaries are on the Department of Environmental Quality's (DEQ) 303(d) list for several water quality issues. Some JWC members also hold municipal water rights on the Willamette River and non-municipal water rights on tributaries in the Tualatin River basin that are 303(d) listed for multiple water quality impairments within the reach of the permitted points of diversion. Water quality issues by source are listed for JWC municipal water rights and for non-JWC municipal and non-municipal water rights held by JWC Member Agencies in Appendix D.

2.12.2. Listed Fish Species

Listed fish species with state or federal protections that occur in the Tualatin River watershed, Trask River watershed, and the Willamette River (at approximately River Mile 39) are summarized in Exhibit 2-62. The Trask River watershed contains JWC water sources, the Tualatin River watershed contains JWC water sources and non-JWC water sources held by JWC Member Agencies, and the Willamette River is a non-JWC water source held by some JWC Member Agencies.

Exhibit 2-62. Native Fish Species that Occur Within the Tualatin River Basin (includes JWC and non-JWC water sources held by JWC Member Agencies), Trask River Basin (includes JWC water source), and Willamette River (non-JWC water source held by JWC Member Agencies) that are Listed as Sensitive, Threatened, or Endangered Under the Oregon or Federal Endangered Species Acts

Listed Fish Species	Type of Listing		Evolutionarily Significant Unit (ESU)/ Species Management Unit (SMU) (i.e., Range of Federal/State Listing)	Affected Watershed(s)
	Federal	State		
Fall Chinook	Threatened	Sensitive-Critical	Lower Columbia River	Tualatin, Willamette
Spring Chinook	Threatened	Sensitive-Critical	Lower Columbia River, Upper Willamette River	Tualatin, Willamette
Coastal Cutthroat		Sensitive-Vulnerable, below Willamette Falls	Lower Columbia River, including up to Willamette Falls; Coastal Cutthroat Trout Species Management Unit (SMU)	Tualatin, Willamette, Trask
Coho Salmon	Threatened	Endangered	Lower Columbia River, including up to Willamette Falls	Tualatin, Willamette
Coastal Spring Chinook		Sensitive-Critical	Coastal Spring Chinook SMU	Trask
Coastal Coho Salmon	Threatened	Sensitive-Vulnerable	Coastal Coho Salmon SMU/ Oregon Coast	Trask
Coastal Winter Steelhead		Sensitive-Vulnerable	Oregon Coast	Trask
Winter Steelhead	Threatened	Sensitive-Critical	Lower Columbia River, Upper Willamette River	Tualatin, Willamette
Summer Steelhead		Sensitive-Vulnerable	Oregon Coast ESU/Coastal SMU	Trask
		Sensitive-Critical	Lower Columbia SMU/ESU	Tualatin, Willamette
Chum Salmon	Threatened	Sensitive-Critical	Columbia River	Tualatin, Willamette
Oregon Chub		Sensitive-Vulnerable	Willamette SMU	Tualatin, Willamette
Bull Trout		Sensitive-Vulnerable	Willamette SMU	Tualatin, Willamette

Listed Fish Species	Type of Listing		Evolutionarily Significant Unit (ESU)/ Species Management Unit (SMU) (i.e., Range of Federal/State Listing)	Affected Watershed(s)
	Federal	State		
Western Brook Lamprey		Sensitive-Vulnerable	Columbia River System	Tualatin, Willamette, Trask
Pacific Lamprey	Petitioned for listing	Sensitive-Vulnerable	Columbia River System	Tualatin, Willamette, Trask
Pacific Eulachon	Threatened	Sensitive-Vulnerable	Southern DPS, Northern Oregon and Washington	Tualatin, Willamette, Trask

Sources:

ESA listed species, from the National Oceanic and Atmospheric Administration (NOAA).
https://archive.fisheries.noaa.gov/wcr/publications/gis_maps/maps/salmon_steelhead/critical_habitat/wcr_salmonid_ch_esa_july2016.pdf

Oregon State Sensitive Species, from the Oregon Department of Fish and Wildlife:
https://www.dfw.state.or.us/wildlife/diversity/species/docs/2017_Sensitive_Species_List.pdf

Federal Species of Concern, from the U.S. Fish and Wildlife Service, Oregon Fish and Wildlife Office:
http://www.fws.gov/oregonfwo/Species/Data/PacificLamprey/default.asp

2.12.3. Critical Groundwater Areas

JWC Water rights

The JWC does not hold native groundwater rights for municipal water supply, so a critical groundwater area designation does not apply to its municipal water rights.

Non-JWC Water Rights held By Member Agencies

The Cities of Hillsboro and Forest Grove do not hold native groundwater rights for municipal water supply, so a critical groundwater area designation does not apply to their municipal water rights. The City of Hillsboro’s non-municipal groundwater rights are not located within critical groundwater areas. The City of Beaverton’s native groundwater right (groundwater registration GR-343 modified by T-10990) for municipal water supply is within the Cooper Mountain-Bull Mountain Critical Groundwater Area. The City of Beaverton’s ASR wells are located adjacent to the wells under the native groundwater right. TVWD’s groundwater rights are located within the Cooper Mountain-Bull Mountain Critical Groundwater Area, as well.

2.13. Evaluation of Water Rights and Supply

2.13.1. Tualatin River Basin and Barney Reservoir Water Supply

The amount of water available to satisfy the JWC's water rights is a function of streamflow, water right priority date, and stored water.

Almost all precipitation in the Tualatin River Basin falls as rain during the months of November through April. This leads to high winter flows, with peak flows on the magnitude of 2,000 to 3,200 cfs near the JWC WTP. Little precipitation occurs during the low-flow months of May through October. The lowest river flows, typically less than 200 cfs, occur during the months of July, August, and September.[10] In the months of June through September, the Tualatin River yields less than 2 percent of its total annual discharge.[11]

As with all waters in the State of Oregon, the waters of the Tualatin and Trask Rivers are administered through OWRD's water right process. The Tualatin River has numerous water rights for consumptive uses (e.g., irrigation, industrial and municipal uses) and non-consumptive uses (e.g., recreation, fish protection and pollution abatement). These water rights are all regulated under the prior appropriation system. During water shortages, senior water rights have priority, and the junior water rights may be curtailed or regulated off by the Tualatin River Basin Watermaster to serve the senior water right holders' needs.

Water rights in the Tualatin River Basin date back to 1880, and as a result, even the JWC's most senior natural flow water right with a priority date of January 22, 1912 (Certificate 81026) has the potential to be regulated off. Five times in the past six years, every Tualatin River natural flow right used by the JWC was regulated off because of low flows and junior priority dates. These occurred from: July 31 through August 7, 2015; September 2 through 19, 2017; and in 2018 from August 31 through September 12, September 21 through October 9, and October 29 through 31. The Watermaster looks at flows at the Golf Course gage to regulate most of the JWC's water rights.

Exhibit 2-63 depicts in "red" the JWC water rights that are typically regulated off during the peak season. Beginning in mid-May to early June, the following rights are typically regulated off: Certificates 85913, Certificate 85914, and Certificate 85916, and Transfer T-11677. In addition, the authorized season of use for Permit S-54737 (and Application S-88506 if a permit is issued) preclude use from June through October. Although not depicted in the exhibit, the two Sain Creek water rights are periodically regulated off in September, and in an average year, these natural flow water rights are available for use again in mid-October or early November.

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[10] USGS: *Sediment Oxygen Demand in the Tualatin River Basin*, Oregon 1992-1996.

[11] http://www.epa.gov/fedrgstr/EPA-IMPACT/2001/December/Day-13/i30775.htm

To provide water during low-flow summer months, JWC members currently rely on stored water, and as needed, individual member agencies rely on ASR, City of Portland, and non-JWC water rights. Starting in early June, JWC's releases from Scoggins and Barney Reservoirs can average 115 acre-feet per day for 140 days. The JWC stores water during November through April or May for use during the low-flow, peak season months. Exhibit 2-63 depicts in "yellow" the secondary water rights for use of stored water that the JWC typically does not use during the non-peak season: Certificate 81020, Certificate 87304, and Permit S-55219.

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Exhibit 2-63. JWC municipal water rights, monthly rates, seasonal volumes, and typical regulation during peak season

(Red = JWC water rights typically regulated off during the peak season; Yellow = secondary water rights for use of stored water that the JWC typically does not use during the non-peak season)

Source	Priority Date	Application and Permit	Certificate or Transfer	Entity name on water right	Type of Beneficial Use	Authorized Rate (cfs)	Authorized Volume (AF)	Monthly Rate or Seasonal Volume (cfs unless otherwise noted)												
								Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep 1-14	Sep 15-30	Oct	Nov	Dec
Sain Creek	1/22/1912	A: S-2016 P: S-1136	c. 81026	City of Hillsboro	MU	3	n/a	3	3	3	3	3	3	3	3	3	3	3	3	3
Sain Creek	5/1/1915	A: S-4250 P: S-2443	c. 81027	City of Hillsboro	MU	2	n/a	2	2	2	2	2	2	2	2	2	2	2	2	2
Tualatin River	8/15/1930	A: S-13681 P: S-10408	c. 67891	City of Hillsboro	MU	9	n/a	9	9	9	9	9	9	9	9	9	9	9	9	9
Tualatin River	2/6/1974	A: S-51643 P: S-46423	c. 85913	City of Hillsboro	MU	43	n/a	43	43	43	43	43	43	43	43	43	43	43	43	43
Tualatin River	7/15/1980	A: S-60357 P: S-45455	c. 85914	City of Beaverton	MU	25	n/a	25	25	25	25	25	25	25	0	0	25	25	25	25
Tualatin River	4/28/1976	A: S-54203 P: S-40615	c.85916	City of Forest Grove	MU	33	n/a	33	33	33	33	33	33	33	33	33	33	33	33	33
Scoggins Creek	6/9/1988	A: S-69637 P: S-54737	--	Joint Water Commission	MU	75	n/a	75	75	75	75	75	0	0	0	0	0	75	75	75
Tualatin River	1/31/2018	A: S-88506	--	Joint Water Commission	MU	44	n/a					0	0	0	0	0	0	0	0	
Gales Creek	2/14/1947	A: S-22251 P: S-17549	T-11677	Forest Grove	MU	4.46	n/a	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46
Middle Fork of the North Fork Trask River and (Barney Reservoir)	6/26/1958	A: S-32421 P: S-32139	c. 81020	City of Hillsboro	MU	38.7	n/a	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7
Scoggins Reservoir	2/20/1963	A: S-38447 P: S-35792	c. 87304	Bureau of Reclamation	MU	70	13,000	70	70	70	70	70	70	70	70	70	70	70	70	70
Barney Reservoir	12/26/2017	A: S-88492 P: S-55219	--	Barney Reservoir Joint Ownership Commission	MU	30	8734	30	30	30	30	30	30	30	30	30	30	30	30	30
Subtotals (With Typical Regulation)								**194.46**	**194.46**	**194.46**	**194.46**	**194.46**	**152.7**	**152.7**	**152.7**	**152.7**	**152.7**	**152.7**	**194.46**	**194.46**

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The reliability of Permit S-54737 (up to 75 cfs from Scoggins Creek during the non-peak season) is affected by permit extension conditions. As part of the municipal permit extension process, the Oregon Department of Fish and Wildlife (ODFW) recommended to OWRD that the extensions of time for this permit include conditions intended to “maintain the persistence of listed fish.” These conditions include curtailment beginning any time flows drop below 175 cfs at the point of diversion, which is the maximum authorized rate of Permit S-54737 (75 cfs) plus the target flows of 100 cfs on the Tualatin River measured at U.S. Geological Survey (USGS) Gage 14204800 (Golf Course Gage). If flows drop below 175 cfs, use of the undeveloped portion of the permit would be reduced based on the remaining flows measured at the Golf Course Gage as calculated and described in Permit S-54737. Exhibit 2-64 shows the curtailment flow under Permit S-54737, as well as average minimum flows from 2000 through 2018 and minimum flows in 2018. Exhibit 2-65 shows the number of days and range of months that the seven-day rolling average flow did not meet the above-described curtailment flows, as well as the rate and percentage by which the curtailment flows were missed. The curtailment flows often are not met in October as a result of such factors as low flows, ongoing water diversions by TVID, and refilling of Scoggins Reservoir. The curtailment flows often are not met in May as a result of such factors as increasing irrigation diversions, increasing municipal diversions, and refilling of Scoggins Reservoir.

Exhibit 2-64. Curtailment Flows for Fish Persistence in the Tualatin River for Permit S-54737, Measured at U.S. Geological Survey (USGS) Gage 14204800 at Golf Course Gage

Period	Curtailment Flow (cfs)	2000 - 2018 Averaged Minimum 7-day Rolling Average (cfs)	2018 Minimum 7-day Rolling Average (cfs)
October	175	91	85
November	175	169	53
December	175	549	90
January	175	719	1,079
February	175	543	406
March	175	679	524
April	175	477	555
May	175	179	81

Exhibit 2-65. Tualatin River Flows at Golf Course Gage (seven-day rolling average) compared to Permit S-54737 Curtailment Flows, 2000-2018

Year	Number of Days Flow Target Missed	Range	Average Deficit (cfs)	Average Deficit (%)	Max Deficit (cfs)	Max Deficit (%)
2008	61	October 1 - December 27	37	49%	75	100%
2009	39	October 1 - November 8	48	65%	75	100%
2010	26	October 1 - October 26	47	63%	71	94%
2011	50	October 1 - November 19	52	69%	75	100%
2012	29	October 1 - October 29	49	65%	70	94%
2013	46	May 2 - November 7	46	62%	70	93%
2014	37	January 4 - November 23	49	66%	69	92%
2015	74	April 27 - November 14	57	76%	75	100%
2016	36	May 6 - October 10	59	78%	75	100%
2017	28	October 1 - November 7	49	66%	65	87%
2018	79	May 18 - December 13	55	73%	75	100%
2019	92	May 8 - December 13	56	75%	75	100%

2.13.2. JWC ASR Program

TVWD and the Cities of Hillsboro and Beaverton have initiated an ASR project, which is authorized by ASR limited license #019 (held by the JWC). The limited license authorizes a maximum storage volume of 2.1 billion gallons and a maximum combined recovery rate of 40.3 mgd (62.3 mgd). To date, water has not been stored under this ASR limited license.

2.13.3. City of Beaverton/TVWD ASR Program

The City of Beaverton holds a joint ASR limited license with TVWD for a maximum authorized rate of 14.4 mgd from 13 wells. Water is injected into these wells under Certificate 85914 sourced from the Tualatin River via JWC.[12] In addition to the ASR limited license, the City of Beaverton holds groundwater rights totaling 3.06 cfs (1,350 gpm) from the same City of Beaverton wells used for their ASR operation. The City of Beaverton relies on two ASR wells to

[12] LL-019 allows water to be sourced from both the Tualatin River under Certificate 85914 and the Bull Run River under ORS 538.420, but Beaverton and TVWD sources only from the Tualatin River for their ASR programs.

meet its summer demand; these wells have a maximum combined capacity of approximately 5.0 mgd, although the optimal operating output for the wells is 2.0 mgd.

Although natural flow water rights served by JWC can have limitations (as described above), wintertime diversions for recharging of the ASR wells reduces the potential for surface water availability constraints because of greater winter stream flows. With that said, the ASR limited license does not have the same administrative protections of permitted or certificated water rights, and continued operations will have to meet OWRD's requirements, which could change over time.

2.13.4. TVWD Groundwater

TVWD's groundwater rights authorize the use of a total of up to 3.88 cfs. TVWD currently has three wells (Scheupbach, Grabhorn, and 189th Avenue) to appropriate groundwater under its groundwater rights. TVWD's current production capacity from these three wells is 3,036 gpm (6.8 cfs), which is sufficient to meet the maximum authorized rates of its existing groundwater rights. Two of the wells are used as emergency or backup supply sources (Scheupbach and 189th Avenue) while the other well (Grabhorn) is actively used for ASR.

Moreover, TVWD's groundwater rights are within the Cooper Mountain-Bull Mountain Critical Ground Water Area (CMBM CGWA). The CMBM CGWA order limits the total use of groundwater from the basalt aquifer within the CGWA to 2,900 acre-feet per year and provides that OWRD will allocate that amount among the existing water right holders. In recent years, the use of groundwater within the CGWA has been significantly less than the 2,900 acre-foot limitation. There is, however, no guarantee that groundwater use under existing water rights in the area will not increase in the future. In that event, OWRD could limit TVWD's use of groundwater to maintain the 2,900 acre-foot limitation. Despite this limitation, the water supply provided by these groundwater rights is relatively secure. The groundwater levels within the CMBM CGWA are stable or rising and TVWD's groundwater rights provide a reliable emergency or backup water supply.

2.13.5. Willamette River Water for Hillsboro, Beaverton, and TVWD

The Willamette River is scheduled to be a water supply source for TVWD, and the cities of Hillsboro and Beaverton in 2026. As previously described, the City of Hillsboro holds a 56 cfs portion of Permit S-55045 that will be used to meet future demands and to provide water supply redundancy. The City of Beaverton holds Permit S-54940 for 33.7 cfs that will be used to provide water supply redundancy and a reliable winter supply for recharging its ASR wells. TVWD will rely on water supply from the WRWC's Permit S-49240 to replace the wholesale purchase of City of Portland water. Permit S-49240 authorizes up to 202 cfs of withdrawal from the Willamette River. The reliability of these water rights on the Willamette River are described in the individual WMCPs developed by TVWD and the cities of Hillsboro and Beaverton.

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3. Water Conservation Element

This section satisfies the requirements of OAR 690-086-0150.

3.1. Introduction

This section of the WMCP addresses the water conservation activities undertaken by the JWC Member Agencies, as well as conservation efforts implemented regionally that result in reduced water use by JWC Member Agencies and their customers. Each Member Agency's current conservation efforts and those planned for the future are described.

3.2. Progress Report

OAR 690-086-0150(1)

The JWC developed a WMCP Progress Report in 2015, as required under the WMCP Final Order issued by OWRD on September 14, 2010. The 2015 JWC WMCP Progress Report described progress made towards implementing five-year water conservation benchmarks outlined in the OWRD-approved 2010 WMCP. Exhibits 3-1 through 3-4 presents an update of JWC Member Agency efforts to implement those five-year water conservation benchmarks.

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City of Hillsboro

Exhibit 3-1. City of Hillsboro Water Conservation Progress Report

Section Requirement	Sub-section Requirement	2010 Benchmarks	2019 Benchmark Status
OAR 690-086-150 (4) A description of the specific activities, along with a schedule that establishes five-year benchmarks, for implementation of each of the following conservation measures that are required of all municipal water suppliers:	(a) An annual water audit that includes a systematic and documented methodology for estimating any un-metered authorized and unauthorized uses	Continue to conduct annual water audit, collect water audits from other JWC members, and submit water audit information to OWRD.	The City continues to conduct annual water audits. The City ceased submitting water audit reports to OWRD on an annual basis after OWRD stated that it only wanted annual water audit reports with WMCP updates and progress reports.
		Install an AMR system.	See OAR 690-086-150(4)(b).
		Revise and improve the bulk water program used for construction purposes, including requiring contractors to rent a hydrant meter instead of estimating water use. The new program and policy will be adopted by the City's Utilities Commission by the end of 2010.	The City approved and implemented a new bulk water program in Spring 2010. Contractors are no longer allowed to estimate bulk water usage then pay based on that estimate. Contractors must use a hydrant meter and pay for the metered water usage.
	(b) If the system is not fully metered, a program to install meters on all un-metered water service connections.	Fully install an automated meter reading (AMR) system within 10 years.	The City completed its AMR install in October 2018, ahead of schedule, and all customers were transferred to monthly billing in May 2019.
		Continue to meter all connections.	All connections are metered.
	(c) A meter testing and maintenance program	Replace all City of Hillsboro and JWC sonic master meters with magnetic flow meters in the next treatment plant expansion project scheduled to occur between 2016 and 2020.	The City replaced all City of Hillsboro sonic master meters in Fall 2010 with magnetic meters. Replacement of these master meters has resulted in more accurate unaccounted-for water data. The City continues to track system gains/losses. JWC sonic master meters were also replaced in FY 2015/2016. The City also performs an annual meter audit on meters 3-inches or larger.
	(d) A rate structure under which customers' bills are based, at least in part, on the quantity of water metered at the service connections	Evaluate the potential impact on water conservation of adjusting its tiered rates during the next rate study planned for 2013.	The City completed the rate study and the most recent rate changes were made in January 2020.
		Continue to analyze the monthly and seasonal peaking of each customer category and compare those factors to the rate structure.	The City completed the rate study and adjusted the rate structure so each class is billed fairly for system demand.
	(e) If the annual water audit indicates that system leakage	Continue regular leak surveys and line maintenance to continue to decrease the loss in the system.	The City conducts leak surveys during the winter. Leaks are then evaluated for their potential water loss and fixed on a prioritized basis. The City has a leakage rate of less than 10%. In addition, the City

Section Requirement	Sub-section Requirement	2010 Benchmarks	2019 Benchmark Status
	exceeds 10 percent, a regularly scheduled and systematic program to detect leaks in the transmission and distribution system using methods and technology appropriate to the size and capabilities of the municipal water supplier;		purchased new leak detection equipment. From February 2016 - July 2019 the City surveyed 669 miles of pipeline and found 49 leaks.
		Use the new AMR program to more closely monitor for leaks resulting in even less water loss.	The AMR program is designed to flag both intermittent leaks and sustained leaks in the customer side of the distribution system. The City notifies the customer of the potential leak so the customer can take corrective action.
OAR 690-086-150 (6) If the supplier serves a population greater than 1,000 and proposes to expand or initiate diversion of water under an extended permit for which resource issues have been identified under OAR 690-086-0140(5)(i), or if the supplier serves a population greater than 7,500, description of the specific activities, along with a schedule that establishes five-year	(f) A public education program to encourage efficient water use and the use of low water use landscaping that includes regular communication of the supplier's water conservation activities and schedule to customers	Continue the aggressive public outreach conservation program.	The City continues to have an aggressive public outreach program. In 2010, the City added another Conservation staff person to further implement conservation programs. In 2011, the City added a residential WaterSense toilet rebate program and in 2014 an irrigation controller rebate program, and partnered on an indoor water and energy audit program with the Energy Trust of Oregon. In 2014, the audit program changed from including a site visit to operating completely online, and as of 2019, City staff conduct residential water audits. In 2013, the City designed a water-saving devices display board for events, which allows customers to only take the devices that they want to install rather than handing out generic conservation kits. The City continues to provide conservation information and water-saving devices at local events, such as the Latino Festival, Celebrate Hillsboro, County Fair, Earth Day events, Community Action Fair, and Watershed Tour Event. The City continues to implement its youth education program, which consists of classroom presentations about water resources that integrate water conservation messages. The Water Department continues to administer an annual conservation calendar for all elementary students related to water conservation messaging. Calendars are distributed to all participating schools. The City also contributes $1,000 and staff time to help coordinate the annual Clean Water Festival, a regional water educational learning opportunity for fourth graders. The City installed a Water Wise demonstration garden in Jackson Bottom Wetland Preserve in 2018 and continues to fund the garden for new plants and maintenance.
		Update the Hillsboro Water Department website to include more information on indoor and outdoor conservation tips by mid-2010.	The City continues to have the www.hillsborowater.org website. The City added descriptions of water conservation programs to the website, along with teacher resources for conservation education. The City continues to have the Regional Water Providers website www.regionalh2o.org, which has updated water conservation videos along with emergency preparedness information. The City added a gardening website, www.hillsborogardening.org with local sustainable plant options. The City also participated in several news segments about water conservation on several local news channels from 2013 – present. Since 2017 the City added a link to a Toilet Tips page and

Section Requirement	Sub-section Requirement	2010 Benchmarks	2019 Benchmark Status
benchmarks, for implementation of each of the following measures;			provided new links to "how to" water conservation videos. A new tree care webpage was added to the conservation section on the City's website to promote healthy tree care and water efficiency.
		Revamp overall website layout to make the information more accessible.	In 2010, the City launched a water supply website that included a water conservation section. The Water Department website will be revamped again in July 2021, which will include an updated water conservation webpage.
or documentation showing implementation of the measures is neither feasible nor appropriate for ensuring the efficient use of water and the prevention of waste	(a) A system-wide leak repair or line replacement program to reduce system leakage to 15 percent and if the reduction of system leakage to 15 percent is found to be feasible and appropriate, to reduce system leakage to 10 percent	Continue to maintain the leak adjustment policy and budget.	The City updated its leak adjustment policy in 2020. To ensure that leaks are fixed properly and to avoid fraud, a customer now only qualifies for a leak adjustment once in an eighteen-month period, and must provide authentic receipt as proof of payment for expenses related to leak repair. The City added a better explanation of how to check for leaks to its website.
		Continue to maintain an annual budget for the steel line replacement program targeting high priority aging infrastructure.	The City targets approximately $2 million per year in funded depreciation projects to replace high priority aging infrastructure. The actual dollar value budget varies each year based on revenue and overall expenditure projections. In 2011, the City replaced 6,666 linear feet and spent $600,000. In 2012, the City replaced 1,831 linear feet and spent $50,000. In 2013, the City replaced 9,662 linear feet and spent $235,000. In 2014, the City replaced 10,701 linear feet and spent $2.6 million. In FY 2015, the City replaced 9,953 linear feet and spent $147,000. In FY 2016, the City replaced 6,002 linear feet and spent $794,000. In FY 2017, the City replaced 4,901 linear feet and spent $1,704,000. In FY 2018, the City replaced 748 linear feet and spent $718,000. In FY 2019, the City replaced 227 linear feet and spent $11,000. From February 2016-July 2019, 669 miles of pipeline were surveyed and 49 leaks were repaired. *Cost for linear foot varies widely based on pipe size and scope of project. The cost of the 2014 pipe replacement includes a large scale replacement project on two major streets owned by ODOT - Oak and Baseline. The City uses its GIS system to track pipe age. This information is used to decide which part of the system is in most need of replacement when funded depreciation projects are chosen annually.
		Continue to adjust customer bills when leaks are repaired.	The City continues to adjust customer bills when leaks are repaired, according to the policy updated in 2020.
	(b) Technical and financial assistance programs to encourage and aid residential, commercial, and industrial	The Parks Department is considering expansion of its Community Garden program to other sites and the Water	In the past five years, the City has provided compost, water-wise gardening educational information, rain gauges, aqua spikes, and planting brochures to Cavalry and Sunrise Community Gardens. The City contributed compost and materials to City View Charter School's water-wise gardening program. In 2018, the City completed the Water Wise demonstration garden at Jackson Bottom. The

Section Requirement	Sub-section Requirement	2010 Benchmarks	2019 Benchmark Status
	customers in implementation of conservation measures;	Department will take its water-wise message, educational materials and water-conserving tools to those sites as well.	City has also provided mulch and multi-stream rotators that save up to 30% water at several parks in Hillsboro in partnership with the Hillsboro Parks Department. Signs have been displayed to educate public of these partnerships and water efficiency updates.
		Work with Master Gardeners at the Washington County Fair Complex Demonstration Garden to provide an educational showcase of water-wise gardening techniques for the general public.	In recent years, the Master Gardeners have said that they do not have a need for the City's assistance, so the City has focused on supporting other garden programs. The City has been assisting community gardens by providing compost and water-wise education materials and equipment. In 2010, the City assisted with the development of a water-wise demonstration garden at Dairy Creek in cooperation with Parks Dept. and local high school students. In 2011, the City partnered with City View Charter School and 4-H on a water-wise educational garden. In 2013, the City developed a partnership with Jackson Bottom to establish a water-wise demonstration garden and provided $5,000 for the project. The project was completed in 2018. Jackson Bottom is a City park and a high-traffic recreation area. The City continues to seek opportunities to promote water-wise gardening techniques at community garden events and considers the development of new gardens a priority. In addition, the City provided a water audit and expertise in behavioral changes to Calvary Lutheran Church in 2011.
		Become a member of the Alliance for Water Efficiency by 2010.	The City became an Alliance for Water Efficiency member in 2010.
	(c) Supplier financed retrofitting or replacement of existing inefficient water using fixtures, including distribution of residential conservation kits and rebates for customer investments in water conservation;	Complete a feasibility study (in conjunction with the City of Beaverton) on the most cost effective rebate programs within EPA's new WaterSense certification and labeling program by 2011.	The City completed the feasibility study in 2010 using funding from the Water Conservation, Reuse and Storage Grant Program (established by Senate Bill 1069). The City received a report from HDR with descriptions of potential WaterSense conservation programs to pursue. The report describes various types of rebate programs and included cost-benefit analyses.
		The feasibility study will analyze the types of rebate programs including landscape rebates, washing machines, low flow and high-efficiency toilets, and weather-based irrigation controllers.	The City presented results to the Utilities Commission in 2010 after receiving approval of the report from the State. In 2011, the Utilities Commission approved the recommendations to add WaterSense-labeled high-efficiency toilet rebates and to partner with the Energy Trust for affordable indoor audits. The City implemented both programs in 2011 and the programs are ongoing. In 2013, the City expanded the rebate program to include mobile homes, condominiums, and town homes if the residence is owned, even if the residence is served by a common meter. In addition to a water audit and expertise in behavioral changes that the City provided to Calvary Lutheran Church, City staff provided $1,500 in funding for toilet replacements. The retrofits

Section Requirement	Sub-section Requirement	2010 Benchmarks	2019 Benchmark Status
			reduced average daily usage an average of 470 gallons per day. The City currently offers rebates for water efficient toilets, weather-based irrigation controllers, and water efficient washing machines.
		The program will analyze the water savings and complete a cost benefit analysis of the different types of rebates including projected budgets for each organization.	The City monitored TVWD's ET controller pilot program. Based on what the City learned from TVWD and the rebate feasibility study, City staff decided to implement a similar ET program for City customers. In 2014, the City added $200 residential rebates for WaterSense-labeled Weather-Based Irrigation Controllers. The ET program has been very popular. The City consulted with TVWD staff to set up the program. In 2014, the City also funded a WaterSense-labeled Irrigation Controller for International Paper. From 2014 – 2019, the City has issued rebates for weather-based irrigation controllers at several commercial and HOA properties.
		By 2012, obtain data, determine how well waterless urinals work in a school setting, and evaluate the feasibility of encouraging Hillsboro School District and other non-profit, industrial, or commercial sites to consider making the change.	The City interviewed Forest Hills (previously known as Westside Lutheran) on the effectiveness, satisfaction level, and maintenance issues related to the waterless urinals pilot project. Forest Hills is very happy with the three waterless urinals that were installed in 2009. There were no problems with any aspects, including odor and drain lines, and the satisfaction level on performance is very high. No clear correlations could be made between reduced bills or consumption and the installations due to school enrollment changing from year to year. However, it is known that the new equipment uses less water than traditional fixtures, so savings are occurring. The maintenance and cleaning of this equipment is greater than traditional fixtures. Thus, their application in high-use settings is not highly recommended. If a specific customer expressed interest and a high level of commitment, attempts to partner would be made. In 2014, the City funded two additional urinals for the school as part of the City's efforts to increase water conservation among its industrial, commercial, and institutional customers. No problems have occurred with any aspect, including odor and drain lines, and the satisfaction level on performance continues to be high.
	(d) Adoption of rate structures, billing schedules, and other associated programs that support and encourage water conservation;	Continue to promote conservation based rate structures.	The City continues to promote a conservation-based rate structure. The City's Irrigation customer class rate is set high to promote conservation and to reduce water demand peaks during the summer season. The City occasionally talks with third-tier customers (customers with high enough water usage that their water use is charged at a higher, third-tier rate) about their water usage and the impact of the three-tier rate structure on their water bill. The City educates these customers and provides tips for lowering water use to help them stay out of the third tier. After completing the AMR meter install in October 2018, all customers were transferred to monthly billing in May 2019 to encourage water conservation by allowing customers to see their bills sooner. New rates continue to be implemented every year.
		Conduct a rate study by 2013, and determine if the adopted rate structure had the expected conservation results on water use by each customer category.	The City completed its latest rate study in 2018, and is in its third year of implementing rate recommendations. Rate adjustments are recommended in the study and considered by the Utilities Commission for implementation on an annual basis (usually in January of each year). The City continues to have a three-tiered water rate system. The base rate was frozen for residential

Section Requirement	Sub-section Requirement	2010 Benchmarks	2019 Benchmark Status
			customers the last two years, with the rate increase applying to the consumption rate only, to give customers more control over their water charges and encourage them to pursue conservation measures. The Multi-Family Class had its rate structure changed to include a peaking factor, in order to encourage reduced peaking and reward multi-family complexes that conserve water during summer (peaking) months. The next rate study is planned for 2023.
	(e) Water reuse, recycling, and non-potable water opportunities; and	Include a preliminary feasibility study related to water reuse in the City's high volume industrial areas in the next Hillsboro Water Master Plan in 2009.	The City completed the Water System Master Plan in 2014. Appendix 1.1 includes Tech Memo 07 on "Water Reuse - Waste Stream Quantity and Quality Analysis," and Tech Memo 08 on "Water Reuse - Water Reuse Treatment Process Requirements." The Water System Master Plan identified two sources of wastewater for reuse purposes: treated effluent from Clean Water Service's Rock Creek Advanced Wastewater Treatment Facility for domestic potable water supply, and the "process wastewater" stream from industries in the Hillsboro Dawson Creek area. The City continues to explore water reuse feasibility with Clean Water Services and other industrial customers. The City evaluated providing reuse water to a City park for irrigation, but the project was not implemented due to the significant infrastructure improvements identified.

City of Forest Grove

Exhibit 3-2. City of Forest Grove Water Conservation Progress Report

Section Requirement	Sub-section Requirement	2010 Benchmarks	2019 Benchmark Status
OAR 690-086-150 (4) A description of the specific activities, along with a schedule that establishes five-year benchmarks, for implementation of each of the following conservation measures that are required of all municipal water suppliers:	(a) An annual water audit that includes a systematic and documented methodology for estimating any un-metered authorized and unauthorized uses	By 2011, improve water audit record keeping and consider ways of changing computer software to better compare and report water use.	In 2012, the City implemented improvements in water audit record keeping. Production and consumption reports are generated and used to analyze water loss.
	(b) If the system is not fully metered, a program to install meters on all un-metered water service connections	Continue to meter all connections.	The City continues to meter all connections.
	(c) A meter testing and maintenance program	Convert all meters to AMR meters within the next 5 to 7 years.	The City completed its conversion to AMR meters and uses AMR meters for all new customer connections
	(d) A rate structure under which customers' bills are based, at least in part, on the quantity of water metered at the service connections	Continue a volumetric rate for each customer class and continue the three-tier rate structure for the single-family customer category.	The City continues to use a volumetric rate for each customer class and a three-tier rate structure for the single-family customer category.
	(e) If the annual water audit indicates that system leakage exceeds 10 percent, a regularly scheduled and systematic program to detect leaks in the transmission and distribution system using methods and technology appropriate to the size and capabilities of the municipal water supplier;	Continue the current leak detection and repair program.	The City continues to implement its leak detection and repair program as described in the JWC's 2010 WMCP. The City completed a project in early January 2015 to repair a leak at the Forest Grove Water Treatment Plant. The leak was estimated at 60-70 gallons per minute. The City also recently completed City Water Treatment Plant Filter Leak repairs and repaired a leak on a 5 MG storage reservoir.
	(f) A public education program to encourage efficient water use and the use of low water use	Continue the current public education activities.	The City continues to implement the public education activities described in the JWC's 2010 WMCP. The City also distributes low flow showerheads, hose nozzles, and faucet aerators and offers toilet rebates.

Section Requirement	Sub-section Requirement	2010 Benchmarks	2019 Benchmark Status
	landscaping that includes regular communication of the supplier's water conservation activities and schedule to customers	By 2012, expand the website to include more water conservation information, including a link to ET data.	The City is still working to add more water conservation information to its website, including a link to ET data.
OAR 690-086-150 (6) If the supplier serves a population greater than 1,000 and proposes to expand or initiate diversion of water under an extended permit for which resource issues have been identified under OAR 690-086-0140(5)(i), or if the supplier serves a population greater than 7,500, description of the specific activities, along with a schedule that establishes five-year benchmarks, for	(a) A system-wide leak repair or line replacement program to reduce system leakage to 15 percent and if the reduction of system leakage to 15 percent is found to be feasible and appropriate, to reduce system leakage to 10 percent	Continue the current system-wide leak repair program.	The City continues to implement its system-wide leak repair program, as described in the JWC's 2010 WMCP. The City conducts sonic leak tests on 50,000ft of system distribution piping per year (approximately 12% of the total system).
	(b) Technical and financial assistance programs to encourage and aid residential, commercial, and industrial customers in implementation of conservation measures;	Within 5 years, evaluate expanding the current home energy audit program to include more water conservation consultation.	The City evaluated the current home energy audit program and decided not to include more water conservation consultation at this time. The City will focus its resources on its other water conservation measures instead.
	(c) Supplier financed retrofitting or replacement of existing inefficient water using fixtures, including distribution of residential conservation kits and rebates for customer investments in water conservation;	In 2010, evaluate the potential costs, market penetration, and water savings from expansion of the rebate program to also include toilets, landscape equipment, and weather-based irrigation controllers.	The City Council created a goal to provide a residential high-efficiency toilet rebate and implemented the program in 7/1/19 ($525 distributed so far).
	(d) Adoption of rate structures, billing schedules, and other associated programs that support and encourage water conservation;	Continue providing conservation messages on water bills.	The City continues to provide water conservation messages in water bills.

Section Requirement	Sub-section Requirement	2010 Benchmarks	2019 Benchmark Status
implementation of each of the following measures; or documentation showing implementation of the measures is neither feasible nor appropriate for ensuring the efficient use of water and the prevention of waste	(e) Water reuse, recycling, and non-potable water opportunities; and	Continue to forward customer and business inquiries on water reuse and recycling to Clean Water Services.	The City continues to forward customer and business inquiries on water reuse and recycling to Clean Water Services.
		Continuing to recycle backwash water and to seek non-potable water use opportunities.	The City continues to recycle backwash water and to seek non-potable water use opportunities.
	(f) Any other conservation measures identified by the water supplier that would improve water use efficiency.	None.	None.

City of Beaverton

Exhibit 3-3. City of Beaverton Water Conservation Progress Report

Section Requirement	Sub-section Requirement	2010 Benchmarks	2019 Benchmark Status
OAR 690-086-150 (4) A description of the specific activities, along with a schedule that establishes five-year benchmarks, for implementation of each of the following conservation measures that are required of all municipal water suppliers:	(a) An annual water audit that includes a systematic and documented methodology for estimating any un-metered authorized and unauthorized uses	Continue to conduct an annual water audit and to participate in the JWC annual water audit program.	The City continues to conduct an annual water audit and to participate in the JWC annual water audit program. The City relocated and replaced the 36-inch master meter that was at Cornelius Pass Rd due to suspected errors in the old meter as the result of a lightning strike. The new magnetic meter is now located at the SE corner of Tualatin Valley Highway and SW 209th. The work was completed in early 2015 as part of the Reeds Crossing Waterline Project, which is a project to establish a connection between the JWC and the WWSP transmission systems.
	(b) If the system is not fully metered, a program to install meters on all un-metered water service connections.	Pilot an AMR program, and if feasible, replace approximately 10 percent of existing meters by 2015.	The City is fully metered and has approximately 18,500 meters. The City investigated an AMR program in 2010-2011 and found that the program would not have a reasonable economic benefit to the City under current pricing of AMR meters, including the field installation costs. The City also made contact over multiple years with PGE regarding the possibility of a joint fixed-network AMR system, which PGE was in the process of building for electrical power metering and data transfer. The City learned that PGE decided not to pursue the joint project in 2011. Since AMR was not found to be feasible for the City at this time, the City has been investigating a product called "Virtual Network," which is backed by Verizon and is supposed to be capable of retrofitting existing meters to achieve the equivalent of a fixed network automated meter reading system using cell phone technology.
	(c) A meter testing and maintenance program	Continue the current meter testing and maintenance program.	Continue the current meter testing and maintenance program, including annual testing of the largest meters.
		Continue the aggressive meter replacement program with a goal of replacing 700 residential meters annually, and commercial meters as needed.	The City replaced the following number of meters: 350 meters in 2010, 530 meters in 2011, 350 meters in 2012, 360 meters in 2013, and 440 meters in 2014. The City continues to replace 10-15 meters over 3 inches in diameter a year and replaces approximately 1,000 meters less than 3 inches in diameter each year.
	(d) A rate structure under which customers' bills are based, at least in part, on the quantity of water metered at the service connections	Conduct a rate study that will evaluate alternative rate structures intended to encourage water conservation. Present results of the study and recommended actions to the City Council by January 1, 2015.	The City completed a rate study in 2012 that evaluated rate alternatives and developed a rate model to test various rate modifications. The rate study determined that a "Tiered Rate Structure" is not in the best interest of the City at this time, because it would not be effective at helping to conserve water, would require a high administrative burden, and could not be carried out with the City's existing financial software. The City has implemented one recommendation from the study by increasing fixed monthly charges to improve revenue stability. The City's annual rates have increased approximately 5 percent per year in recent years by modifying base and commodity charges. Based on recommendations from an HDR study on System Development Costs, the City recently started reading meters monthly.

Section Requirement	Sub-section Requirement	2010 Benchmarks	2019 Benchmark Status
	(e) If the annual water audit indicates that system leakage exceeds 10 percent, a regularly scheduled and systematic program to detect leaks in the transmission and distribution system using methods and technology appropriate to the size and capabilities of the municipal water supplier;	Continue spending approximately $1,000,000 annually over the next five years on repairs, replacements, and upgrades to existing water distribution mains, including replacement of service lines, valves, fire hydrants and customer meters.	The City continues to implement its annual capital improvements program to identify old and leaking mains and replacement/renewal projects of high priority water lines. The City replaces water lines based on the history of leaks in a particular water line and cost-effectiveness, and is beginning to consider the need to replace water lines based on corrosion potential. The City's budget continues to meet or exceed $1 million for replacement/renewal of aging water distribution system facilities. Calls reporting leaks are logged and addressed by Public Works staff. The City contracts for leak detection surveys as needed.
	(f) A public education program to encourage efficient water use and the use of low water use landscaping that includes regular communication of the supplier's water conservation activities and schedule to customers	Continue to participate in local, JWC EEC, and regional public education and outreach activities as identified by the city and those particular committees.	The backbone of the City's conservation program is its participation in the long-running Regional Water Providers Consortium water conservation program, which has an aggressive media campaign and educational opportunities for the public. The City's annual water conservation budget is $34,000, of which $17,000 goes to the Consortium conservation program. The City continues to participate in local, JWC Education and Events Committee, and regional public education and outreach activities, such as the Children's Clean Water Festival. The City had 6 grade school water conservation performances and distributed conservation literature. The City annually staffs a conservation booth at large public gatherings, such as fairs and local farmers markets, where it provides conservation information and water savings devices. The City also provides water audits each year to large water customers. Conservation information and water savings devices are available to the public at City Hall and the City Public Library, as well.
OAR 690-086-150 (6) If the supplier serves a population greater than 1,000 and proposes to expand or initiate diversion of water under an	(a) A system-wide leak repair or line replacement program to reduce system leakage to 15 percent and if the reduction of system leakage to 15 percent is found to be feasible and appropriate, to reduce system leakage to 10 percent	Continue with an ongoing leak detection and distribution system replacement program to help keep unaccounted-for water rates below 10 percent.	The City has a leak detection and line replacement program, as described above. In addition, the City has asset-management software that helps City staff maintain the water system and stay aware of the age of water lines. The software tracks what the date of water line installation, location of installation, and waterline material. The following shows the number of miles of waterline replaced by year: 0.8 miles in 2010, 2.1 miles in 2011, 0.9 miles in 2012, and 0.2 miles in 2013. Since 2013, 2.9 miles of waterline has been replaced. The City's budget continues to meet or exceed $1 million for replacement or renewal of aging water distribution system facilities.
	(b) Technical and financial assistance programs to	In 2008-2009, conduct a water audit for the Beaverton School District, one of Beaverton's top ten water customers.	The City completed the Beaverton School District water audit.

Section Requirement	Sub-section Requirement	2010 Benchmarks	2019 Benchmark Status
extended permit for which resource issues have been identified under OAR 690-086-0140(5)(i), or if the supplier serves a population greater than 7,500, description of the specific activities, along with a schedule that establishes five-year benchmarks, for implementation of each of the following measures; or documentation showing implementation of the measures is neither feasible nor appropriate for ensuring the efficient use of water and the prevention of waste	encourage and aid residential, commercial, and industrial customers in implementation of conservation measures;	Continue to offer two free water audits per year for large water users.	In 2011, the City completed a water audit for a homeowners association that evaluated the common area irrigation system and identified many areas in need of maintenance and repairs. The City continues to offer two free water audits per year for large water users.
	(c) Supplier financed retrofitting or replacement of existing inefficient water using fixtures, including distribution of residential conservation kits and rebates for customer investments in water conservation;	Complete a feasibility study (in conjunction with the City of Hillsboro) on the most cost effective rebate programs within EPA's new WaterSense certification and labeling program by 2011. • The feasibility study will analyze the types of rebate programs including landscape rebates, washing machines, low flow and high-efficiency toilets, and weather-based irrigation controllers. • The program will analyze the water savings and complete a cost benefit analysis of the different types of rebates including projected budgets for each organization.	The City completed the feasibility study in 2010 using funding from the Water Conservation, Reuse and Storage Grant Program (established by Senate Bill 1069). In 2010, the Beaverton City Council approved a WaterSense-based rebate program to replace washing machines and toilets with more water efficient models. Annual funding of the program has ranged between $10,000 and $20,000. The program has resulted in the following number of rebates (by fiscal year): 131 toilet rebates in FY 2012-2013, 135 toilet rebates in FY 2013-2014, and 114 toilet rebates and 10 washing machines rebates in FY 2014-2015, 2017-18: Toilet - 144, Washing Machine - 8 FY 2018-19: Toilet - 190, Washing Machine – 45.
	(d) Adoption of rate structures, billing schedules, and other associated programs that support and encourage water conservation;	Conduct a rate study that will evaluate alternative rate structures intended to encourage water conservation. Present results of the study and recommended actions to the City Council by January 1, 2015.	As previously described, the City completed a rate study in 2012 that evaluated rate alternatives and developed a rate model to test various rate modifications. The rate study determined that a "Tiered Rate Structure" is not in the best interest of the City at this time, because it would not be effective at helping to conserve water, would require a high administration burden, and could not be carried out with the City's existing financial software. The City has implemented one recommendation from the study by increasing fixed monthly charges to improve revenue stability. The City's annual rates have increased approximately 5 percent per year in recent years by modifying base and commodity charges. Based on recommendations from an HDR study on Service Development Costs, the City recently started reading meters monthly. The City has always billed monthly for sewer and storm drain charges, and started billing monthly for water usage in June 2013.
		Evaluate the opportunity to develop a program of providing information/messages on water bills to encourage water conservation.	Currently, mailed water bills do not include a graphic of water use, but the City includes approximately 2 conservation inserts per year in mailed water bills. The City plans to use new hard copy bills in Spring 2016, which will have space for small water conservation messages. The City's website for online payments began showing previous water use in customer water bills in August

Section Requirement	Sub-section Requirement	2010 Benchmarks	2019 Benchmark Status
			2015 and the City has initiated discussions about adding water conservation messages to water bills. As of March 2014, approximately 27 percent of City customers pay online, and that percentage is expected to increase over time. The City is currently exploring the option of offering billing messages for customers using the online payment website.
	(e) Water reuse, recycling, and non-potable water opportunities; and	Continue to forward customer and business inquiries on water reuse and recycling to Clean Water Services.	The City continues to forward customer and business inquiries on water reuse and recycling to Clean Water Services.
		Consider non-potable water use opportunities as they arise, such as for city irrigation.	The City recently annexed 540 acres of undeveloped land and expect up to 13,000 residents to reside there as land is developed. The City is planning to use an existing ASR test well to serve non-potable water (for irrigation, toilet flushing, etc.) to new customers (e.g. new high school, fire station, commercial sites, and high density housing) through a "purple pipe" water distribution system.
	(f) Any other conservation measures identified by the water supplier that would improve water use efficiency.	Expand the ASR program by adding approximately two new wells over the next 5-10 years.	The City became one of three entities participating in a new JWC ASR program in 2010. The JWC ASR program participants conducted a major ASR feasibility study in 2010 to evaluate a potential ASR program on Cooper Mountain with up to 14 wells. The potential ASR program would store up to 2.5 billion gallons of treated drinking water from plentiful winter river flows and the JWC would pump out the stored water for summer use. This program would conserve a large amount of water currently withdrawn from surface water impoundments that release water into the Tualatin River, a water quality limited stream as designated by Oregon DEQ. The JWC ASR program participants drilled two 14-inch diameter wells to 1,000-ft depths as ASR test wells in 2011. Both test wells were successful and showed a future pumping capacity of 12 mgd to meet summer peak use, which can be used to reduce demands on surface water sources during periods of low flow. The City also is preparing to update its Water System Master Plan in FY 2015-2016, which will include recommended efforts to reduce unaccounted-for water and to increase water conservation.
			The City is a member of the Consortium and has enjoyed the benefits of membership including conservation programming opportunities.
			The City's Conservation Program Specialist regularly attends trainings to learn about new programs and technology that can improve the City's conservation program. Trainings include American Water Works Association (AWWA) workshops/conferences and an annual WaterSmart Innovations conference.
			The City is researching the possibility of performing a conservation measures cost-effectiveness analyses, which would identify other conservation measures that will deliver cost-effective and high-impact water savings.

Section Requirement	Sub-section Requirement	2010 Benchmarks	2019 Benchmark Status
			The City has observed that new residential development has a higher peaking factor than older residential developments and anticipates future residential growth will also have greater summer demand by comparison. Therefore, the City is considering targeting outdoor conservation measures to customers in these higher peak areas.

Exhibit 3-4. TVWD Water Conservation Progress Report

Section Requirement	Sub-section Requirement	2010 Benchmarks	2019 Benchmark Status
OAR 690-086-150 (4) A description of the specific activities, along with a schedule that establishes five-year benchmarks, for implementation of each of the following conservation measures that are required of all municipal water suppliers:	(a) An annual water audit that includes a systematic and documented methodology for estimating any un-metered authorized and unauthorized uses	Continue to conduct annual water audits and to submit annual water audits to the JWC.	The 2014 water audit indicated that water loss was negative, which TVWD attributes to historical malfunctioning of its main supply meter from the Portland Water Bureau. This issue was known and in the process of being addressed by PWB during that time period. After replacement of the main supply meter was completed in 2015, water loss estimates have consistently been within industry guidelines. From 2015 through 2019 water loss ranged from a high of 7.0% to a low of 2.4%. Water loss in 2019 was 4.7%.
		Examine water use data to determine trends or abrupt changes.	TVWD examines water use data to determine trends for abrupt changes on an ongoing basis. TVWD completed a thorough investigation of District operations and found no issues in its billing system or the operation of its interties with other water systems. TVWD has worked with neighboring water agencies to verify intertie valves are accounted for and in the "closed" position, and has been performing system leak audits in specific areas of the District.
	(b) If the system is not fully metered, a program to install meters on all un-metered water service connections.	Install AMR meters for all commercial accounts by 2013.	TVWD has installed AMR meters on approximately 96 percent of its 3-inch to 10-inch commercial accounts, which represents over 292 meters. This includes commercial (119), irrigation (4), multi-family residential (153), and production (16) meters. Some of these meters have data logging capability to aid in leak detection, troubleshooting, and conservation efforts. Any remaining non-AMR meters 3-inch and larger will be replaced as they fail to test to specification or as parts become difficult to acquire. Fireline meters are omitted as these assemblies are owned by the customers.
		Evaluate the feasibility of expanding the AMR program, including the possible water conservation benefits, by 2015.	Based on an assessment of the benefits, costs, and feasibility of a broader scale AMR program, TVWD expanded its AMR program. TVWD has installed 21,478 AMR meters.
	(c) A meter testing and maintenance program	Continue the current meter testing and maintenance program.	TVWD has continued its current meter testing and maintenance program. TVWD tests, repairs, or replaces as necessary all meters greater than 2-inches in diameter every two years or less. The 12 remaining large, non-AMR meters will be replaced as they reach the end of their functionality, as parts become difficult to acquire, or as opportunity projects arise. TVWD tests small meters (2 inches or less) in response to customer inquiries or deficiencies noted by staff.
	(d) A rate structure under which customers' bills are based, at least in part, on the quantity of water metered at the service connections	Continue the two-tiered inclining block rate structure.	TVWD continues to have a two-tiered inclining block volume usage charge, known as Block 1 and Block 2, to incentivize conservation. TVWD has used this water rate structure consistently since it was implemented in 1994.

Section Requirement	Sub-section Requirement	2010 Benchmarks	2019 Benchmark Status
	(e) If the annual water audit indicates that system leakage exceeds 10 percent, a regularly scheduled and systematic program to detect leaks in the transmission and distribution system using methods and technology appropriate to the size and capabilities of the municipal water supplier;	Continue to periodically perform leak detection surveys of portions of its system, and respond to identified leaks.	From 2015 through 2019 water loss ranged from a high of 7.0% to a low of 2.4%. Water loss in 2019 was 4.7%. TVWD continues to periodically perform leak detection surveys of portions of its system and to respond to identified leaks. TVWD has conducted several focused leak detection surveys since 2015. These surveys were conducted in isolated areas of the District to investigate specific, suspected leaks. Several different methods for leak detection are used, including: acoustical listing devices on valves, hydrants, and service lines; water quality testing to detect chlorine and fluoride; and investigating the presence of water in unexpected areas (e.g., surface water runoff occurring during periods of dry weather).
		Continue to educate customers about customer-side leak detection and repair and to notify customers of higher than normal usage.	TVWD continues to promote customer-side leak awareness through utility newsletters, its website, leak kits, participation in the Regional Water Providers Consortium's "Fix-a-Leak" month-long campaign, and Customer Service staff actively investigating and contacting customers with unusual meter readings or high water usage.
	(f) A public education program to encourage efficient water use and the use of low water use landscaping that includes regular communication of the supplier's water conservation activities and schedule to customers	Work with local schools to develop new and creative programs that foster water stewardship.	TVWD continues to implement a comprehensive Youth Education Program, which provides water conservation materials, presentations, and activities to students at elementary schools and regional events to foster water stewardship. As part of that program, TVWD staff has developed two new presentations ("Water Jeopardy" and "How Clean Is Your Drinking Water?"). TVWD has an active and strong relationship with multiple schools in its service area. Staff also hosts booths at various science fairs.

Section Requirement	Sub-section Requirement	2010 Benchmarks	2019 Benchmark Status
OAR 690-086-150 (6) If the supplier serves a population greater than 1,000 and proposes to expand or initiate diversion of water under an extended permit for which resource issues have been identified under OAR 690-086-0140(5)(i), or if the supplier serves a population greater than 7,500, description of the specific activities, along with a schedule that establishes five-year benchmarks, for implementation of each of the following measures; or documentation showing implementation	(a) A system-wide leak repair or line replacement program to reduce system leakage to 15 percent and if the reduction of system leakage to 15 percent is found to be feasible and appropriate, to reduce system leakage to 10 percent	Continue the current leak detection and repair and water line replacement program.	From 2015 through 2019 water loss ranged from a high of 7.0% to a low of 2.4%. Water loss in 2019 was 4.7%. Regardless of system leakage being less than 10%, TVWD continues to implement a comprehensive leak detection and repair program that emphasizes leak detection surveys and immediate repair of identified leaks. Additionally, TVWD's ongoing capital improvement plan (CIP) has invested approximately $18.4 million in mains replacement since 2014 (This excludes projects slated strictly for fire flow and includes County projects requiring relocations). Miles of water line replaced by year: 2014 - 0.68 miles 2016 - 1.44 miles 2018 - 1.29 miles 2015 - 0.83 miles 2017 - 1.56 miles 2019 - 1.57 miles
	(b) Technical and financial assistance programs to encourage and aid residential, commercial, and industrial customers in implementation of conservation measures;	Evaluate the home water assessment pilot program by 2012 and determine if the program will be continued or expanded.	In 2012, TVWD reviewed the home water assessment pilot program and decided to continue this program along with four other regional water providers. However, TVWD subsequently decided to discontinue contracted home water assessments through Energy Trust of Oregon, and instead have TVWD staff provide indoor and outdoor water use assessments to TVWD customer upon request and when recommended by staff due to high water use. Since Fiscal Year 2015-2016, TVWD staff has provided 14 indoor and 72 outdoor water use assessments.
		Continue to promote the Commercial, Industrial and Institutional (CII) program and use it as a platform for influencing large water users to conserve.	Commercial, Industrial, and Institutional (CII) customers continue to have access to rebates for the installation of high-efficiency toilets, weather-based irrigation controllers, high-efficiency irrigation nozzles, and customer organized proposals. Water use assessment services are also available to commercial customers. <u>Number of CII rebates in Calendar Year 2010</u> Toilet rebate: 101, Weather-Based Irrigation rebates: 18, Cooling Tower rebate: 1, Assessments: Landscape 169 irrigation zones, and Indoor Assessments: 12. <u>Number of CII rebates in Calendar Year 2011</u> Toilet rebate: 122, Weather-Based Irrigation rebates: 3, Multi-team Multi-trajectory Rotating Nozzle rebate: 124, Cooling Tower Rebate: 1, Assessments: Landscape 148 irrigation zones, and Indoor Assessments: 10. <u>Number of CII rebates in Calendar Year 2012</u> HET: 83, Weather-Based Irrigation rebates: 11, Multi-stream Multi-trajectory Rotating Nozzle rebate: 134, Customer Organized Proposal rebate: 1, Assessments: Landscape 295 irrigation zones, and Indoor Assessments: 13.

Section Requirement	Sub-section Requirement	2010 Benchmarks	2019 Benchmark Status
of the measures is neither feasible nor appropriate for ensuring the efficient use of water and the prevention of waste			Number of CII rebates in Calendar Year 2013 HET: 132, Weather-Based Irrigation rebates: 7, Multi-stream Multi-trajectory Rotating Nozzle rebate: 615, Customer Organized Proposal rebate: 1, Assessments: Landscape 4 sites, and Indoor Assessments:2. Number of CII rebates in Calendar Year 2014 HET: 154, Weather-Based Irrigation rebates: 3, Multi-stream Multi-trajectory Rotating Nozzle rebate: 725. Number of CII rebates in FY 2014-2015 Toilet: 468, Weather Based Irrigation Controllers: 12, Multi-stream Rotating Nozzles: 82. Number of CII rebates in FY 2015-2016 Toilet: 167, Weather Based Irrigation Controllers: 19, Multi-stream Rotating Nozzles: 0, Customer Organized Proposal rebate: 0. Number of CII rebates in FY 2016-2017 Toilet: 26, Weather Based Irrigation Controllers: 1, Multi-stream Rotating Nozzles: 0, Customer Organized Proposal rebate: 0. Number of CII rebates in FY 2017-2018 Toilet: 458, Weather Based Irrigation Controllers: 0, Multi-stream Rotating Nozzles: 0, Customer Organized Proposal rebate: 0. Number of CII rebates in FY 2018-2019 Toilet: 29, Weather Based Irrigation Controllers: 0, Multi-stream Rotating Nozzles: 0, Customer Organized Proposal rebate: 0.
		Continue current efforts to market the use of evapotranspiration to be used in landscape irrigation practices.	TVWD offers commercial and residential rebates to promote ET technology. TVWD offers workshops and presentations to educate customers and landscape professionals on ET technology. TVWD networks with manufactures and distributers to stay educated on new technologies and opportunities. The Water Efficient Demonstration Garden at TVWD headquarters incorporates ET technology to establish and apply irrigation schedules. TVWD has supported the continuous education of landscape construction professionals licensed through the Oregon Landscape Contractor's Board (LCB) and TVWD's Conservation Technician served as a member of the LCB Board from 2008-2013. In addition, TVWD presented to a variety of regional organizations during this time period, including but not limited to Washington County Master Gardeners (2019), Oregon Landscape Contractors Association Annual Expo (2017), and the Oregon Department of Transportation (2017).

Section Requirement	Sub-section Requirement	2010 Benchmarks	2019 Benchmark Status
	(d) Adoption of rate structures, billing schedules, and other associated programs that support and encourage water conservation;	Continue the two-tiered inclining block rate structure.	TVWD continues to have a two-tiered inclining block volume usage charge, known as Block 1 and Block 2, to incentivize conservation. Billing statements have a small space available for brief conservation messages.
	(e) Water reuse, recycling, and non-potable water opportunities; and	Develop opportunities to work with CII customers that will encourage re-use, recycling, and water conservation and water efficiency.	The District is solely a water provider; wastewater generated by the District's customers is conveyed by the Cities of Tigard, Beaverton, and Hillsboro, and Clean Water Services (CWS) to regional treatment facilities operated by CWS. CWS is an industry leader in developing new and innovative methods for reuse of water conveyed to the treatment facilities. The District's CII program also encourages commercial and production customers to recycle and reuse water, and to reduce their water consumption to the extent possible. As a regional participant in major water resource projects and the largest water supplier in Washington County, the District continues to support regional development of these efforts. Between FY 2013-2014 and FY 2018-2019 the District administered 2,064 CII rebates The Customer Organized Proposal Rebate program (COPR) provides rebates for water reuse and recycling projects, such as the elimination of single-pass cooling and improved cooling tower water treatment. The COPR is designed to be flexible and open enough to encourage innovative water reuse and recycling proposals from customers. No COPR rebates have been administered since 2015.
	(f) Any other conservation measures identified by the water supplier that would improve water use efficiency.	None.	TVWD has utilized several software tools to track the number of customers participating in the rebate programs since its inception. Tracking tools also estimate the potential conservation savings by performing cost-benefit analyses. TVWD is a member of: the Pacific Northwest Section-AWWA, Conservation Committee; Regional Water Providers Consortium Board and all committees; Alliance for Water Efficiency, WaterSense and Water-Efficient Products Committee; Irrigation Association, Smart Water Application Technology Technical Working Group; Oregon Landscape Contractors Association, and Landscape Expo Planning Committee. TVWD also is a partner with the EPA WaterSense program. TVWD staff is active in the development of regional conferences and training programs to ensure technical sessions in water conservation are represented. TVWD hosts various workshops, training sessions, and presentations that cover various topics including water efficient irrigation, evapotranspiration, soil composition, and seven steps to a water efficient landscape. TVWD staff efforts reach all customer classes, as well as landscape professionals and other trade ally groups. TVWD partners with private businesses collaborating to create long-term and sustainable changes in the landscape and irrigation products market.

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3.3. Current Conservation Measures

OAR 690-086-0150(3)

3.3.1. Regional Water Conservation Efforts

JWC Events and Education Committee

The JWC EEC was formed during the drought of 2001 to coordinate JWC partner conservation efforts.

The JWC EEC oversees public participation, joint public messaging, and outreach efforts in conservation and water science. Key objectives of the group include increasing name recognition for the JWC and educating Washington County customers about water conservation, backflow prevention, emergency preparedness, and the significance of the Tualatin Basin for water supply.

The JWC EEC has primarily used its website to reach its audience, along with public relations and occasional paid-media efforts. The annual events and website budget is $25,000. The JWC EEC uses the www.jwcwater.org site to promote water conservation. The site also contains a link to the Regional Water Providers Consortium (RWPC) website, www.regionalh2o.org. (More information about the RWPC is included below.) The RWPC website is the primary water conservation website for the tri-county area (Washington, Multnomah, and Clackamas Counties.) All JWC partners are members in the RWPC, share in development costs for the RWPC website, and rely on links to its extensive information, rather than duplicating web development individually.

The JWC participates in County-wide events that draw attendance throughout the county. The following are descriptions of the activities in which the EEC has chosen to participate:

Washington County Fair

The JWC uses this event to promote its high quality drinking water and educational water programs, including water conservation, to the entire county. JWC distributes free, fresh, cold water from a distribution board known as the Hometown Tap to hot and thirsty fairgoers as a means to engage in discussions about water conservation. Fair booth staffers from Hillsboro, Forest Grove, Beaverton, and TVWD also hand out dog tags, sunglasses, and writing tablets promoting the JWC website. Displays always include a water conservation component and illustrate a water educational theme. Plans are to make the Washington County Fair a 10-day fair in the near future.

Community Action Fairs

The JWC participates in the Washington County Community Action Fair because it serves all of Washington County. The Fair's objective is to provide information and other forms of utility assistance to minorities and other low-income groups. The Fair changes venues every couple of years and has been located in Hillsboro, Beaverton, and Aloha in recent years. The JWC staffs this event with at least one bilingual agency representative and hands out water-saving devices with tips in English and Spanish for lowering water usage.

Oregon International Air Show

The Oregon International Air Show is an annual event held at the Hillsboro Airport. The event began in 1988, and has an annual attendance of 65,000. The JWC has played an important role at the Oregon International Air Show since 2010 by providing two Hometown Tap water distribution boards. The Hometown Tap provides free cold drinking water on-site to Air Show attendees. The JWC also staffs a table to provide information on the JWC and to distribute logoed items.

Earth Day Fairs: Genentech and Intel

Genentech and Intel are among the largest industrial customers. JWC staffs a table at their employee Earth Day Fairs each year during Earth Week. Genentech and Intel staff live in all four partnering agencies, making these great events for JWC staff to attend. Outreach at these events are related to indoor conservation savings. JWC provides showerheads, bathroom and kitchen aerators, and leak detection tablets to attendees interested in saving water at home. The table is staffed by two JWC partner representatives. Although JWC has participated in these events for several years, Intel has put the Earth Day Fair on hold. If Intel decides to bring the fair back, we will partner in the event again.

The JWC serves a significant number of Spanish speaking customers and is working towards providing water conservation and outreach materials in both Spanish and English. In FY 2018/2019, as part of the RWPC's Strategic Plan initiative to increase accessibility of messaging and outreach materials, the RWPC undertook the following measures:

- **Added emergency preparedness messaging to the annual KUNP television campaign** so that it had conservation messaging for two months (July - August) and emergency preparedness messaging for one month (September) for a second year. The Consortium developed four new ads to use with the conservation campaign.
- **Developed a conservation-focused radio ad and purchased a month-long campaign on Bustos radio.** This was the first time that the Consortium's media campaigns included a Spanish radio buy.
- **Developed an Español section to the Regionalh2o.org website** that includes conservation and emergency preparedness information and resources. https://www.regionalh2o.org/Español
- **Developed and distributed two e-newsletters through a partnership with KUNP television.** The conservation issue was sent in June 2019 the emergency preparedness issue was sent September 2019. The e-newsletter has 25,000 recipients per issue.
- **Produced two how-to videos** "Como Encontrar una Fuga de Inodoro" (How to Check

Your Toilet for Leaks) and “Como Almacenar en Case de Emergencia” (How to Store Water in Case of an Emergency).

- **Collaborated with KUNP television, Community Engagement Liaisons (CELs), and other community partners** to translate conservation and emergency preparedness information and resources including two print pieces, regionalh2o.org, e-newsletters, and television campaign elements.
- **Collaborated with Oregon Landscape Contractors Association (OLCA) to develop two presentations in Spanish at their annual expo in December.** More than 75 people attended the two presentations “Protección de Reflujo y Prevención de Conexión Cruzada” (Backflow Protection & Cross Connection Prevention) and “Se Inteligente con Controladores de Riego Basados en el Clima con la Etiqueta WaterSense” (Get Smart with WaterSense Weather-Based Irrigation Controllers).

Regional Water Providers Consortium

A unique and invaluable component of the JWC member agencies’ water conservation programming is their participation in the RWPC. The RWPC was formed in 1996 by an Intergovernmental Agreement to coordinate the implementation of the Regional Water Supply Plan for the Portland Metropolitan Area. The conservation organization, the Columbia-Willamette Water Conservation Committee (CWWCC) was formed in 1993 and existed as a separate entity, though most of the member agencies were the same as the RWPC. The RWPC managers decided to bring the CWWCC under the RWPC to make the structure and budget easier to manage. Participation in the RWPC and the Consortium Conservation Committee (CCC) is voluntary and is funded through membership dues. An entity cannot participate in the CCC without first belonging to the RWPC. All JWC agencies are RWPC members and are active participants in program implementation, planning, and events. By working together, the member agencies can maximize their marketing dollars and effectiveness. The CCC also provides a forum where conservation programs and new technologies can be discussed, and new partnerships are formed.

As members of the RWPC, water providers retain full authority to manage their individual water systems. The RWPC has many functions, including intergovernmental coordination, source water protection strategy development and implementation, water conservation program implementation, emergency planning and response coordination, and public education. The RWPC is made up of a Board, Executive Committee, Technical Committee, Emergency Preparedness Committee and Conservation Committee, a four-person conservation staff provided by the City of Portland. The RWPC’s Strategic Plan and most recent Annual Report can be found at www.regionalh2o.org.

The RWPC's current strategic initiatives for conservation and meeting water needs are as follows:

- Make best use of available water resources and partnerships to meet regional water needs as outlined in the Regional Water Supply Plan
- Provide programs and resources that help water providers meet water conservation requirements
- Provide public education and outreach materials that promote conservation, source water protection, and the value of water
- Anticipate and respond to changes in demand, population, and customer in public expectations
- Increase accessibility of messaging and outreach materials to diverse audiences and stakeholders

The RWPC's water conservation program consists of the following elements:

- **Outreach materials and conservation devices**
  - The RWPC staff, in collaboration with member agency staff, develops water conservation materials for the use of its member agencies and for RWPC specific events. Each agency receives a certain quantity of each item, with the option to order additional pieces. The RWPC then orders them in bulk, which achieves significant economies of scale. All materials are also accessible as pdf files on the RWPC website.
  - The RWPC regularly purchases various water conservation devices and supplies member agencies with items for distribution to customers, such as outdoor watering gauges and shower timers. Indoor and outdoor kits are also advertised to RWPC member customers.
  - Outreach materials consist of more than 25 print pieces, social media, e-newsletters, and a robust website that includes:
    - how-to videos, rebates information, a weekly water number that informs customers how many inches of water said they should apply to turf in a given week, and indoor and outdoor water conservation tips and resources tips and resources.
  - Information is also provided in Spanish.
- **School assembly programs and Children's Clean Water Festival Sponsor**
  - RWPC partners with Mad Science to provide students with school assembly shows along with activity booklets.

  - The Clean Water Festival hosts roughly 1,400 4th grade students from the Portland Metro area in an event that teaches about the environmental and scientific impacts we have on water and water has on us. Experts from Oregon and Washington volunteer to teach 25-minute classes on water science and watershed ecology at Portland Community College's Sylvania campus. The RWPC, Hillsboro, TVWD, Forest Grove, and Beaverton provide funding to hold the event and are active members.

- **Community events and workshops**
  - Staff distribute outreach materials and devices to attendees.
  - 2018-2019 Events included:
    - Portland House and Outdoor Living Show
    - Children's Clean Water Festival
    - Association of Landscape Designers Garden Tour
    - Oregon Landscape Contractors Association Field Day (Presentations offered in Spanish and English).

- **Media campaigns**
  - The RWPC conducts two conservation-focused multi-media campaigns annually. The indoor-focused television campaign runs for about six-weeks each winter. The outdoor-focused campaign is a combination of television (English and Spanish language) and radio and runs three months each summer. In addition, the RWPC runs a regional website and social media presence throughout the year, which includes messaging, how to videos, and other resources for the public. The RWPC publishes the accomplishments of its multimedia campaigns and programs it its annual report each year on its website www.regionalh2.org.

- **Development of outreach materials**

  Conservation kits have been a key outreach material used by all of the JWC agencies. The RWPC and staff from member agencies have developed both indoor and outdoor conservation kits that are distributed to the public at a variety of events throughout the metro area. Many of the JWC members also distribute the conservation kits to their own customers upon request. However, customers may also request individual items, if they don't think they will use every item in the kit. The following details the contents of each kit.

Indoor Kit:

− One 5-minute shower timer

− One faucet aerator 2.0 gpm max flow rate

− One faucet aerator 1.5 gpm max flow rate

− One showerhead 2.0 gpm max flow rate

− Two toilet leak detector tablets

− Instruction sheet in English and Spanish

Outdoor Kit:

− Two 2-inch rain gauges

− One plastic hose nozzle with variable spray

− One hose timer 5-120 minutes

− One package of drought resistant plant seeds

− Information sheet on evapotranspiration

− Brochure on general outdoor conservation tips

− Brochure on lawn planting and care

- **Outreach events.** The RWPC conservation staff, along with staff from member agencies, tend informational booths at numerous community and regional events that include:
    1. OLCA Exposition – Staff provides information on outdoor conservation programs to professional landscapers at the Oregon Landscape Contractors Association show in December.
    2. Numerous Nursery Events – Throughout the tri-county region, the RWPC sponsors water conservation themed events at various nurseries including Drake's 7 Dees, Al's Garden Centers, Farmington Gardens, and Portland Nurseries.
    3. Children's Clean Water Festival – The RWPC provides funding for this festival, as well as a kid-themed conservation activity for a booth in the Exhibit Hall.

- **Website.** The RWPC website, www.regionalh2o.org, is a professionally-executed site devoted to conservation and emergency preparedness. This site's content was developed with feedback and input from the member agencies and RWPC staff. The site is assessed and upgraded regularly and there is a consultant dedicated to the site for over 20 hours per month. JWC member agencies are interactive in providing information and supporting the data needs of this website.

- **School programs.** The RWPC staff contracts with vendors to develop and present water conservation programs at elementary schools in the region. Currently, there are two programs, one for grades K-2 and one for grades 3-5. Each member agency is entitled to one free program per year at a school in its service area. The two shows offered by the RWPC rotate sponsorship year to year. Currently, Mad Science is touring and performing "Where's the Water Watson" for K – 2nd grade and "What do you know about H2O?" for the upper grades.

- **Regional Collaboration.** Perhaps the most important function of the RWPC conservation staff is to facilitate ongoing and effective collaboration among the region's conservation professionals and to ensure that all agencies will benefit from the RWPC's programming. The RWPC members also benefit from pooling the resources of the individual agencies to reach a broader audience and develop more effective programs. The RWPC is a key component of water conservation outreach and marketing in the Portland metro region for all member agencies.

JWC's Transmission Line Inspection Project

In 2006, JWC decided to inspect the transmission lines to determine their condition and integrity. The goals of the inspection project included the following.

- Assess pipe condition, including conducting a leak survey.
- Identify areas where the pipe's mortar coating may be damaged.
- Excavate and visually inspect suspected areas of corrosion.
- Install cathodic protection and/or monitoring devices to facilitate future monitoring of corrosion potential.
- Recommend corrective measures if necessary.
- We have undertaken an update of the corrosion protection study. The draft report is currently under review.
- Part of the JWC Master Plan will be to establish a comprehensive assessment program.

3.3.2. JWC Efforts: Current Conservation Measures

The JWC supports conservation through dues paid to regional water conservation organizations and through its individual member's conservation efforts. Each JWC Member Agency and wholesale customer pays a portion of the monthly operations and maintenance and administrative expenses for the JWC-owned facilities based on the amount of water supplied to each entity.

In addition to each JWC Member Agency's individual conservation measures, the JWC's rate structure encourages conservation. Each of the JWC Member Agencies pays for operations and maintenance expenses for the JWC Water Treatment Plant facilities, including administrative expenses, on a monthly basis. The charge is based on the amount of water use at the Member Agency's master meter connections. Each Member Agency's total metered water use is multiplied by the operation and maintenance expense rate. The method for calculating the expense rate is based on a 12-month rolling average of the operational and maintenance costs. This rate structure encourages conservation since lower water use by a particular member agency or wholesale water customer results in lower payments owed to the JWC. The JWC will conduct a rate study in the next few years to update these charges as needed.

Likewise, each JWC wholesale member agency receives similar monetary benefits for lower water use. Payments for wholesale water are based on the amount of water use at the wholesale agency's master meter connection multiplied by the wholesale water rate.

The following is a description of the current status of the JWC Member Agencies' conservation programming required under OAR 690-086-0150(3).

City of Hillsboro Conservation Highlights

- The City has a three-tiered rate structure for the single-family residential and a higher cost per unit when a base volume is exceeded for the commercial, public entities, and non-profit, customer categories.
- The 2020 Water Department Budget includes $2.3 million in Funded Depreciation funds for capital replacement projects. This money is used to replace aging and out-of-date water infrastructure.
- The City distributes free leak detection tablets, bathroom and kitchen sink aerators, showerheads, and shower timers at the utility billing office.
- The City's water conservation education program elements include several websites promoting water conservation, water conservation presentations and activities for youth, "how to" videos that help customers reduce water use inside and outside the home, distribution of devices and information that encourage community gardeners to conserve water, and outreach at local and regional events.
- The City now offers water audits for single family and multi-family residences.

City of Forest Grove Conservation Highlights

- The City distributes indoor and outdoor water conservation items, including low flow showerheads, hose nozzles, and faucet aerators, to residential customers.
- In July of 2019, the City expanded its water-efficient toilet rebate program and $525 in rebates have been given out since this time.
- The City includes water conservation messages bi-annually and graphs depicting customer water use over time in its water bills to encourage customers to be aware of their usage and to conserve water.

- The City bills water usage using a progressive three tiered increasing block rate structure for single-family and residential customers to encourage water conservation through economic incentive.
- The City is exploring the possibility of switching the City over to an Advanced Metering Infrastructure (AMI) meter system for improved monitoring and communications of water usage.

City of Beaverton Conservation Highlights

- The City has secured a Water Infrastructure Finance and Innovation Act (WIFIA) grant from the EPA that is funding the conversion of all meters in the City to AMI meters. Approximately 5-10 percent of the City's AMR meters have already been converted to AMI.
- The City's budget exceeds $1 million for replacement and repair of aging water distribution system infrastructure.
- The City is committed to public education about water conservation. The City has a full time conservation program coordinator and a budget of $57,000 for conservation activities. The City is a member of the Regional Water Provider's consortium and the JWC's Education and Event Committee (EEC), and it works with these groups and independently to provide conduct water conservation outreach. Outreach includes television; radio; social media messaging campaigns; a comprehensive website focused on regional water conservation information, tools, and resources; school education programs tailored to different grade levels; and community outreach events and workshops.
- The City is developing a "purple pipe" program that would deliver water from ASR 3 via purple pipes to the SCM area. This project would help to offset surface water supply.
- The City is exploring the feasibility of storing treated stormwater in Well 3 to be used for irrigation in the SCM district. Stored water from Well 3 would be delivered via the purple pipe system and would help to offset potable demand.

TVWD Conservation Highlights

- TVWD has replaced nearly all non-single family residential class meters 3-inch and larger with Badger ORION AMR water meters. Many of these meters have data logging capability to aid leak detection troubleshooting and conservation efforts.
- The Portland Water Bureau, in collaboration with TVWD, replaced both the 24-inch and 42-inch meters at the main Portland intertie on the Washington County Supply Line in 2015 and 2019, respectively. These improvements have corrected the annual water loss figures.

- TVWD has a commercial, industrial, and institutional (CII) water conservation program to reduce non-residential water use, which includes technical assistance and water efficiency incentives, giveaways of free water-efficient pre-rent spray valves, and financial assistance through the Customer Organized Proposal Rebate program.
- TVWD uses software tools to track the number of customers participating in its rebate programs since their inception and to estimate the potential conservation savings.
- Since 2014, the District initiated several new conservation outreach programs including: mail postcards with water conservation material, water conservation email outreach, and advertising of existing conservation programs through door-to-door outreach and open-house style events.

3.4. City of Hillsboro

3.4.1. Water Use and Reporting Program

OAR 690-086-0150(2)

The City of Hillsboro manages the water use measurement and reporting program for the JWC managed water rights and for the JWC's facilities. The JWC’s water withdrawals are measured at two raw water meters in the raw water pipelines between the SHPP Intake and the JWC’s WTP. Since the 2010 JWC WMCP, the raw and finished water meters were replaced to ensure the highest accuracy. The City of Hillsboro’s water withdrawals at the Cherry Grove WTP are measured downstream of the WTP near the soda ash station. The City of Forest Grove tracks and reports water withdrawals at the Forest Grove WTP.

The water withdrawal measurements are used for reporting that complies with the measurement standards in OAR Chapter 690, Division 85. The JWC’s water use records can be found on the OWRD webpage: http://apps.wrd.state.or.us/apps/wr/wateruse_report/.

In addition to the measurement and reporting required by the water use reporting program, the JWC submits weekly withdrawal reports to the District 18 Watermaster during the peak season to coordinate stored water releases and instream flows. Furthermore, the JWC reports stored water releases annually to OWRD.

Currently, all the meters that measure flow from the JWC transmission lines to the Member Agency are owned by the respective Member. Recently, the JWC began a process to transfer ownership of all of master meters related to the JWC water system from JWC Member Agencies to the JWC in order to standardize maintenance and record keeping.

3.4.2. Required Conservation Programs

OAR 690-086-0150(4)

OAR 690-086-150(4) requires that all water suppliers establish five-year benchmarks for implementing the following water management and conservation measures:

- Annual water audit
- System-wide metering
- Meter testing and maintenance
- Unit-based billing
- Water Loss Analysis
- Public education

Five-Year Benchmarks for Required Conservation Measures

During the next five years, the City plans to initiate, continue, or expand the following conservation measures that are required of all municipal water suppliers.

Annual Water Audit

The City conducts annual water audits. The City calculates water loss as the difference between total water demand and total metered consumption. To calculate water loss, the City tracks annual water demand and metered water consumption. Water loss represents the sum of unmetered uses (e.g. hydrant flushing and distribution system flushing), system leakage, overflows, and inaccurate measurements at the production or customer meters. The City estimates the volume of water used for distribution system flushing and tracks the volume of water used for construction purposes. Contractors use a hydrant meter and pay for the metered water usage.

The City's water loss in 2019 was 1%. The City's accounting of water loss has improved since the 2017 Hillsboro WMCP as a result of City actions such as: replacing all sonic master meters with magnetic master meters and installing Automated Meter Reading (AMR) meters.

In addition, the City has taken steps towards beginning to use AWWA's M36 water loss analysis tool to enhance its water auditing practices. The Water Loss Analysis discussion below further describes the City's efforts to increase efficiency.

Five-Year Benchmarks: The City will continue to conduct annual water audits. The City will integrate an AWWA M36 water loss analysis into its water auditing practices.

System-wide Metering

The City is completely metered. The City installs meters that are 2 inches or smaller and hires contractors to install larger meters on new connections. The City recently converted to an AMR system, replacing all existing meters with AMR meters. The City plans to install AMR meters at all new connections moving forward. These AMR Neptune meters are equipped with notification alarms that indicate a leak is present when a meter runs continuously, or may be present when a meter runs for 18 hours. The new AMR system is also capable of alerting customers and Water Department staff when meters fail to function properly.

Five-Year Benchmarks: The City will continue to install meters at all new connections.

Meter Testing and Maintenance

The City manages the meter testing and maintenance program for the master meters that the City currently owns. The City has a biennial testing and maintenance program for meters less than three inches in diameter. The City tests meters three inches or larger annually, and it has a large meter replacement program that replaces 3 to 5 meters per year. Any meters that fail testing are promptly either rebuilt or replaced. The City has begun a program to add frequency testing program when testing sonic meters. Recently, the City replaced its sonic meters measuring raw water at SSFP and tests it annually. Replacement of these meters has resulted in more accurate water loss calculations.

Five-Year Benchmarks: The City will continue to implement its meter testing and maintenance programs and to follow manufacturer protocols for maintenance and calibration program for newly installed AMR meters.

Water Rate Structure

The City charges its retail water customers a base rate based on meter size and a usage rate based on the volume of water consumed. The City has a three-tiered rate structure for the single-family residential customer category and a higher cost per unit when a base volume is exceeded for the multi-family, commercial, industrial, public entities, and non-profit customer categories. The net impact of these rate structures is that customers pay a higher unit cost for water use above what is considered essential to life/basic needs, which encourages customers to conserve water to save money, and in the case of commercial, public entities, and non-profits, the goal is to encourage those customers to reduce their summer peaks. The rates are based on analyses in a rate study completed in 2019 and are designed to bill each customer category fairly for its share of system demand. Appendix E shows the water rates for the City's customer classes as of January 1, 2020.

Five-Year Benchmarks: The City will continue to bill customers based on the volume of water consumed, with pricing structures set to encourage conservation, especially during peak season. The City will continue to regularly conduct rate studies.

Water Loss Analysis

In 2019, the City's water loss was 1% of all water use. The City has numerous measures in place to minimize water loss.

The City has a comprehensive leak detection and repair program, which it recently enhanced. In 2016, the City bought $40,000 worth of leak detection equipment, including 10 data loggers, a correlator set, and active listening devices. The City also bought a vehicle and has outfitted it with a canopy, the newly purchased equipment for the leak detection program, and other tools and equipment (e.g. wrenches, keys for opening and closing valves, and water quality equipment). In addition, the City is now dedicating two employees to the year-round leak detection program. These two employees use leak detection equipment to check areas for leaks, which is a daily responsibility. When they are informed of leaks needing investigation, the employees prioritize repairs based on urgency, then either complete their current task or immediately respond. They use such information as quarter sections and addresses to plan and track the leak detection survey work. They also estimates leakage amounts for all leaks and this estimated volume is used to track their potential water loss. Leaks are then fixed on a prioritized basis based on the risk of injury and property damage. Leaks deemed as having immediate risk to injury or property damage are considered an emergency and are responded to immediately. Less urgent leaks are addressed as soon as the more urgent leaks are repaired.

The City also uses its AMR program to flag both intermittent leaks and sustained leaks on the customer side of the meter. The City notifies the customer of the potential leak so the customer can take corrective action. The City also has a policy (adopted in a 1988 resolution, updated in 2019) to adjust the leak portion of a customer's bill if the customer repairs the leak within 30 days of it being reported and provides proof of repair, and the customer hasn't received another leak adjustment over a prior 18-month period. The program is designed to encourage customers to identify and repair leaks in a timely manner.

The City targets allocation of $2.1 million per year in funded depreciation projects to replace high priority aging infrastructure, as well. (The actual dollar value budget varies each year based on revenue and overall expenditure projections). The City uses pipe age, tracked in GIS, to decide which part of the system is in the greatest need of replacement when funded depreciation projects are chosen annually.

From February 2016 to July 2019 the City surveyed 669 miles of pipeline and found and repaired 49 leaks. The survey began in areas suspected to have a high possibility of leaks, including the older areas of the distribution system. In addition, the City inspected all four distribution reservoirs for cracks and leaks in 2016.

Five-Year Benchmarks: The City will continue conducting leak surveys and utilizing its AMR meters in an effort to minimize water loss. The City will continue to budget for replacement of high priority aging infrastructure and will continue to inspect all four distribution reservoirs for cracks and leaks every five years.

Public Education

The City's public education program utilizes a variety of approaches to encourage customers to conserve water. The City communicates regularly with its customers via brochures, bill inserts, City newsletters, websites, local outreach events, social media, and other media outlets. The City also organizes local water conservation programs and water education outreach activities. The elements comprising the City's public education program are described in greater detail below.

Print and Media

The City's Water Department website (www.hillsborowater.org) contains water conservation information, descriptions of the City's water conservation programs, water-efficiency rebate information, a weekly watering tool to help Hillsboro residents know how much to water during summer months, and teacher resources for water conservation education. The website also contains a link to the Regional Water Providers Consortium (RWPC) conservation website (www.regionalh2o.org), which provides more detailed conservation tips and resources, web tools for assistance in water-wise planning, and water conservation.

The City provides a significant portion of the funding for RWPC Conservation Committee programs, served on the panel to select the web design firm for the RWPC website, and actively participates in web development for the site. In addition, the City has a water supply website (www.hillsborowatersupply.org) that includes water conservation content, and a sustainable gardening website (www.hillsborogardening.org) that suggests water-efficient planting guides and provides watering tips specific to our region. In 2016, the City hired a videographer who helped create "how-to" water conservation and other water education videos, including freeze protection and leak repair. Since 2016, several water conservation "how to" videos were added to the RWPC website and linked to the City's homepage. The City also has participated in several news segments about water conservation on local news stations.

Youth Education

The City's youth education program consists of classroom lessons about water resources that integrate water conservation messages. The City tailors these school lessons to match proper developmental stages for students and to ensure that the lessons meet state benchmarks, curriculum guidelines, and Science, Technology, Engineering, and Math (STEM) requirements. This specific lesson targeting results in an improved level of acceptance from teachers and deepens the City's ability to reach more students in more schools. The following are examples of classroom lessons.

K-2nd (Primary Benchmarks: Water Cycle, Weather):

Incredible Journey – A curriculum activity that uses beads for graphing a water drop's journey through the water cycle. This presentation meets state STEM requirements.

3rd-5th (Primary Benchmarks: Communities, Environment, Water Cycle):

Drop in the Bucket – Another activity that meets STEM requirement that visually demonstrates how little fresh water is actually available in the world for drinking.

Common Water – A STEM activity that was modified by staff to include a lesson on Hillsboro city history. Students learn how the water available in the Tualatin River Watershed is the same amount as what was available 200 years ago. They see how the water needs to be shared with people, plants, animals, fish, the river, etc.

Incredible, Edible Aquifer – An activity that teaches about point source pollution and what happens if an aquifer is depleted due to overuse.

The Long Haul – An activity that teaches how water was retrieved before pipes made the process as easy as turning on the tap. Students discuss how much less water was used back then per person and why, and if they would find ways to use less if they still had to haul water today. The lesson ends with ideas about how to reduce water use in current society, why that is still important, and why we should never take drinking water for granted.

Mad Science "Where's the Water Watson?" and "What do you know about H2O?" – Assembly programs that were developed by a joint venture between Mad Science, an organization that offers science programs, and the RWPC that teaches water science and conservation.

Upper Elementary (Primary Benchmarks: Basic Chemistry, States of Matter and Physical Properties):

Water Quality and Quantity – Teaches students the importance of high quality water and what that means for supply issues. Students are taught that high quality water is not available in endless quantities and as supplies are stretched source quality can deteriorate.

Since 2005, the City has hosted an annual calendar contest in which elementary school students enter water-themed drawings (primarily featuring water-wise tips) for a calendar. Themes have included "The Water Cycle" and "Having Fun with Water." Announcements for the yearly contest also share information about other school programs that the Water Department offers including stage shows for school assemblies and in-class presentations. Teachers often call for a presentation and then encourage their students to participate in the contest by illustrating the new water facts and conservation tips they have learned.

6th Grade and Above:

From Source to Tap – This in-depth lesson teaches students to care about their water and their watershed. It emphasizes how water demands grow but sources typically don't grow and how all life in a watershed is dependent on the supply. It also includes conversation about infrastructure, including why it is important that the City keep water loss to a minimum, and to find and repair leaks in its transmission and distribution lines. The lesson ends with focus on the students and their water usage. How much water do they use? What kind of demands does that put on the system? Why is it important to find and repair leaks at home? What is the student's "water footprint" on the environment and finally, what actions can they take to save water?

Water Quality Day – An all-day event focused on water quality and public health that includes presentations on how drinking water is treated and culminates in a field trip to the JWC's water treatment plant.

Water Audit Curriculum -- The City developed a water audit curriculum that can be implemented over a three-week period in middle schools. This is a partnership with the Hillsboro School District and Adelante Mujeres – Chicas Program. The goal is to empower, excite, encourage and engage middle school girls in STEM education and future careers.

The Water Department has begun coordinating with other city departments to provide a "one-stop shopping" opportunity for teachers. A webpage and brochure are under development that will inform teachers of all educational programs available through the City. The goal of this collaborative effort is to increase promotional efficiency of City-offered programs, and should increase the number of teachers participating in water educational programs in their classrooms.

Community (All Ages) Outreach

The Hillsboro Water Department puts a high priority on educational programs focused on reducing peak season water use. The Water Department has partnered with the Parks Department to run a community garden program, which encourages community gardeners to use water-wise gardening practices and provides information on the "how-to" of water-wise gardening at the gardeners yearly kick-off meeting. The City also provides incentive equipment and supplies for water-wise gardening. Tools and supplies include soaker hoses, compost, water-wise seeds, hose nozzles, and special nozzles called "Aqua Spikes." An Aqua Spike can be screwed on to a soda bottle full of water and inserted into the ground. Water is gradually delivered directly to the root-zone of nearby plantings, with very little water lost to evaporation.

The City's "Seven Steps for Water-Efficient Gardening" activity, which is commonly used at summer events, promotes water-wise plant choices and teaches proper planting techniques. Kids and adults choose water-wise seeds from a plethora of choices and then plant the seeds in a peat pot. While they follow the planting steps that are detailed in signage and also explained by staff, participants learn why it's important to amend dirt with compost to increase nutrient load and water-holding capacity and why they should use mulch to reduce evaporation and suppress weeds. Finally, the City encourages participants to water regularly until the seeds are established, then reduce or eliminate watering altogether.

In 2018, the City installed a water-wise demonstration garden at the Jackson Bottom Wetland Preserve site. The garden at Jackson Bottom is interactive, allowing preserve visitors to learn about water-wise gardening through observation. Classes on water-wise gardening can also be held on site.

City staff also provides both child and adult-oriented learning opportunities to other community organizations. Those groups include Boy and Girl Scout troops, the American Association of Retired Persons, Chicas (Adelante Mujeres), community garden groups, and civic organizations. The presentations are tailored to the individual group, such as a "Seven Steps to Water-Wise Gardening" presentation for gardening groups and presentations/tours tailored to meet requirements for waterworks badges when working with Scout troops.

Each year, the City contributes $1,000 and staff time to help coordinate the annual Children's Clean Water Festival, a regional water educational learning opportunity for fourth graders that includes a variety of interactive conservation activities.

In 2017, the City finished construction of a Tualatin River Watershed Display. The Watershed Display is used in both classroom activities and outreach events to promote source water protection and conservation efforts in the Tualatin Basin.

The City is expanding its "Hometown Tap" program. Hometown Taps are placed throughout the City where people can fill their water bottles. All Hometown Taps have information about the City's water system and water conservation tips posted. The City is creating a Seasonal Hometown Tap station that can be installed in a high event location in downtown Hillsboro that will remain on site from April to October. The artwork was created by a local artist that was selected by a committee comprised of City staff and downtown business members.

Five-Year Benchmarks: The City will continue its extensive public education and outreach programs. The City will explore the feasibility of developing a permanent Hometown Tap with educational displays at Gordon Faber Recreation Complex, a 7000-seat multipurpose sports complex that has seven full size baseball fields.

3.4.3. Additional Conservation Measures

OAR 690-086-0150(5)

OAR 690-086-0150(5) requires municipal water suppliers that serve a population greater than 1,000 and propose to expand or initiate the diversion of water under an extended permit for which resource issues have been identified, or if the population served is greater than 7,500, to provide a description of the specific activities, along with a five-year schedule to implement several additional conservation measures. The City meets both of these criteria.

Technical and Financial Assistance Programs

The City set aside $10,000 in its conservation budget each year from 2010-2015 to offer technical and financial incentives to commercial, multi-family, non-profits, and industrial customers throughout the City (ICI (Industrial, Commercial and Institutional) Program). In 2016, this budget increased from $10,000 to $20,000 to provide more conservation assistance to non-residential customers, especially in the area of outdoor irrigation. The City continues to offer financial and technical assistance to these customers on a case by case basis. Exhibit 3-5 is a table summarizing the ICI projects that occurred from 2014 to 2019 and associated costs.

Exhibit 3-5. Industrial Commercial and Institutional Rebate Projects 2014-2019

Year	Toilet (Count)	Toilet (Cost)	Washing Machine (Count)	Washing Machine (Cost)	Irrigation Controller (Count)	Irrigation Controller (Cost)	Mulch, Native Plants, Other (Count)	Mulch, Native Plants, Other (Cost)	Total Rebates (Count)	Total Rebates (Cost)
2014	5	$375	0	$0	0	$0	0	$0	5	$375
2015	6	$450	1	$50	1	$249	0	$0	8	$749
2016	13	$975	0	$0	1	$2,500	0	$0	14	$3,475
2017	1	$75	0	$0	4	$9,221	0	$0	5	$9,296
2018	0	$0	0	$0	5	$10,427	0	$0	5	$10,427
2019	0	$0	0	$0	1	$2,500	1	$2,500	2	$5,000
Total	25	$1,875	1	$50	12	$24,897	1	$2,500	39	$29,322

In 2019, the City partnered with a 200-unit apartment complex to check all units for toilet leaks, replace inefficient showerheads and replace bathroom and kitchen aerators. This resulted in an immediate estimated savings of 3,454,000 gallons per year.

In 2011, the City partnered with the Energy Trust of Oregon on an indoor water and energy audit program for residential customers. In 2014, the audit program changed from including a site visit to operating completely online. After the partnership with the Energy Trust ended, the City provided staff with specialized training in water auditing and then expanded its audit program in 2019 to include both free indoor and outdoor audits to residential customers conducted by City staff. These audits include checking for leaks, replacing showerheads and faucets with more efficient models and reviewing the Utility Bill with the customer.

The City has provided technical and financial assistance to the Hillsboro School District and Intel, its largest institutional and industrial customers. In 2008, the Pacific Northwest Section of AWWA deemed the City's School Audit Program the best non-residential conservation program run by a middle-sized agency. For Intel, the City hired a consultant (SBW Consulting) to provide a list of implementation recommendations, along with a cost/benefit analysis for which recommendations had the quickest payback. Intel is currently planning to expand their water reuse plant in order to reduce their water use further. In addition to providing the audit and recommendation report, the City and consultant also installed low-flow showerheads, low-flow faucet aerators, water-efficient toilets, and water-efficient pre-rinse spray heads on Intel's four campuses. This resulted in an immediate savings of 322,000 gallons per year.

In addition to providing a water audit and sharing expertise in behavioral changes, the City also provided Calvary Lutheran Church $1,500 in funding for toilet replacements. Hillsboro Water Department staff conducting the audit also discovered a significant leak. The retrofits and the leak repair reduced daily usage an average of 470 gallons per day, or 17,155 gallons per year – to less than half of the amount of water the church had been using before the audit.

The City assisted with funding for a WaterSense-labeled irrigation controller that waters based on evapotranspiration (ET) rates. In 2014, the City also funded a WaterSense-labeled Irrigation Controller for International Paper. In 2015, the City provided financial assistance to Avamere Rehabilitation Center for the replacement of water-chilled compressors for air-chilled compressors, which produces an estimated savings of 1.3 million gallons per year for the compressors and a 25% reduction in outdoor water use for the controller.

The City has also partnered with many Home Owner Associations (HOAs) and multi-family management companies to update irrigation controllers and other water-using technology. In 2015/2016 fiscal year, the City provided financial assistance (and some technical assistance as needed) to Avamere, Avana at Orenco Station, Brookwood HOA, and The Parks at Laurel Oaks HOA for the replacement of regular irrigation controllers with WaterSmart irrigation controllers. These replacements are estimated to result in 25% outdoor water savings in future years for the complexes.

The City continues to partner with its Parks Department to provide technical assistance and water saving devices. After completion of a successful weather station venture, the Water

Department and Parks Department worked together again in 2010, along with local high school students, on the City's very first demonstration garden project at Dairy Creek. The Water Department provided educational materials, water-conserving tools (such as rain gauges, soaker hoses, hose nozzles, water-wise seeds and aqua spikes) along with a load of compost for amending the soil to improve its water-holding capabilities. The garden had a very successful first year, and provided water-wise gardening examples for the entire community.

The success of the City's first community garden project at Calvary Lutheran Church led the City to provide assistance to other community gardens and to school gardening programs. The City subsequently began providing compost, water-wise gardening educational information, rain gauges, aqua spikes, and planting brochures to David Hill and Sonrise Community Gardens. In 2011, the City partnered with City View Charter School and 4-H group on a water-wise educational garden, contributing compost and materials. In 2013, the City developed a partnership with Jackson Bottom to establish a water-wise demonstration garden and provided $10,000 for the project. The City completed the garden in 2018, but continues to provide annual funding for maintenance and plants.

In 2015, the City installed water-wise planting strips surrounding its new parking lot for the Shute Park Aquatic and Recreational Center (SHARC). The new parking strips demonstrate a water-wise, non-grass alternative for parking strips to SHARC users and other members of the public.

The City has been partnering with the Parks Department to audit and make water conservation improvements at local parks. This includes a full audit of the irrigation system, changing irrigation spray heads to more efficient heads, providing mulch and posting signs to educate the public about the conservation improvements that took place. The partnership will continue to offset the annual rate increase. The City is one of our top 10 water users in the city, so water conservation is extremely important.

Five-Year Benchmarks: The City promotes itself as a water efficiency resource for the community, and will continue to set aside budget each year to offer technical and financial incentives to both residential and non-residential customers (known as the ICI Program). The City will continue to offer water saving devices to all classes of customers. The City will continue to offer residential water audits, and will explore offering water audits to additional customer classes. Staff will work closely with its ICI customers, including multi-family customers, to find innovative ways to reduce water use at those facilities through improved technology and maintenance. The City will also continue to seek opportunities to promote water-wise gardening techniques at community garden events and to develop new community and school water-wise gardens and outdoor areas, such as parking strips. The City will continue to provide City parks with technical and financial assistance that supports irrigation improvements.

Supplier Financed Retrofit or Replacement of Inefficient Fixtures

The City has a washing machine rebate program, toilet rebate program, weather based irrigation controller program, and provides free water-saving devices.

In 2010, the City used funding from OWRD's Water Conservation, Reuse and Storage Grant Program (established by Senate Bill 1069) to complete a WaterSense Rebate Feasibility Study to identify the most cost-effective rebate programs within the EPA's WaterSense certification and labeling program. The study's final report included descriptions and cost-benefit analyses of potential WaterSense conservation programs to pursue. In 2011, the Utilities Commission approved the recommendations to add WaterSense-labeled high-efficiency toilet rebates and to partner with the Energy Trust for affordable indoor audits.

The City implemented both study-recommended programs in 2011 and the programs are ongoing, however, the Energy Trust program has since evolved away from staff-intensive in-home inspections and has introduced a less intrusive process providing a do-it-yourself guide online. The City updated its program again in 2019 to include both indoor and outdoor home audits. The City also reviews the customer's utility bills with them during the free home audits. If customers understand how to read their utility bills, see how much water they are using, and how much that water use is costing them, they may be encouraged to take actions to conserve water.

The City currently offers a $50 washing machine rebate, $75 toilet rebate, and $200 weather based irrigation controller rebate. From FY 2012/2013 through December 2019, the City has given out 5,143 rebates at a cost to the City of $335,976. The high-efficiency toilet rebate program has given out 4,005 rebates for replacements of non-high efficiency toilets at a cost to the City of $300,375 to date. In 2013, the City expanded the rebate program to include mobile homes, condominiums, and town homes if the residence is owner-occupied, even if the residence is served by a common meter. The City also has also issued toilet rebates for various local businesses, as part of its ICI technical assistance program. Overall, the rebate program has been very popular and the City has continued to increase its conservation budget to match the rebate demands from the community. The current budget for the three rebates is $60,000.

As mentioned above, the City provided water-saving devices to the Hillsboro School District and Intel for the replacement of toilets, showerheads, faucet aerators and pre-rinse sprayheads. The City also provides water-saving devices at local events and uses a water-saving devices display board (designed by the City) for event, which allows customers to only take the specific devices that they want to install rather than handing out kits. Devices available include: leak detection tablets, bathroom and kitchen faucet aerators, water-efficient showerheads, and shower timers. The City does not currently track number of devices distributed.

The City ran a waterless urinal pilot project with Forest Hills Lutheran School, as described above. Waterless urinals have been successful at the school due to the dedication of maintenance staff and the relatively low volume of use. The success of waterless urinals depends highly on those two factors. Consequently, the City is willing to partner with and provide waterless urinal funding to ICI applicants that have urinals with low volumes of use and that demonstrate dedication to waterless urinal maintenance.

As previously described, the City also hired SWB Consulting to conduct urinal audits at several older Hillsboro School District schools. Instead of doing costly urinal replacements, SWB Consulting recommended throttling the shutoff valves on the existing urinals to cut the water requirements for flushing urinals approximately in half, an action that essentially carries no cost. In addition, the City provided some funding for toilet replacements at older schools in the Hillsboro School District.

Finally, the City monitored TVWD's evapotranspiration (ET) controller pilot program, and based on TVWD's experience and the 2010 WaterSense Rebate Feasibility Study, the City decided to implement a similar ET program. In 2014, the City began offering residential customers rebates of up to $200 for WaterSense-labeled weather-based irrigation controllers. The ET program has been very popular. Since the start of the program, the City has provided 176 residential controller rebates at a cost to the City of $30,019.

Five-Year Benchmarks: The City will continue to explore the feasibility and effectiveness of offering a rebate for Smart Water Monitoring devices to their residential customers. The City will continue to offer rebates to customers for replacement of high water use fixtures and/or devices with those that are engineered to be more water-efficient. The rebate program operates with some flexibility regarding what market transformations are needed to increase the availability of water efficient devices, along with consistency in Washington County with other water providers. The City will continue to offer free water saving devices, such as low-flow faucet aerators and low-flow showerheads.

Rate Structure and Billing Practices that Encourage Conservation

The City continues to promote a three-tiered conservation-based rate structure for the single-family residential class. City staff will provide an account review and offer advice on ways to conserve water whenever a customer expresses interest. When the City suspects that a customer has a leak, the City notifies them about the high water usage, or continuous flow at the meter, and suggests that the customer check for a leak using instructions provided on the Department webpage. The City talks regularly with customers and provides tips for lowering water use to help them keep their water usage under the amount that bills at the third-tier rate.

In 2019, the City finished installing AMR meters and moved all customers to monthly billing. The more immediate feedback on water usage provides customers the opportunity to reduce usage a month earlier than in the past, which can be particularly helpful in summer. A customer who would have received a bill in September for July/August usage, now will see July usage in August and may decrease usage, or call for conservation assistance, especially if outdoor watering has landed the customer in the third billing tier.

Improvements were made to customer utility bills, making them a more effective communication tool. The bills include graphs that show 13 months of past usage, enabling customers to compare water use to the same month the previous year and to recent months. Notes promoting conservation, or providing water efficiency tips are often placed on the customer bills, and sometimes customer conservation programs are promoted more in-depth using bill stuffer format. Finally, customers are notified when excessive use suggests that a customer account may be experience a water leak. These notifications are separate from the utility bills, but part of the utility bill program.

Customers calling Utility Billing to conduct business are put into a queue where they listen to prerecorded messages as they wait for a customer service representative. There is always at least one message promoting conservation programs for the queued customers, and all messages are recorded in English and Spanish.

Five-Year Benchmarks: The City will continue to have a three-tiered water rate system for the single family residential class to promote water use efficiency and to bill customers monthly. The City will continue to include graphs showing past usage and to include water conservation information in water bills. The City will also continue to explore the best ways to help their customers understand their water bills.

Water Reuse, Recycling, and Non-potable Opportunities

Clean Water Services (CWS) manages the water reuse program in Washington County. Wastewater from customers in the City's municipal water system is reclaimed by CWS at the Rock Creek Wastewater Treatment Facility.

The City's 2014 Water System Master Plan Appendix 1.1 includes Technical Memo 07 on "Water Reuse - Waste Stream Quantity and Quality Analysis," and Technical Memo 08 on "Water Reuse - Water Reuse Treatment Process Requirements" . These memos identified two sources of wastewater for reuse purposes: treated effluent from Clean Water Service's Rock Creek Advanced Wastewater Treatment Facility for domestic potable water supply, and the "process wastewater" stream from industries in the Hillsboro's Dawson Creek area. The City is exploring these water reuse opportunities and is encouraging customers, especially industrial water users, to investigate water reuse options. The City especially encourages the elimination of single-pass cooling, and provides technical assistance on improving cooling tower efficiencies on request. Intel is currently working on a plan to expand its on-site water reuse treatment facility and other industrial customers are exploring on-site water reuse, as well.

In addition, the City's system for cataloging and tracking non-municipal water rights may reveal non-potable water opportunities. As described in Section 2, when City Departments are purchasing or selling property, the Water Department is now contacted to perform a search for appurtenant water rights and assist with the land exchange if needed. The City's Water Department provides education, guidance, administrative support, and contracting with water rights consultants to other City Departments. The other City Departments then inform the Water Department of completed land acquisitions, at which point the Water Department begins tracking any appurtenant water rights. During this process, the Water Department will be evaluating the potential for non-potable water opportunities related to the new non-municipal water rights.

Five-Year Benchmarks: The City will continue to actively seek out opportunities for water recycling and non-potable opportunities. The City will continue to review newly acquired non-municipal water rights for potential non-potable water use opportunities.

Other Conservation Measures

The City is a member of the Regional Water Providers Consortium and the Alliance for Water Efficiency, and City staff is active on the Conservation Committee of the Pacific Northwest Section of the American Water Works Association (AWWA). Nationally, the City is a promotional partner with the EPA's WaterSense Program.

The Hillsboro Conservation Program Specialists regularly attends trainings to learn about new programs and technology that will improve the City's conservation program. Trainings include AWWA workshops/conferences and an annual WaterSmart Innovations conference. The Conservation Program Specialist and another staff member became a G3 Certified Watershed Wise Landscape Professional.

Five-Year Benchmarks: The City will continue to be a member of the Regional Water Providers Consortium, the Alliance for Water Efficiency, and an active participant on the Conservation Committee of the Pacific Northwest Section of the AWWA. The Conservation Program Specialist will continue to attend trainings and conferences that provide education and insight to potentially grow and enhance existing City conservation programs. The City will use GIS to map locations of rebate approvals in the City. As part of this effort, the City will complete a process to integrate data between different departments, such as Planning, Finance, and Water.

Exhibit 3-6 presents a summary of the City's 5-year water conservation benchmarks.

Exhibit 3-6. Hillsboro Five-Year Water Conservation Benchmark

Conservation Measures	Five-Year Benchmarks
Annual Water Audit	Continue to conduct annual water audits.
	Integrate an AWWA M36 water loss analysis into its water auditing practices.
System-wide Metering	Continue installing meters at all new connections.
Meter Testing and Maintenance	Continue to implement meter testing and maintenance program
	Continue to follow manufacturer protocols for maintenance and calibration program for newly installed AMR meters.
Water Rate Structure	Continue to bill customers based on the volume of water consumed, with pricing structures set to encourage conservation, especially during peak season.
	The City will continue to regularly conduct rate studies.

Conservation Measures	Five-Year Benchmarks
Water Loss Analysis	Continue to conduct leak surveys utilizing AMR program meters in an effort to minimize water loss.
	Continue to budget for replacement of high priority aging infrastructure.
	Continue to inspect all four distribution reservoirs for cracks and leaks every five years.
Public Education	Continue extensive public education and outreach programs.
	Explore the feasibility of developing a permanent Hometown Tap water system with educational displays at Gordon Faber Recreation Complex and highly attended event areas.
Technical and Financial Assistance Programs	Continue to set aside budget each year to offer technical and financial incentives to both residential and non-residential customers.
	Continue to offer technical and financial assistance to all classes of customers including free indoor and outdoor water conservation devices.
	Continue to offer residential water audits, and explore offering water audits to additional customer classes.
	Work closely with ICI customers, including multi-family customers, to find innovative ways to reduce water use through improved technology and maintenance.
	Continue to seek opportunities to promote water-wise gardening techniques at community garden events and to develop new community and school water-wise gardens and outdoor areas.
	Continue to provide City Parks with financial and technical assistance that supports irrigation improvements.
Supplier Financed Retrofit or Replacement of Inefficient Fixtures	Explore the feasibility and effectiveness of offering Smart Water Monitors to customers.
	Continue to offer rebates to customers for replacement of high water use fixtures and/or devices with those that are engineered to be more water-efficient.
	Continue to offer free water saving devices.

Conservation Measures	Five-Year Benchmarks
Rate Structure and Billing Practices that Encourage Conservation	Continue to have a three-tiered water rate system for the single family residential class to promote water use efficiency, bill customers monthly, include graphs showing past usage, and include water conservation information in water bills.
	Explore the best ways to help customers understand their water bills.
Water Reuse, Recycling, and Nonpotable Opportunities	Review newly acquired non-municipal water rights for potential non-potable water use opportunities.
	Continue to actively seek out opportunities for water recycling and non-potable opportunities.
Other Conservation Measures	The Conservation Program Specialist will continue to attend trainings and conferences that provide education and insight to potentially grow and enhance existing City conservation programs.
	The City will use GIS to map locations of rebate approvals in the City. As part of this effort, the City will complete a process to integrate data between different departments, such as Planning, Finance, and Water.
	Continue to be a member of the Regional Water Providers Consortium, the Alliance for Water Efficiency, and an active participant on the Conservation Committee of the Pacific Northwest Section of the AWWA.

3.5. City of Forest Grove

3.5.1. Water Use and Reporting Program

OAR 690-086-0150(2)

The City of Forest Grove has a water use measurement and reporting program that complies with the measurement standards in OAR Chapter 690, Division 85. Production records from the Forest Grove Water Treatment Plant and from the JWC Water Treatment Plant are used to determine total annual water production. There is one production meter at the Forest Grove Water Treatment Plant. The metering at the JWC Water Treatment Plant is described in the Hillsboro section. The City's water use records can be found on the OWRD webpage.

3.5.2. Required Conservation Programs

OAR 690-086-0150(4)

OAR 690-086-150(4) requires that all water suppliers establish five-year benchmarks for implementing the following water management and conservation measures:

- Annual water audit
- System-wide metering
- Meter testing and maintenance
- Unit-based billing
- Water Loss Analysis
- Public education

Annual water audit

Forest Grove conducts an annual audit and submits the results to the JWC. Hillsboro then submits the combined audit report to OWRD for the JWC member agencies. The City measures water loss as the difference between: (1) Forest Grove water treatment plant demand plus delivered flow from JWC water treatment plant, and (2) water sold to customers. The calculation is based on monthly records. Water loss ranged from 9% to 15% between 2015 and 2019, and was 15% in 2019. The Water Loss Analysis discussion below describes suspected sources of water loss and approaches to reduce water loss.

Five-Year Benchmark: The City will continue its annual water audits. The City will implement actions to improve the ease of accessing and reporting consumption data.

System Metering

Forest Grove is completely metered with AMR meters. The City is considering upgrading its system to AMI meters, which would increase customer access to consumption data by allowing them to see their water usage in real time.

The City is also in the process of replacing two of its master meters. This project will be completed in January 2020 and will help improve the accuracy of the City's system wide water audits.

Five-Year Benchmark: Forest Grove will continue to meter all connections. Forest Grove will finish replacing two of its master meters. Forest Grove will continue to explore the possibility of converting the City's system to AMI meters.

Meter testing and maintenance

Forest Grove tests 40 compound meters on an annual basis to check for accuracy. The City also has a meter replacement program in which all meters, including residential and commercial meters, are replaced every 15 years.

Five-Year Benchmark: The City will continue its regular meter testing and replacement program.

Rate structure

Forest Grove has a volumetric rate for each of the four customer classes (single-family residential, multi-family residential, commercial, and industrial). The single family rate (which accounted for an average of 46 percent of total consumption from 2008 through 2018) is a three-tier increasing-block structure. Appendix F presents Forest Grove's water rates as of July 1, 2019.

Five-Year Benchmark: Forest Grove will continue a volumetric rate for each customer class, and will continue its three-tier rate structure for the single-family customer category.

Water Loss Analysis

Forest Grove's water loss was 15.0 percent in 2019. Forest Grove suspects that leaks in old water lines in the Gales Creek service area are contributing to the elevated water loss percentage. Improvements in water production and consumption accounting practices, such as closer alignment of production and consumption meter readings, could also potentially reduce water loss.

Forest Grove is working diligently to address water loss in its system. In 2018, the City finished fixing leaky filters at the Forest Grove WTP and fixed leaks in the City's main storage tank. Fixing these two sources of water loss should immediately lead to significant water loss reduction. Twelve percent of Forest Grove's distribution system (approximately 50,000 linear feet of pipe) is sonically leak tested annually. Approximately 1 percent of the distribution is replaced on an annual basis. The Gales Creek service area will be a focus area for a leak detection.

Forest Grove understands that OAR 690-086-0150(4)(e)(A) and (B) requires it to provide a description and analysis identifying potential factors for loss and selected actions for remedy to OWRD within two years of approval of this WMCP, and if the selected actions do not reduce water loss to less than 10 percent within five years of approval of the WMCP, the City will have to take additional leak detection and repair measures.

Five-Year Benchmarks: Within two years of approval of this WMCP, the City shall provide OWRD with a description and analysis identifying potential factors for the water loss and selected actions for remedy. If the selected actions do not reduce water loss to less than 10 percent within five years of approval of the WMCP, the City will either develop and implement a regularly scheduled and systematic program to detect and repair leaks in the transmission and distribution system or develop and implement a water loss program consistent with AWWA standards.

Public Education

Forest Grove holds an annual open house at which there is a water conservation table and indoor and outdoor conservation fixtures are distributed (low-flow shower heads, hose nozzles, and faucet aerators). In addition, the City participates in various events coordinated by the RWPC and JWC EEC (see above). In addition, the City offers two RWPC school presentations per year. Conservation information is included with water bills bi-annually. The city's website also includes conservation information and tips, which were most recently updated in 2018.

Five-Year Benchmark: The City will continue to hold its annual open house, actively participate in RWPC and JWC EEC events, and update its website when appropriate.

3.5.3. Additional Conservation Measures

OAR 690-086-0150(5)

OAR 690-086-0150 (5) requires municipal water suppliers serving a population greater than 7,500 to implement an additional set of conservation measures or to provide documentation showing that implementation of the measures is neither feasible nor appropriate. Following are descriptions of Forest Grove's implementation to date and 5-year benchmarks for these measures.

Technical and financial assistance

Water-efficient showerheads, faucet aerators, hose nozzles, dye tablets for detecting toilet leaks, outdoor watering gauges, and shower timers are made available at the Forest Grove's Engineering office on a first-come first-served basis and some items are available at water conservation events.

In addition, Forest Grove has implemented a leak repair incentive program. If a leak that has resulted in a bill increase is identified and repaired by the resident, the city will investigate the issue on a case-by-case basis and re-rate consumption over the customer's typical usage from a comparable month at the current industrial rate, up to a maximum of six months.

Five-Year Benchmark: Forest Grove will continue to offer home energy audits that include fixture giveaways and will continue to offer free water conservation items.

Supplier Financed Retrofits and Replacement of Inefficient Fixtures

As described above, Forest Grove offers free water-efficient faucet aerators, showerheads, and hose nozzles at its Engineering office. Forest Grove provides a rebate for water-efficient toilets and heat pump water heaters in partnership with FGL&P. Forest Grove is also currently exploring the feasibility of implementing a rebate program for weather-based irrigation controllers.

Five-Year Benchmark: Forest Grove will continue to provide rebates for water-efficient washing machines, water heater pumps, and toilets. Forest Grove will explore the feasibility of implementing a rebate program for weather-based irrigation controllers.

Rate structures and billing schedules

Forest Grove's rate structure and associated benchmark was described in the previous section. In addition to the described rate structure, Forest Grove will continue its program of providing conservation messages on its water bills bi-annually.

Five-Year Benchmark: Forest Grove will continue to utilize its volumetric rate structure and continue to provide conservation messages with billing inserts.

Water reuse and recycling

Clean Water Services (CWS) is working with DEQ and exploring new water reuse opportunities. Clean Water Services' Forest Grove Wastewater Treatment Facility serves portions of Forest Grove and all of Cornelius and Gaston. The facility produces Class C recycled water which is applied at storage ponds adjacent to the facility. Some recycled water is used to irrigate two acres of native plants at a nursery.

During the dry season, the Forest Grove Wastewater Treatment Facility pumps all wastewater to the Rock Creek Advanced Wastewater Treatment Plant for higher level of treatment. Forest Grove has a conventional filter water treatment plant that requires frequent backwashing of the filters. The backwash water is sent to a settling pond. In 2006, a "recycle" line was added to the settling pond so the water can be put back through the water treatment plant for distribution.

Two examples of opportunities to evaluate the use of non-potable water include Pacific University incorporating rain water harvesting into a new dormitory and the Forest Grove School District irrigating with non-potable water from Tualatin Valley Irrigation District. Clean Water Services is also proposing development of a natural treatment system (NTS) consisting of treatment wetlands in conjunction with surface and hyporheic discharge near the Forest Grove Wastewater Treatment Facility.

Five-Year Benchmark: Forest Grove will continue to forward customer and business inquiries on water reuse and recycling to CWS, as well as continuing to recycle backwash water. Forest Grove will seek non-potable water use opportunities.

Other Conservation Measures

Forest Grove is a member of the AWWA and RWPC.

Five-Year Benchmark: Forest Grove will continue to participate in the AWWA and RWPC.

Exhibit 3-7 presents a summary of the City's 5-year water conservation benchmarks.

Exhibit 3-7. Summary of 5-year conservation benchmarks

Conservation Measures	Five-Year Benchmarks
Annual Water Audit	Continue annual water audits
System-wide Metering	Replace two master meters
	Explore switching the City to an AMI system
Meter Testing and Maintenance	Continue regular meter testing and replacement program
Water Rate Structure and Billing Practices that Encourage Conservation	Continue volumetric rate structure for each customer class
Water Loss Analysis	Within two years of approval of this WMCP, the City shall provide OWRD with a description and analysis identifying potential factors for the water loss and selected actions for remedy. If the selected actions do not reduce water loss to less than 10 percent within five years of approval of the WMCP, the City will either develop and implement a regularly scheduled and systematic program to detect and repair leaks in the transmission and distribution system or develop and implement a water loss program consistent with AWWA standards.
Public Education	Continue to hold an annual open house, participate in RWPC and JWC EEC events, and update the City website when appropriate
Technical and Financial Assistance Programs	Evaluate expansion of the current home energy audit program to include more water conservation consultation
Supplier Financed Retrofit or Replacement of Inefficient Fixtures	Continue to provide rebates for low-water-use washing machines, dishwashers, and toilets
	Explore the feasibility of implementing a rebate program for weather based irrigation controllers
Rate Structure and Billing Practices that Encourage Conservation	Continue to utilize a volumetric rate structure and continue to provide conservation messages with billing inserts
Water Reuse, Recycling, and Nonpotable Opportunities	Continue to forward customer and business inquiries on water reuse and recycling to CWS, continue to recycle backwash water, and seek non-potable water use opportunities

3.6. City of Beaverton

3.6.1. Water Use and Reporting Program

OAR 690-086-0150(2)

The water withdrawal measurements are used for reporting that complies with the measurement standards in OAR Chapter 690, Division 85. The City's water use records can be found on the OWRD webpage: http://apps.wrd.state.or.us/apps/wr/wateruse_report/.

The City participates in a water use measurement and reporting program associated with JWC-managed water rights and also has implemented a program for the City's facilities and water rights. The metering at the JWC Water Treatment Plant is described in the Hillsboro section.

Water is measured in numerous locations as it enters and is conveyed through Beaverton's distribution system. Primary water from JWC is metered as it enters Beaverton's 36-inch-diameter southern transmission line located outside the city limits. Water is measured with magnetic flow meters and flow data are transmitted to the City's telemetry/supervisory control and data acquisition (SCADA) system. Flow meters at pressure reducing stations within Beaverton's distribution system provide additional data. Water entering the City's terminal storage reservoirs (15 MG and 5 MG) is metered, and change in storage is measured and recorded by telemetry/SCADA. Water leaving the City's highest reservoir, Cooper Mountain (overflow at 794 feet), also is metered. Injection and recovery volumes are measured at Beaverton's two ASR wells.

The City reports on water use to OWRD annually for the following City facilities and water rights: Old City of Beaverton Well 1, Hanson Road Well/ASR 1, Willamette River right (Permit S-54940), ASR No. 2, and ASR No. 4.

In addition to the measurement and reporting required by the water use reporting program, JWC submits weekly withdrawal reports to the District 18 watermaster during the peak season to coordinate stored water releases and instream flows.

3.6.2. Required Conservation Programs

OAR 690-086-0150(4)

OAR 690-086-150(4) requires that all water suppliers establish 5-year benchmarks for implementing the following water management and conservation measures:

- Annual water audit
- System-wide metering
- Meter testing and maintenance
- Unit-based billing

- Water Loss Analysis
- Public education

Annual Water Audit

OWRD defines a water audit as an analysis of the water system that includes a thorough accounting of all water entering and leaving the system to identify leaks in the system and authorized and unauthorized water uses, either metered or estimated. The water audit also includes analysis of the water supplier's own water use.

The City conducts annual water audits. The City calculates water loss as the difference between total water demand and total metered consumption. Water loss represents the sum of unmetered uses (e.g., hydrant flushing and distribution system flushing), system leakage, overflows, and inaccurate measurements at the production or customer meters. The City conducts an annual water audit for internal purposes and for JWC's annual water audit program.

The City's water loss was approximately 6.7 percent in FY 2018/2019. The Water Loss Analysis discussion below explains the City's efforts to increase efficiency.

Five-Year Benchmarks: The City will continue to conduct annual water audits.

System-wide Metering

All of the City's 21,000 connections are metered and all new customers are metered as they are added to the City's utility roll. During the last 10 years, the City has considered upgrading its system using Automated Meter Reading (AMR) technology. To date, only the newly annexed and underdeveloped SCM area is metered with AMR. The City was recently awarded a WIFIA grant from the EPA to fund the conversion of all meters in the City to AMI meters in the next 7 years. All AMR meters that have already been installed will be converted to AMI meters and all new meters installed will be AMI meters. Approximately 5 to 10 percent of the City's current AMR meters have already been converted to AMI.

Five-Year Benchmarks: The City will continue to meter all connections. Over the next five years, the City will work towards the seven year goal of converting all meters to AMI meters.

Meter Testing and Maintenance

The City has a robust meter testing program. Until recently, the City annually tested all meters that are 3 inches and larger. When meters' readings deviated from the manufacturers' recommended standards, meters were either replaced or repaired. The City also had an ongoing replacement program for those meters based on age, and replaced approximately 10 to 15 per year. During replacement, magnetic flow meters were installed that are known for their long-term accuracy. The City also replaced smaller meters at a rate of approximately 1,000 per year, which equates to an approximately 20-year replacement schedule for the entire system. Now that the City will begin converting all meters to AMI, any meters that deviate from manufacturers recommended standards will be replaced with AMI meters. Once AMI meters are installed, the City will follow manufacturer's specifications for meter testing and maintenance and will also track AMI meter data for signs of functioning meters.

Five-Year Benchmarks: The City will follow manufacturer's specifications for AMI meter testing and maintenance. The City will track meter data for signs of malfunctioning meters and will replace any malfunctioning meters promptly.

Water Rate Structure

The City charges its water customers a base charge that is based on meter size and a usage rate that is based on the volume of water consumed. Appendix G shows water rates for the City's customer classes as of July 1, 2019. The City regularly considers modifications to its water utility rate structure. During the most recent rate review, the City determined that a progressive tiered rate structure (i.e. inclining block rate) was not feasible at that time. In mid-2013, the City began reading all meters monthly instead of bi-monthly and began sending customers' water bills monthly. One of the advantages of a monthly billing cycle is that customers receive feedback on their water use up to one month earlier, thereby allowing customers to adjust habits (e.g., peak season water use) more quickly as needed.

Five-Year Benchmarks: The City will continue to bill customers based, in part, on the volume of water consumed on a monthly basis. The City will continue to assess its rate structure in the future for modification to adequately fund the operation and maintenance of its water system, including consideration of a progressive tiered-rate structure (i.e. inclining block rate) in the next five years.

Water Loss Analysis

The City's water loss does not exceed 10 percent (6.7 percent in FY 2018/2019). To minimize water loss, the City maintains a leak detection and repair program to help ensure leakage remains low. The City continues to fund annually a capital improvements program that allows for the replacing or repairing of high priority water lines. Lines selected for repair or replacement are those with a history of leaks and those where significant leaks are identified. The City identifies water line leaks using visual observations and acoustic detection technology. Since 2013, the City has replaced 15,356 linear feet of existing pipeline. The City's budget continues to meet or exceed $1 million for replacement or renewal of aging water distribution system facilities. Calls from customers reporting leaks are logged and addressed by the Public Works staff in a timely manner.

Five-Year Benchmarks: The City will continue to conduct its leak detection program. The City will continue to budget for replacement of high-priority aging infrastructure that contributes to leaks.

Public Education

The City's public education program uses a variety of approaches to encourage customers to conserve water. The City has a robust conservation program, devoting 0.3 full-time equivalent (FTE) to conservation in the form of a water conservation program coordinator position, and it enjoys the benefits of memberships and participation in the Regional Water Provider's Consortium (Consortium) and JWC's Education and Event Committee (EEC). The City's 2018-2019 water conservation budget was $62,000 plus $14,000 in staff time, of which a significant portion goes toward the Consortium's conservation program. The remaining funds go to the City's rebate program, multi-media shows, devices, outreach and educational materials, and other items and activities as explained below.

As a member of the Consortium, the City benefits from the Consortium's conservation services. For example, the City is able to offer eight elementary schools water conservation performances annually that the Consortium makes available through a contract with Mad Science. The City's conservation program coordinator participates on the Consortium's conservation committee, helping to develop and promote the Consortium's program for the benefit of Beaverton and the other Consortium members.

The City participates in regional and local public education and outreach events. These are sponsored by the Consortium, JWC, and the City. Through Consortium sponsorship, the City staffs booths at the annual Children's Clean Water Festival and the annual Home and Garden Show. JWC's EEC also sponsors events, as previously described. The City staffs booths at a variety of City-specific events as well, including Picnic in the Park, farmers markets, Bay Tree Lighting Ceremony, and an annual Public Work's Week public event. At these events, the City provides conservation information and distributes printed material and water savings devices. The water savings devices offered by the City at these events or other locations include showerheads, faucet aerators, toilet tablets, shower times, and rain gauges.

Five-Year Benchmarks: The City will continue its public education program and continue to participate in the Consortium and JWC's EEC.

3.6.3. Additional Conservation Measures

OAR 690-086-0150(5)

OAR 690-086-0150(5) requires municipal water suppliers that serve a population greater than 1,000 and propose to expand or initiate the diversion of water under an extended permit for which resource issues have been identified, or if the population served is greater than 7,500, to provide a description of the specific activities, along with a 5-year schedule to implement several additional conservation measures. The City meets the latter criterion.

Technical and Financial Assistance Programs

The City provides technical and financial assistance to its water utility customers. This assistance comes in two primary forms, as described below.

- Free watering gauges are provided by the City to customers upon request to help customers measure irrigation volumes and to prevent overwatering.
- Informative brochures provided by the City and described on the Consortium's website (linked from the City's website) discuss irrigation techniques to homeowners to assist in efficient water use during peak season. Other water savings techniques can be found on these webpages as well, including toilet leak testing and repair.

The City is also considering contracting with other JWC members to perform free irrigation audits at its multi-family customers' sites. These other members have acquired technologies and gained knowledge to allow the staff to perform these audits and also may be willing to perform these audits in Beaverton's service area.

Five-Year Benchmarks: The City will continue to provide technical and financial assistance to both residential and non-residential customers. Specifically, the City will continue to offer water-saving devices (e.g., water gauges) and offer information that promotes water conservation self-assessments. The City will explore opportunities to offer additional technical assistance in the form of free irrigation audits to its multi-family customers.

Supplier Financed Retrofit or Replacement of Inefficient Fixtures

The City manages a successful residential water efficiency rebate program initiated in 2002 that now focuses on indoor and outdoor water conservation. Under the program, residential users can receive $75 rebates for replacing older inefficient toilets with high-efficiency toilets (1.28 gallons per flush) and $50 for replacing washing machines with select high-efficiency models. Residents also can receive a $50 rebate for installing a WaterSense Weather-Based Irrigation Controller to help reduce irrigation water waste. This controller rebate program was initiated in 2017.

In fiscal year 2017-2018, the City distributed 144 toilet rebates, 8 washing machine rebates, and 15 irrigation controller rebates. In fiscal year 2018-2019, the number of irrigation controller rebates distributed increased to 20. Overall, the rebate program has been popular and the City has continued to increase its conservation budget to match the rebate demands from the community.

The City also distributes free water-saving devices, such as water-efficient faucet aerators and showerheads, to customers at specific locations in the City and upon request.

Five-Year Benchmarks: The City will continue to offer rebates and incentives to customers to retrofit or replace inefficient fixtures. The City will continue to offer water-saving devices.

Rate Structure and Billing Practices that Encourage Conservation

The City continues to promote conservation through its rate structure. The City bills all customer classes based on the quantity of water used—the rate for the 2019-2020 fiscal year is \$3.57 per hundred cubic meter. Customers' bills also include a base charge that is based on meter size. In 2013, the City began reading all meters monthly instead of bi-monthly, improving customers' feedback of water consumption and thereby allowing customers to adjust use in a timely manner. For example, a customer who would have received a bill in September for July/August usage under bi-monthly billing now obtains July usage in their August bill, allowing them to have an impact on usage during peak season.

City personnel can provide an account review and offer advice on ways to conserve water whenever a customer expresses interest. When the City suspects that a customer has a leak, the City notifies the customer about the high water usage and suggests that the customer check for a leak using instructions provided on the City's webpage.

The utility bills received by customers include past usage volumes, enabling customers to compare water use to the same month of the previous year.

Five-Year Benchmarks: The City will continue to charge for water based on the volume of water used as means to promote water use efficiency. The City will continue to bill customers monthly.

Water Reuse, Recycling, and Nonpotable Opportunities

The City is developing a "purple pipe" program in the SCM area to meet irrigation demands. To date, the City has installed 1.5 miles of purple pipe. The City estimates that it will ultimately install up to 12 miles of purple pipe, which will serve residential irrigation systems and a high school irrigation system. Over the past two summers, the purple pipe system has had a total demand of approximately 13.33 MG. ASR 3 will supply the SCM using the City's native groundwater right. Historically, ASR 3 has met all water quality standards, however, a higher level of manganese affects taste of the water. Using the water for irrigation allows the City to reduce demand on its surface water supplies.

A separate project initiated by CWS, the regional stormwater and wastewater service provider, is being developed to inject stormwater into the City's Well 3 for irrigation use in the SCM area. CWS and OWRD have provided funding to the City to study the feasibility of this project. OWRD awarded the City and CWS \$700,000 for stormwater diversion, treatment, and injection into ASR wells. Stormwater, once captured, would be injected into Well 3 in the winter and pumped and distributed as irrigation water to the SCM area in the summer. If implemented, the City hopes to offset the entire irrigation demand of the SCM area at full build out of the area (approximately 8,000 homes). Water pumped from Well 3 would be distributed in purple pipes.

Five-Year Benchmarks: The City will continue to develop and pilot test a stormwater capture project with CWS and continue to develop their purple pipe project in the SCM area.

Other Conservation Measures

The City performs the following additional conservation measures:

- The City is a member of the RWPC and has enjoyed the benefits of membership including conservation programming opportunities.
- The City's Conservation Program Specialist regularly attends trainings to learn about new programs and technology that can improve the City's conservation program. Trainings include American Water Works Association (AWWA) workshops/conferences and an annual WaterSmart Innovations conference.
- The City is researching the possibility of performing a conservation measures cost-effectiveness analyses, which would identify other conservation measures that will deliver cost-effective and high-impact water savings.
- The City has observed that new residential development has a higher peaking factor than older residential developments and anticipates future residential growth will also have greater summer demand by comparison. Therefore, the City is considering targeting outdoor conservation measures to customers in these higher peak areas.

Five-Year Benchmarks: The City will continue to be a member of the Consortium and offer the services provided through membership to its customers. The Conservation Program Specialist will continue to attend trainings and conferences that provide education and insight to potentially grow and enhance existing City conservation programs. The City will consider performing a conservation measures cost-effectiveness analyses to identify new conservation measures for implementation. The City will consider implementing measures targeting customers in areas with higher peaking factors.

Exhibit 3-8 presents a summary of the City's 5-year water conservation benchmarks.

Exhibit 3-8. Summary of 5-year water conservation benchmarks

Conservation Measures	Five-Year Benchmarks
Annual Water Audit	Continue to conduct annual water audits over the next 5 years
System-wide Metering	Continue to meter all connections
	Over the next five years, the City will work towards the seven year goal of converting all meters to AMI meters.
Meter Testing and Maintenance	The City will follow manufacturer's specifications for AMI meter testing and maintenance.
	The City will track meter data for signs of malfunctioning meters and will replace any malfunctioning meters promptly

Conservation Measures	Five-Year Benchmarks
Water Rate Structure	Continue to bill customers based, in part, on the volume of water consumed on a monthly basis
	Continue to assess rate structure for modification in order to adequately fund the operation and maintenance of the City's water system, including consideration of a progressive tiered-rate structure
Water Loss Analysis	Continue to conduct leak detection program
	Continue to budget for replacement of high-priority aging infrastructure
Public Education	Continue public education program and participation in the Consortium and JWC EEC
Technical and Financial Assistance Programs	Continue to provide technical and financial assistance to residential and non-residential customers by continuing to offer water saving devices and information that promotes water conservation.
	Explore a free irrigation audits program for multi-family customers
Supplier Financed Retrofit or Replacement of Inefficient Fixtures	Continue to offer rebates and incentives to customers to retrofit or replace inefficient fixtures.
	Continue to offer water saving devices
Rate Structure and Billing Practices that Encourage Conservation	Continue to charge for water based on the volume of water used as means to promote water use efficiency.
	Continue to bill customers monthly.
Water Reuse, Recycling, and Non-potable Opportunities	Continue to develop and pilot test a stormwater capture project with CWS
	Continue to develop the purple pipe project in the SCM area

Conservation Measures	Five-Year Benchmarks
Other Conservation Measures	Continue to be a member of the Consortium and offer the services provided through membership to its customers
	The Conservation Program Specialist will continue to attend trainings and conferences that provide education and insight to potentially grow and enhance existing City conservation programs.
	Consider performing a conservation measures cost-effectiveness analyses to identify new conservation measures for implementation

3.7. TVWD

3.7.1. Water Use and Reporting Program

OAR 690-086-0150(2)

The District has a water use measurement and reporting program that complies with the measurement standards in OAR Chapter 690, Division 85. The District's water use records can be found on the OWRD webpage: http://apps.wrd.state.or.us/apps/wr/wateruse_report/.

Water enters the District's supply system at four primary locations: two from the JWC (Cornelius Pass and 75th Ave) and two from the City of Portland (primary connection at the Portland WCSL meter at Beaverton-Hillsdale Hwy and the primary Metzger service area meter at Florence Lane). The District has magnetic meters at each of these four locations and these meters are on the District's SCADA system. The SCADA system reports water demand in one-minute intervals and these data are summarized for the District's annual water use reporting to OWRD.

3.7.2. Required Conservation Programs

OAR 690-086-0150(4)

OAR 690-086-150(4) requires that all water suppliers establish 5-year benchmarks for implementing the following water management and conservation measures:

- Annual water audit
- System-wide metering
- Meter testing and maintenance
- Unit-based billing
- Water Loss Analysis
- Public education

Annual Water Audit

TVWD performs an annual water audit that incorporates a comprehensive data set, including total demand (volume of water purchased that enters the distribution system), total volume of water consumed by customers through metered service connections, wheeled water (i.e., water that's moved through the District's water distribution system for Portland Water Bureau and City of Beaverton customers), and non-revenue uses, such as pipeline flushing and hydrant usage. Annual water audits are currently performed based on fiscal years (e.g., 2014 data is from July 2013 through June 2014).

From 2015 through 2019, water loss ranged from a high of 7.0% to a low of 2.4%. Water loss in 2019 was 4.7%.

As described in Section 2, the Portland supply meter is owned by the PWB. The District worked with PWB in July of 2015 to replace a 24-inch bore mag meter and a 42-inch insertion mag meter at this location in 2019. Currently, the majority of flow is routed through the 24-inch bore mag meter, which was installed in 2015. The 42-inch insertion mag meter is intended to be used during high flows when the capacity of the smaller meter is exceeded. The replacement of both meters will help improve the accuracy of the Districts water audits.

Since 2015, TVWD has also verified that emergency water intertie valves with neighboring water agencies are in the 'closed' position and has performed system leak audits in specific areas of the District. Additional actions that TVWD is taking to increase efficiency are described below under Water Loss Analysis.

Five-Year Benchmarks: TVWD will continue to perform a comprehensive annual water audit in order to continually assess water loss from all potential causes. TVWD will continue to track usage by customer class to evaluate consumption trends.

System-wide Metering

The District's system is fully metered including all permanent connections to the Portland Water Bureau, the Joint Water Commission, and the District's groundwater or aquifer storage and recovery wells. The District installs Badger ORION Automatic Meter Read (AMR) meters in all new customer meter installations. When new meters are initially installed, they are provided with non-AMR meters for approximately 6 months. This is the period during which activity around the meter (i.e., site construction) has a greater potential to damage the meter. After the high activity period, an AMR meter is installed for final use.

TVWD has installed AMR meters on approximately 96 percent of its 3-inch to 10-inch commercial accounts, which represents 292 meters. This includes commercial (119), irrigation (4), multi-family residential (153), and production (16) class meters. Meters installed since 2016 have data logging capability to aid in leak detection, troubleshooting, and conservation efforts. Any remaining non-AMR meters 3-inch and larger will be replaced as they fail to test to specification or as parts become difficult to acquire. Fireline meters are omitted as these assemblies are owned by the customers. To date, the District has installed approximately 21,478 AMR meters throughout its system.

Five-Year Benchmarks: The District will continue to install AMR in all new meter installations or as metering devices fail to perform to District specifications. Additionally, the District is evaluating the use of Advanced Metering Infrastructure (AMI) for consideration in the development of a long-term meter reading strategy.

Meter Testing and Maintenance

TVWD tests, repairs, or replaces as necessary all meters greater than 2-inch in diameter every two years or less. The District has replaced nearly all large meters with new AMR models. Only

12 meters of this size classification remain to be replaced. These remaining meters are still performing within specification. The District also tests meters 2-inch or less in response to customer inquiries or deficiencies noted by staff. When non-AMR meters need to be repaired, the District will replace the meter with a new AMR meter.

Five-Year Benchmarks: The 12-remaining large, non-AMR meters will be replaced as they reach the end of their functionality, as parts become difficult to acquire, or as opportunity projects arise. The meter testing program will continue to test large meters every two years or less and small meters (2-inch or less) upon request.

Water Rate Structure

The District continues to use base charge billing, which is determined by meter size. This is followed by a two-tiered block volume usage charge, known as Block 1 and Block 2. The District developed this water rate structure to incentivize conservation and has used this method consistently since implementation. TVWD customers continue to receive their bills shortly after their meter is read on a bi-monthly basis. Billing statements show water use over the previous 18 months, provide a breakdown of Block 1 and Block 2 usage and rates, and at times include a conservation message. Appendix H presents the District's base charges and block volume charges.

In addition, the District periodically reviews the rate structure. This occurred most recently in 2016 and 2017 through the use of a TVWD Rate Advisory Committee utilizing residential and commercial customers as active Committee members. This process reaffirmed the conservation-based billing structure and identified future measures for consideration, such as monthly billing.

Five-Year Benchmarks: The District will continue its current rate structure and bi-monthly billing schedule along with providing periodic conservation messages and recent water use in billing statements. The District is also in the process of procuring a new customer information system (i.e., billing software) with implementation scheduled for completion during the 2021-2022 fiscal year. This change is expected to offer increased flexibility for customer billing and messaging.

Water Loss Analysis

From 2015 through 2019, TVWD's water loss ranged from a high of 7.0% to a low of 2.4%. Water loss in 2019 was 4.7%.

The District dedicates substantial resources towards minimizing water loss, including a comprehensive leak detection and repair program that emphasizes leak detection surveys and immediate repair of identified leaks, AMR record review, and customer education.

TVWD has conducted several focused leak detection surveys since 2015. The District conducted these surveys in isolated areas of the District in an attempt to investigate specific, suspected leaks. Several leak detection methods are used, including: the use of acoustical listening devices on valves, hydrants, and service lines; water quality testing for chlorine or fluoride; and visual observations of water in unexpected places. If a leak is detected in the distribution system, the District repairs the leak immediately, schedules a repair, or records and monitors the leak in future leak detection surveys. The action taken depends on the severity of the leak. Additionally, TVWD's ongoing capital improvement plan (CIP) has invested approximately $18.4 Million in mains replacement since 2014 to address priority areas and reduce water loss through preventative actions.

The District reviews data from AMR meter residential consumption records on a bi-monthly basis and AMR meter commercial consumption records on a monthly basis for water consumption changes that may indicate a leak at a customer's premises. Residential AMR meters are read digitally using handheld devices. Meters 3-inches or greater are the new generation of Badger ORION AMR meters that are read digitally and also have a data logging capability that allows the District to capture flow readings at one hour intervals. A reading that is greater than two times the reading for the same period during the previous year, or is greater than two times the last reading, results in the customer's inclusion on a "High Read" exception list of meters with suspected leaks that need to be investigated. District staff may be sent to the service address to verify a suspected leak and the District contacts the customer if a leak is found. Badger ORION data logging meters have been very helpful in diagnosing leak conditions on non-residential meters 3-inches and larger. District staff is able to analyze time and flow values that provide clues about where to look to confirm the presence of a leak, such as in an irrigation system known to run at 5:00AM and at a specific theoretical flow rate for each zone. This method is a reliable approach for detecting leaks in most cases, but for sites like large multi-family complexes or production facilities, this method is used to indicate that further investigation is warranted.

In addition, the District uses its Website, newsletters, billing messages, post cards, emails, educational videos, and events, such as the RWPC's "Fix-a-Leak" month-long campaign effort each year, to educate customers about leak detection and repair. The District also promotes leak detection and repair through a similar month-long effort promoted by the Regional Water Provider Consortium (RWPC). The District recently won a PNWS-AWWA Excellence in Communication Award for an educational video titled "Game of Seasons" that aimed to help customers prevent leaks due to frozen pipes by weather proofing their homes. TVWD also offers a "Leak Kit" to customers upon request to help them identify leaks.

Five-Year Benchmarks: The District will continue its efforts to minimize water loss, including: conducting leak detection surveys, regularly inspecting fire hydrants with acoustical listening devices, repairing leaks, replacing mains and implementing other activities identified in the District's Capital Improvement Program, reviewing AMR data, implementing special messaging campaigns through newsletters and TVWD's website, and offering "Leak Kits".

Public Education

The District promotes water conservation through print and electronic media, community outreach efforts, school programs, and regional partnerships. The District has been recognized for its public education efforts with various industry awards. Specific details about these efforts are provided in the following sub-sections.

Print and Electronic Media

Conservation information and materials are provided to customers in the District's front lobby area, within bi-monthly billing statements, on its recently updated website, and in customer newsletters. Additional details about each include the following:

- The front lobby contains a kiosk with water conservation brochures, information on rebates, water conservation themed calendars, and Water-Efficient Plants for the Willamette Valley booklets that describe native and naturalized, non-invasive, water-efficient plants that can be used effectively in local landscaping.
- In August of 2019, TVWD launched an updated website. The District's new website provides information about the importance of water conservation for the District and its customers, actionable information on leak detection and repair, indoor and outdoor conservation, technical assistance available for commercial customers, rebates for water efficient devices, and tips on water-efficient landscape design.
- The website also provides links to water conservation resources, such as the Environmental Protection Agency's (EPA) WaterSense program, the Regional Water Providers Consortium (RWPC), and the Alliance for Water Efficiency.
- As noted previously, TVWD's bi-monthly billing statements contain seasonal conservation messages and the District also sends its residential customers the bi-monthly Water Words newsletter, produced jointly by the District and Clean Water Services. This newsletter generally includes both water conservation and water quality messages.

In addition, TVWD's web site provides contact information for the District's Conservation Program, enabling customers to correspond directly with District conservation staff.

Community Outreach

TVWD has conservation staff that speak regularly to public groups interested in learning about water efficiency in residential, commercial and multi-family settings. The District also has a Speaker's Bureau that presents District policies and leads discussions with customer groups, businesses, and organizations. Topics discussed include the Willamette Water Supply Program – TVWD and its partners new source in 2026 – various regional water resources, and District budgeting and rate planning processes. Further topics include water efficiency, conservation, sustainability, and emergency preparation and system resilience.

The District also maintains a Water Efficient Demonstration Garden at its headquarters property. The garden provides a hands-on demonstration tool to teach water efficient principles and practices in landscape design, installation, and maintenance. The garden incorporates interpretive signage and brochures about several key landscaping options designed to promote conservation. These include:

- Native and naturalized non-invasive plants;
- Weather-based irrigation technology; and
- High efficiency multi-stream nozzles and drip irrigation systems

In addition, the garden has a plaza that serves as an outdoor classroom for District staff to hold water conservation events to provide useful information to local students, landscape professionals, and residential and commercial customers.

TVWD recognizes the value of continuous education for landscape contractors and supports best management practices for efficient irrigation system design, installation, and maintenance with an emphasis on weather-based irrigation control technology. Therefore, the District collaborates with the Oregon Landscape Contractor's Board (LCB), the Oregon Landscape Contractors Association (OLCA), and other regional water providers to provide low or no-cost educational workshops and technical session programs for landscape contractors that satisfy the LCB's continuing education requirement.

School Programs

The District has a comprehensive Youth Education Program that provides water conservation materials, presentations, and activities to students at elementary schools and regional events. Presentation themes include the natural water cycle, the path of drinking water from the source to the customer's home, conservation and efficiency, and a variety of water quality topics. The District also contracts with professional actors for school presentations about water conservation.

The District also provides staff for information booths at various science fairs and is an active partner in the annual Children's Clean Water Festival. In addition, TVWD has an annual Conservation Calendar Contest for local elementary school students, which has received national recognition. The TVWD Conservation Calendar has a water conservation theme and provides student produced artistic tips on how to use water wisely.

Partnerships

The District is active in conservation planning and implementation through regional, statewide, and national partnerships and affiliations. TVWD is represented on the Board and committees of the RWPC and through this consortium, is an active member of the OLCA along with the Landscape EXPO Planning Committee. TVWD Conservation staff are also active members of the Water Conservation Committees, a committee of the American Water Works Association, Pacific Northwest Section (AWWA-PNWS). A significant effort of this committee has been working with Lane Community College (LCC) to develop a 2-year Associate of Science Program to promote development of the skills needed to work in the municipal water conservation industry.

Nationally, the District is a promotional partner with the EPA's WaterSense Program and is an active member of the Alliance for Water Efficiency's WaterSense and Water Efficient Products Committee of the national AWWA Water Conservation Committee. TVWD's Conservation Technician is also a Certified Landscape Irrigation Auditor by the Irrigation Association (IA) and participates on the IA's Smart Water Application Technology (SWAT) Technical Working Group.

Awards

TVWD has received numerous communication awards for its public education efforts, including:

- Nominated for a City-County Communications and Marketing Association (3CMA) Savvy Award
- PNWS-AWWA Excellence in Communication Awards (2019) for the following:
- TVWD's Game of Seasons – Winter Preparedness video
- TVWD's Gold Plan Backflow Program
- TVWD's National Preparedness Month Water Storage and Emergency Kit Hands-on Demonstration
- Regional Water Providers Consortium's Water Conservation Awards

Five-Year Benchmarks: The District will continue to use a variety of tools to reach customers, including bill inserts, website updates, various social media platforms, attending public events and facilitating tours, and providing high-value youth education programming. The District will also remain an active member of the RWPC to enhance regional communications and work with local water providers on outreach strategies related to conservation and emergency preparedness.

3.7.3. Additional Conservation Measures

OAR 690-086-0150(5)

OAR 690-086-0150(5) requires municipal water suppliers that serve a population greater than 1,000 and propose to expand or initiate the diversion of water under an extended permit for which resource issues have been identified, or if the population served is greater than 7,500, to provide a description of the specific activities, along with a five-year schedule to implement several additional conservation measures.

Technical and Financial Assistance Program

The District offers a “Welcome Kit” to all new customers and a “Leak Kit” is available upon request to help customers reduce water use. Key details of each kit include the following:

- The “Welcome Kit” provides customers the opportunity to request high efficiency showerheads, bathroom aerators, kitchen aerators, toilet leak test tablets, and conservation brochures free of charge; and
- The “Leak Kit” helps customers identify leaks and other potential reasons for high water bills, such as inefficient fixtures or leaking toilet tanks.

These materials are also provided to customers at community events. Showerheads, aerators, toilet dye tablets, and education brochures are all available in the District’s front lobby to customers as well, free of charge.

In addition to the residentially focused assistance above, the District has a commercial, industrial, and institutional (CII) water conservation program to reduce water use by its non-single-family residential customers. The CII program includes the following elements:

- Technical assistance and water efficiency incentives for facility and property managers that service lavatories, landscape irrigation systems, production kitchens, and unique business processes;
- Conservation staff provide recommendations for improving both indoor and outdoor water efficiency on the District’s website, upon request from customers, or in person at District headquarters or the customer’s property;
- The District offers rebates for upgrading to water efficient fixtures and equipment which is described under Supplier Financed Retrofit or Replacement of Inefficient Fixtures;
- Production kitchens that use older inefficient pre-rinse spray valves are provided new efficient models free of charge when they participate in the District’s free commercial water use assessment program; and
- Customers may request financial assistance from the District for innovative capital improvement projects to improve water efficiency by applying for the Customer Organized Proposal rebate.

The District offers indoor water use assessments to its CII customers, and if an analysis of water records suggests that outdoor water use may be a source of inefficiency, the District also offers irrigation assessments at no charge. An overall goal of the program is to emphasize how improving water use efficiency can save money.

Each summer, the District asks its customers to voluntarily limit water application to 1-inch of water per week for turf areas and less for areas with trees and shrubs. To encourage participation, the District provides a link to the RWPC’s Weekly Watering Number on its website that describes how to program an irrigation controller to apply 1-inch of water per week and make weekly schedule adjustments based on local weather conditions. The RWPC also provides free watering gauge kits to customers upon request or at public outreach events. These gauges can help determine the application rate of irrigation systems and set an effective 1-inch base schedule.

Five-Year Benchmarks: The District will continue to provide indoor and outdoor water use assessment upon request and promotion of these efforts. The District will continue the other elements of its technical and financial assistance program as detailed above.

Supplier Financed Retrofit or Replacement of Inefficient Fixtures

The District offers rebates for upgrading to water efficient fixtures, equipment, and processes. The specific details of the rebate include the following elements:

- Up to $75 per fixture to replace inefficient flush valves, toilets, and urinals with EPA WaterSense labeled fixtures;
- Up to $50 for residential customers (i.e., house, condominium, duplex/multiplex, or manufactured home with a single or master meter) to install or retrofit a WaterSense labeled weather-based irrigation controller;
- Up to $400 per controller (up to a $2,500 maximum rebate) for non-residential commercial, industrial, or institutional customers to install weather-based irrigation control (based on the number of zones per controller; $200 for 1-6 zones, $250 for 7-12 zones, $300 for 13-18 zones, $350 for 19-24 zones, and $400 for 25+ zones);
- Up to $96 for customers to replace inefficient irrigation sprinkler nozzles with multi-stream rotating nozzles (up to $3 per nozzle, limit of 32 nozzles); and
- Up to $5,000 for commercial, industrial, and institutional customer organized proposals for water efficiency projects (Customer Organized Proposal Rebate (COPR) program). For COPR rebates, the customer provides the District with a proposal that describes the type of project and the estimated water savings, which the District will evaluate for merit and rebate incentive level.

Exhibit 3-9 shows the number of rebates distributed by the program to date since fiscal year 2013/2014.

Exhibit 3-9. Rebates distributed by program since fiscal year 2013/2014

TVWD Rebate Program	Number of Rebates Administered							
Residential Rebate Program (Inception Date)	**FY 2013-2014**	**FY 2014-2015**	**FY 2015-2016**	**FY 2016-2017**	**FY 2017-2018**	**FY 2018-2019**	**Jul-19**	**Total**
Clothes Washer (May 2002)	70	D/C	D/C	D/C	D/C	D/C	D/C	70
HET Toilet (November 2005)	1704	1455	1400	1073	1106	804	45	7,587
Weather Based Irrigation Controller (June 2006)	17	37	95	81	58	86	21	395
Multi-Stream Rotating Nozzles (July 2011)	148	158	236	186	33	71	12	844
	Sub-total							**8,896**
B.I.G. Rebate Program (January 2006)								
Toilet/Flush-Valve Rebates	151	468	167	26	458	29	2	1,301
Weather Based Irrigation Rebates	6	12	19	1	0	0	0	38
Multi-Stream Rotating Nozzles (July 2011)	643	82	0	0	0	0	0	725
	Sub-total							**2,064**
	Grand-total							**10,960**

Note: D/C means discontinued.

Five-Year Benchmarks: The District will continue to fund all of the current rebate programs. As the WaterSense program continues to evolve and more products are added to the labeling program, the District will evaluate incorporation of these new products into rebate programs.

Rate Structure and Billing Practices that Encourage Conservation

As previously described, the District continues to use base charge billing, which is determined by meter size. This is followed by a two-tiered block volume usage charge, known as Block 1 and Block 2. The District developed this water rate structure to incentivize conservation and has used this method consistently since implementation. TVWD customers continue to receive their bills shortly after their meter is read on a bi-monthly basis. Billing statements show water use over the previous 18 months, provide a breakdown of Block 1 and Block 2 usage and rates, and at times include a conservation message.

Five-Year Benchmarks: The District will continue its current rate structure and bi-monthly billing schedule along with providing periodic conservation messages and recent water use in billing statements. The District is also in the process of procuring a new customer information system (i.e., billing software) with implementation scheduled for completion during the 2021-2022 fiscal year. This change is expected to offer increased flexibility and opportunity for improved customer billing and messaging.

Water Reuse, Recycling, and Non-potable Opportunities

The District is solely a water provider. Wastewater generated by the District's customers is conveyed by the Cities of Tigard, Beaverton, and Hillsboro, and Clean Water Services (CWS) to regional treatment facilities operated by CWS of Washington County. CWS is an industry leader in developing new and innovative methods for reuse of water conveyed to the treatment facilities. As a regional participant in major water resource projects and the largest water supplier in Washington County, the District will continue to support regional work to develop these efforts.

The District promotes water reuse and recycling among its customers, as well. The District's Commercial, Industrial and Institutional (CII) program encourages commercial and production customers to recycle and reuse water, and to reduce their water consumption. The COPR provides rebate opportunities for water efficiency improvements for commercial applications, such as the elimination of single-pass cooling and improved cooling tower water treatment. Furthermore, the COPR is designed to be flexible and open enough to encourage innovative water reuse or recycling proposals from customers for their unique industrial processes.

Five-Year Benchmarks: The District will continue to support regional efforts in developing innovative methods for reuse of water. The District will continue working with CII customers to support projects that improve production water efficiency through reuse and recycling.

Other Conservation Measures

Tracking Tools

The District has used several software tools to track the number of customers participating in the rebate programs since their inception and to estimate the potential conservation savings. Analyses conducted using these tools indicate that the District's conservation programs have been very successful. Software tools used to track results include in-house developed applications and the Alliance for Water Efficiency's Water Conservation Tracking Tool. The in-house tool is a comprehensive spreadsheet which allows the District to track all conservation rebates, assessments, device giveaways, and education and outreach programs. Savings estimates per participating customer for each measure are built into the spreadsheet and the District calculates a diminishing return based on what part of the fiscal year the measure is implemented. Analysis of water savings produced from rebates provided to Commercial, Industrial, and Institutional customers found that the average water savings was approximately 20 percent.

Pilot Programs

The District actively looks for opportunities to test new conservation methods and technology. Various pilot programs have been explored and implemented, and these programs have focused largely on irrigation technology and evapotranspiration (ET) based irrigation scheduling.

Customer Service & Conservation Staff

The District's mission is to provide the TVWD community quality water and customer service. Staff provides assistance to customers with concerns about high bills, general conservation questions, and water efficient fixture and device questions. The District also hosts various workshops, trainings, and presentations. Conservation staff are available to all customer classes to encourage water conservation, as well as landscape professionals, plumbers, and other trade-ally groups and regional colleagues. The District views the involvement of private businesses as critical to implementing efficient, long-term, and sustainable changes in the landscape and plumbing markets. The District also networks regularly with manufacturers and distributors of water conservation products to stay informed about new technologies and opportunities for District customers.

Five-Year Benchmarks: The District will continue its efforts to provide high quality customer service and facilitate customer engagement and participation in water conservation efforts. The District will continue its current efforts to market the use of advanced irrigation technology in landscape irrigation and promote best landscaping practices using its Water Efficient Demonstration Garden, as well as performing cost-benefit analyses of various conservation programs and methods for both customers and the District.

Exhibit 3- 10 presents TVWD's five-year conservation benchmarks.

Exhibit 3-10. Conservation Five-Year Benchmarks

Conservation Measures	Five-Year Benchmarks
Annual Water Audit	Continue to perform a comprehensive, annual water audit in order to continually assess water loss from all potential causes
	Continue to track usage by customer class to evaluate consumption trends
System-wide Metering	Install AMR in all new meter installations or as metering devices fail to perform to District specifications
	Continue evaluating the use of Advanced Metering Infrastructure (AMI) for consideration in the development of a long-term meter reading strategy
Meter Testing and Maintenance	Continue to test large meters every two years or less and small meters (2-inch or less) upon request
	The 12-remaining large, non-AMR meters will be replaced as they reach the end of their functionality, as parts become difficult to acquire, or as opportunity projects arise
Water Rate Structure and Billing Practices that Encourage Conservation	Continue current rate structure and bi-monthly billing schedule along with providing periodic conservation messages and recent water use in billing statements
	The District is also in the process of procuring a new customer information system (i.e., billing software) with implementation scheduled for completion

Conservation Measures	Five-Year Benchmarks
	during the 2021-2022 fiscal year. This change is expected to offer increased flexibility and opportunity for improved customer billing and messaging.
Water Loss Analysis	Continue its efforts to minimize water loss, including: conducting leak detection surveys, regularly inspecting fire hydrants with acoustical listening devices, repairing leaks, replacing mains and implementing other activities identified in the District's Capital Improvement Program, reviewing AMR data, implementing special messaging campaigns through newsletters and TVWD's website, and offering "Leak Kits"
Public Education	Continue to use a variety of educational tools to reach customers, including bill inserts, website updates, various social media platforms, attending public events and facilitating tours, and providing high-value youth education programming
	Remain an active member of the RWPC to enhance regional communications and work with local water providers on outreach strategies related to conservation and emergency preparedness
Technical and Financial Assistance Programs	Continue to provide indoor and outdoor water use assessment upon request, promote these efforts, and continue other elements of the technical and financial assistance program
Supplier Financed Retrofit or Replacement of Inefficient Fixtures	Continue to fund all of the current rebate programs
	As the WaterSense program continues to evolve and more products are added to the labeling program, the District will evaluate incorporation of these new products into rebate programs
Water Reuse, Recycling, and Nonpotable Opportunities	Continue to support regional efforts in developing innovative methods for reuse of water
	Continue working with CII customers to support projects that improve production water efficiency through reuse and recycling
Other Conservation Measures	Continue efforts to provide high quality customer service and facilitate customer engagement and participation in water conservation efforts
	Continue current efforts to market the use of advanced irrigation technology in landscape irrigation and promote best landscaping practices using Water Efficient Demonstration Garden
	Continue performing cost-benefit analyses of various conservation programs and methods for both customers and the District

4. JWC Curtailment Plan

4.1. Introduction

Curtailment planning is the development of proactive measures to reduce demand during water supply shortages. Shortages may be due to prolonged drought or natural disasters (e.g. flooding, landslides, earthquakes, and contamination); or mechanical or electrical equipment failure including power outages; or events not under control of the JWC (e.g. intentional malevolent acts). Curtailment needs to be considered when demands exceed supplies, and no alternative supplies are available through the JWC or its partners that will meet demands for the duration of the shortage.

The JWC's current curtailment plan was updated in 2017 following winter supply limitations experienced by the JWC. The JWC recognized that an expanded curtailment plan was needed to address demand reductions when water treatment plant (WTP) capacity is limited, as well as to address winter supply limitations. Depending upon the situation, resolution of capacity limitation issues may be handled individually or jointly by agreement between the partners. Limitations to the WTP's capacity does not automatically require curtailment measures, but begins a discussion among the JWC partner agencies: cities of Hillsboro, Forest Grove, Beaverton, and TVWD to determine the availability of alternate supplies for the duration of the shortage.

The General Manager may need to impose mandatory reductions in water availability to JWC partners in an emergency situation. JWC does not have direct authority to regulate member agencies' actions within their own systems. Ultimately, on-the-ground curtailment implementation will be delegated to and implemented by the individual member agencies. Triggers and responses by individual partners will vary due to differing conditions and additional water sources available to JWC partners that may negate or reduce the need for individual partners to curtail. Each JWC partner agency may be required to initiate and implement the progressive stages of their individual curtailment plans based on the status of supply, projected demands, and alternative sources of available supply for their systems. These actions should be communicated with the other JWC partners to facilitate coordinated messaging between partners and limit community confusion.

In addition to the JWC providing a curtailment plan, each JWC Member Agency has provided its individual curtailment plan in this WMCP. Each JWC member agency is required to have a curtailment plan prepared that meets the state's requirements under OAR 690-086-0160. The individual plans are based on their specific water system characteristics, such as varying customer category objectives and alternate supply options.

The JWC expects each agency to implement the appropriate curtailment stages to reduce their demand to the allotments available. Furthermore, the JWC's agreement with wholesale customer the City of North Plains stipulates that the City of North Plains will immediately adopt the same or similar conservation or curtailment measures as those imposed on JWC members during curtailment events, and that the City of North Plains will develop its own curtailment plan that complies with measures imposed by JWC members and will establish a water conservation program.

4.2. Joint Water Commission

4.2.1. History of System Curtailment Episodes

690-086-0160 (1)

Despite several incidents of JWC supply shortages in the past, the JWC has not had to implement mandatory curtailment to date. Those supply incidents are described in greater detail below, but all were handled by operational adjustments and negotiations for alternative supplies with JWC partners. The JWC and its member agencies excel at working together to find alternatives to curtailment while being able to meet the water supply needs of all partners. Curtailment is considered a last resort to achieve decreased demand, but the JWC has a plan to employ curtailment if necessary. Summaries of JWC water supply issues that nearly called for the JWC to implement curtailment protocols are detailed below.

Water Supply Incidents from 1990 to 1999

During the 1990s, the JWC Water Treatment Plant (WTP) experienced incidents that impacted supply/capacity, including: loss of power due to a car hitting a power pole near the WTP, loss of power due to a windstorm, severe raw water quality impacts due to the 1996 floods which affected numerous regions in Oregon, and disruption of deliveries to partners due to a transmission line leak on the WTP site. The incidents all reduced the ability of the JWC to supply water. At that time, there was only one reservoir on Fern Hill with 20 MG available storage, less stored water for emergency backup supply than is available today.

These power supply disruptions led to new JWC response agreements with PGE, and construction of a second finished water pumping station with a supporting power transformer station. In March 2016, a backup power facility was brought online at the WTP. The generators are capable of running the WTP at 50% of current peak capacity, which would be able to fully serve the partners for a large portion of the year, based on average demands.

Drought Incident in 2001

The JWC experienced its first source water shortage in the summer of 2001. This experience is described in brief here and in full detail in the JWC's 2010 WMPC. JWC is generally regulated off its natural flow water rights on the Tualatin River beginning in late May to early June until mid-October. JWC relies primarily on stored water releases from Hagg Lake and Barney Reservoir during this period.

For the first time since construction of Scoggins Dam was completed in 1977, Hagg Lake did not fill in 2001, reaching only 54 percent of its storage capacity. Several JWC member agencies (the Cities of Hillsboro, Beaverton, and Forest Grove) hold contracts with the Bureau of Reclamation

(BOR) for the use of stored water in Hagg Lake that also specify curtailment measures. Based on BOR contract conditions, the JWC partner cities of Hillsboro, Beaverton, and Forest Grove received only about 76% of their normal water allocations from Hagg Lake in 2001. Clean Water Services (CWS) and Tualatin Valley Irrigation District received only 27% and 47%, respectively, of their normal water allocations. Discharge changes at Scoggins Dam were made twice a day, seven days a week to closely match the timing of water orders, avoid waste, and maintain natural flow in the Tualatin River.

In the same year, Barney Reservoir only reached 55% of its storage capacity. After accounting for dead pool storage and releases for fish flows to the Trask River (15% of the available storage), the Barney Reservoir Joint Ownership Commission partners (Hillsboro, Forest Grove, Beaverton, TVWD, and CWS) were allotted only 54% of normal full pool allocations.

The JWC and Barney Reservoir Joint Ownership Committee (BRJOC) partners used a combination of leasing, alternative source options and agreements, and voluntary curtailment to meet summer 2001 demands on the JWC water system. Portland Water Bureau (PWB) had full supplies in both Bull Run and the Columbia River Wellfield. They offered assistance with coordination of regional supply, and provided an alternate source for Tualatin Valley Water District and the City of Beaverton. TVWD allowed Clean Water Services (CWS) to use some of its allocated water in the Barney Reservoir to meet streamflow demands, and CWS paid TVWD the difference between the cost of JWC water and the more expensive PWB water in exchange. It also helped that the summer weather of 2001 was cooler and wetter than usual. No mandatory curtailment was necessary.

North Transmission Line Leak in 2013

On July 24, 2013, a leak was discovered in the North Transmission Line (NTL), which runs along Evergreen Road. The leak was on a section of pipe between 273rd Ave and Sewell Ave, just north of the Hillsboro Airport. Approximately 7,000 feet of pipe was isolated which took 12 hours to dewater. The total response period was 81 hours, with staff and the contractor working around the clock for three consecutive days.

Interconnections delivering water from the JWC to the City of Hillsboro and TVWD service areas were impacted by this event. Hillsboro remained in close contact with industrial users in the immediate area throughout the event. Since the impacted area is normally a high pressure zone, the pressure had to be normalized with the rest of the city and fed by the JWC's South Transmission Line (STL) and Hillsboro's Evergreen Reservoir. TVWD continued to serve their customers through a similar approach, utilizing their interconnection on the STL.

The transmission line was taken out of service for approximately 24 hours. As a result of careful coordination and communications, no customers experienced an interruption to service in either the Hillsboro or TVWD service areas.

Summer Supply Incident in 2015

An abnormal onset of early summer weather, with a record number of days exceeding 90 degrees, caused customer demands to skyrocket. In anticipation of possible shortages for the City and TVWD, the JWC approved leases of stored water and treatment plant capacity at its July 2015 meeting. The summer continued hot and dry, and demands on the WTP were often near its maximum capacity, but all agencies were able to supply their customers without needing curtailment measures.

Winter Supply Incident in 2015

Western Oregon received a record amount of rain from December 7 to 11, 2015. The heavy rain flooded the Tualatin River, and in some places, the flooding was worse than the flood of 1996. This flooding raised water turbidity and changed the chemistry of the raw water entering the WTP, creating significant challenges for treating the water to safe drinking water standards. The more intense treatment required a slower WTP process; production declined to under 20 mgd.

During this time, demands on the WTP were over 20 mgd. Based on the decreased WTP production capacity, the demands of some partners exceeded their ownership percentage of the available capacity. Throughout the week, as the WTP continued to experience treatment challenges, and Fern Hill Reservoirs and the Cities' in-town storage continued to deplete, it became unclear if the City of Hillsboro would continue to meet demands without some measure of mandatory curtailment since the City of Hillsboro does not currently have any alternate supply sources. City of Beaverton voluntarily turned on one ASR well the first day of the event to reduce demands on the WTP and provide more water to the partners, especially the City of Hillsboro. As the event continued, it appeared that the City of Hillsboro might need to curtail its own customers' water usage. On the third day, TVWD shifted demand onto to its PWB supply and ASR well, and the City of Beaverton agreed to turn on a second ASR well, to further lessen their JWC system demand. (The City of Beaverton and TVWD used ASR wells developed under LL #002, not the JWC's ASR LL #019.)

TVWD and the City of Beaverton were meeting their customer demands with these alternate sources, and the City of Forest Grove was still able to meet its customer demands with its share of the reduced JWC WTP capacity that was available. As raw water quality improved, the WTP increased production levels, and by the fourth day of the event, the WTP was again producing enough water to begin refilling the storage reservoirs. The City of Hillsboro did not need to curtail. The event was over by the beginning of the following week, with normal WTP production capacity restored and all partners returning to their normal demand levels at the WTP.

Storm Event in 2018

Similar to December 2015's event an "atmospheric river" dropped an enormous amount of water into the Tualatin Watershed. Rainwater is notoriously hard to treat to drinking water standards because of its naturally low pH and alkalinity. To add to the problematic water chemistry, this was also the first large rainstorm of fall, which is referred to as a "flush" because a large amount of organic material is swept into the river. The entire "flush" happened in a 24-48 hour period. To further complicate matters, due to the low levels of Hagg Lake and Barney Reservoir after the long dry summer there was no release from either reservoir to supplement river flows. This meant that all river flow increase was directly the result of rainfall and rainfall runoff. On December 19th, a 70 cfs release from Hagg Lake (Scoggins Reservoir) was made for Stimsons Lumber Mill. This implies that Stimsons was likely releasing water from one of their log ponds and the release was made to keep them in compliance with their permit.

The rapid and extreme changes to the incoming water chemistry resulted quickly in improper coagulation, which led to poor sedimentation basin performance eventually resulting in high turbidity water flowing to the filters. The filters were unable to handle the high turbidity water, which resulted in a turbidity spike in the finished water. JWC operators, concerned that water would soon not meet drinking water standards turned off the Water Treatment Plant (WTP) while they worked to figure out the correct treatment chemistry. Meanwhile, Fern Hill Reservoir supplemented demands for all partners except TVWD. Over the course of the 3-day emergency event, reservoir levels dropped to the lowest ever (less than 13 feet). Furthermore, the JWC requested that partners curtail demands and switch sources if possible, which led to the JWC Member Agencies taking the following curtailment actions:

- Hillsboro relied on in-system storage reservoirs to minimize demand on JWC, eliminated inspection and construction flushing, asked industrial customers to voluntarily reduce their demands, and closely monitored fire events.
- Forest Grove used their WTP and in-system storage to minimize demand on JWC.
- Beaverton stopped ASR injection and mobilized their ASR system to significantly decrease their demand on JWC.
- TVWD relied on Portland supply, and did not take JWC supply during the event.

Immediate remedial actions taken at the WTP included turning on a caustic soda feed to the rapid mix, which had solved a similar chemistry problem in a similar December 2015 storm event. However, staff saw very limited improvement from this measure this time around, and so continued to look for solutions. Incoming raw water was reduced to a single pipeline from the raw water intake. Staff had to keep pumping and treating water until filterable water was produced. Until that time, staff sent flume water directly to the drying beds and overflow, instead of treating the highly turbid water with the filters. A large diesel pump, which was purchased after the 2015 event, was utilized during this time (continuously for days) to minimize the amount of overflow.

Algae Bloom Event in 2019

In the spring of 2019, JWC water quality staff first observed an algae bloom at Hagg Lake near Scoggins Dam while conducting routine sampling. Immediately, staff began ramping up monitoring per the JWC Algal Response Plan and determined that the dominant species was *Aphanizomenon flos aquae*, a species of potentially toxin cyanobacteria. Based on the JWC Algal

Response Plan, as well as recommendations by the Oregon Health Authority (OHA), JWC staff collected samples for toxic analysis, and determined that there were low levels of the toxin microcystin present at two of the four locations sampled in the reservoir, but no toxins were present in Scoggins Creek downstream of the reservoir outlet or in the JWC raw water. Continued sampling of algal speciation, enumeration, and associated toxins showed a brief increase in enumeration of *Aphanizomenon flos aquae*, followed by a steady decline over the course of the following weeks. All subsequent toxin samples in the reservoir were either at the detection limit or non-detects and toxins were never detected in Scoggins Creek downstream of the reservoir or in the JWC raw water. This event lasted approximately 5 weeks from the initial observation to when cell densities were observed at low enough levels to return to routine monitoring as defined by the JWC Algal Response Plan.

Although this event did not require curtailment, in the event of the detection of toxins at the JWC raw water intake it is possible that curtailment may be necessary depending on the time of year, severity of the algal bloom, and the treatment plants capabilities to properly treat raw water to remove specific toxins. The WTP has the ability to add powdered activated carbon (PAC), which is effective at removing cyanotoxins. For example, if cyanotoxins are detected in the source water and at the JWC intake operators at the WTP may initiate the addition of PAC as a precaution. Dosing of PAC to effectively remove cyanotoxins often requires large amounts of PAC, which may require the WTP to decrease production. This may result in curtailment, depending on demand, storage, and the dose of PAC needed.

Storm Event Analysis

In response to the 2018 Storm Event and 2019 Algae Bloom Event, the JWC commissioned a Storm Event Analysis to review what happened and to provide recommendations to improve storm event preparedness and response. The Storm Event Analysis was finalized in October 2019 and adopted by the JWC on January 10, 2020. The JWC has already begun implementing many of the recommendations.

South Transmission Line Leak in 2019

On November 17, 2019, a leak on the 45-inch South Transmission Line (STL) was reported on SW Tongue Lane, in rural Washington County. The STL delivers water to southern portion of Hillsboro's service are, TVWD, and is the main supply line to Beaverton. Crews were able to isolate the leak and completed repairs on November 22nd. There was no loss of water service to customers as the leak was isolated and water was supplied to the remainder of the STL through the NTL-STL intertie.

Current Capacity Limitation

The JWC's current capacity limitation is the production capacity of the JWC WTP, which has been rated at 85 mgd for peak day capacity. The WTP's production capacity is lower during the winter season due to impacts of colder temperatures on treatment process, and capacity can further decrease during the winter season due to water quality events. Production capacity can be impacted at any time due to equipment failures.

40 Years of Continuing Reliability Improvements

Since its beginning in 1976, the JWC has continued to plan and budget for improvements to increase capacity and reliability of the JWC water system. Past improvements that now benefit the JWC system include:

- Barney Reservoir Expansion project
- Multiple WTP expansions (the most recent completed in 2019 to expand the W TP capacity from 75 mgd to 85 mgd)
- Additional finished water storage
  - Construction of a second JWC Fern Hill Reservoir in 2006. This added an additional 20 MG of finished water capacity to the system for a total of 40 MG.
- Installation of back-up electricity
  - The WTP in cooperation with PGE added a back-up power generator onsite in 2016
- Improvements to water quality treatment
  - The WTP added a powdered activated carbon (PAC) feeder in 2008 to improve treatment of organics
  - The JWC added sedimentation basin plate settlers
- Seismic reinforcement
  - The JWC's Fern Hill Reservoir 1, was seismically upgraded in 2006.
  - The construction of the second JWC Fern Hill Reservoir included seismic hardening and wrapping with rebar in 2007.

In addition, the JWC is planning to add emergency interties at the following locations:

- Emergency Intertie between TVWD and JWC North Transmission Line (NTL) at Cornelius Pass and Highway 26
- Emergency Intertie between the Willamette Water Supply (WWS) and JWC NTL at Cornelius Pass and Highway 26
- Intertie between the WWS Line and JWC South Transmission Line at Cornelius Pass and Tualatin Valley Highway.

JWC partners have taken individual actions to improve reliability and increase emergency preparedness as well. TVWD and Beaverton have added Aquifer Storage and Recovery (ASR) wells; Hillsboro has increased in-town storage with the addition of Crandall Reservoir, has seismically reinforced the 24th Street Reservoir, and has increased storage time by adding chlorine feeders to all of its in-town reservoirs. Forest Grove has made improvements to its water treatment plant as well. Hillsboro, Beaverton, and TVWD are also in the process of building infrastructure to use the Willamette River as an additional water supply source.

4.2.2. Notifications of Source Water Availability

Before Release Season

The JWC notifies its member agencies of the status of storage in Barney Reservoir and Hagg Lake consistently throughout the year. JWC provides its member agencies storage curves for both reservoirs at the semi-monthly JWC Operations Committee meetings and the quarterly JWC Board meetings, and also makes the reports accessible to partners on the web.

The Bureau of Reclamation announces the official storage available to contract holders ahead of storage releases. If applicable, the JWC will contact the Bureau of Reclamation to confirm the levels of water supply and the reduction schedules for each JWC member agency with contracted water in Scoggins Dam (Hagg Lake).

The General Manager informs the Operations Committee and the Management Committee by April 15 if the potential for a water shortage has been identified. (If the potential shortage is not known until a later date, the GM then makes immediate notification to the committees.)

The Operations Committee is notified when the Watermaster determines the regulation of several JWC-related natural flow water rights that impact the start and end dates of the release season.

If a potential shortage is identified after April 15th, the JWC Managing agency requests each JWC agency to provide a seasonal forecast of amount of JWC water needed during release season. (This is the starting point, if discussion of curtailment scenarios and potential solutions needs to begin.)

At the start of release season, JWC provides the storage allocations to each member agency that is allocated storage in Barney Reservoir, has a contract with the Bureau of Reclamation in Hagg Lake, or has a lease agreement with another JWC member agency.

During Release Season

When supplies are being provided from Barney Reservoir and/or Hagg Lake, each JWC agency is required to forecast the amount of water that they will need (commonly referred to as a “call for releases”) in accordance with notification requirements outlined in the JWC Operations Manual.

JWC provides weekly release reports to the member agencies that include the previous week’s daily releases, the allotments of those release volumes charged to each member agency, status of remaining storage, and efficiency of capture of stored water. The frequent distribution of the release reports has made them a valuable resource for storage and release tracking and has helped increase the efficiency of stored water releases in relation to customer demands.

The JWC issues notices of potential shortages in each member agency's allotment during the release season when supplies are reduced or demands are unusually high.

4.2.3. Curtailment Event Triggers and Stages

OAR 690-086-0160(2) and (3)

Curtailment Triggers

Limitations to the WTP's capacity or reductions in supply do not automatically trigger imposition of curtailment measures, but begin a discussion among the JWC partner agencies to determine if partners would be willing to voluntarily reduce their demand by switching to alternate water supply sources. The JWC Managing Agency, through the JWC Operations Committee, has updated the Operations Manual, which distinguishes between normal supply disruptions and when to evoke the curtailment plan provided here. The Operations Manual will work in harmony with the Curtailment Plan, and strive for equitable solutions for all partners. Staff will make sure that the plans reference each other as needed.

Examples of events that could cause the JWC Curtailment Plan to be activated include, but would not be limited to, the following:

Supply Disruption and Capacity Limitations – Short-Term

- Mechanical or electrical malfunction of critical pumping facilities at the JWC's intake or water treatment plant.
- Interruption of local utility electrical service for an unknown or extended period of time.
- Transmission line break resulting in supply disruption to one or more partners.
- Unplanned water quality or other treatment issues that slow JWC WTP production below partner demands in which the timeline for recovery from the condition is uncertain and the risk of total reservoir depletions, at projected rates of production and demand, is high.
- Short-term increase in total partners' demand beyond JWC WTP production capabilities, due to an unforeseen circumstances such as extreme hot weather conditions, fire, or loss of a secondary supply. (This condition would be for short-term shortages, and not long-term shortages, such as one caused by drought.)

Drought Conditions and/or Source Water Scarcity - Peak Season

- Abnormal weather conditions during the storage season, or other conditions, make it unlikely that Barney Reservoir and/or Hagg Lake will fill to their full capacities preceding the summer release season.

- High demands result in drawdown of reservoir supplies at a rate indicative that supplies will not last the duration of release season.
- Loss by any partner agency of an alternate supply source for an entire peak season.

Extreme Supply Disruption – Long-Term

- Catastrophic natural disaster, such as an earthquake, watershed fire, landslide, or volcanic eruption.
- Terrorist act that damages individual critical facilities and/or extensive portions of the JWC's transmission system, and/or lifelines such as electrical power and chemical deliveries.

4.2.4. Curtailment Stages

During the peak summer demand period from June through September when the system is operating at or near its maximum capacity, interruption of supply could present significant challenges to the JWC. This could be due to events such as natural disaster, mechanical failure, terrorist act or loss of source. Therefore, the following triggers and related curtailment stages in this curtailment plan are based primarily on events occurring during this time period. In addition, less critical impacts to the water supply such as forecasted drought, and minor mechanical or electrical failures are addressed in Stages 1 and 2.

This curtailment plan for the JWC is designed to be initiated and implemented in progressive stages. The JWC's curtailment plan has four distinct stages, as shown in Exhibit 4-1, each of which is triggered by one or more of the listed events:

Exhibit 4-1. Curtailment Plan Stages 1 through 4

Curtailment Stages	Potential Initiating Conditions
Stage 1 Advisory Temporary Water Shortage Alert (Short-Term Voluntary)	Short-term[1] interruption of electrical service affecting water treatment and distribution; Harmful algal blooms (HAB) clogs filters and impairs performance or occurrence of a cyanotoxin producing bloom; in which Powder-Activated Carbon (PAC) may need to be added; Minor mechanical or electrical malfunction in pumping facilities or treatment plant; Minor damage to raw or treated water transmission mains (e.g., leaking joint requiring repair); or Forecasts of below-normal[2] levels of stored water in Barney Reservoir and Scoggins Dam (Hagg Lake) that may fall below the historical 25th percentile in the peak season.
Stage 2 Voluntary Long-Term Water Shortage Alert (Long-Term Voluntary)	Forecasts of below-normal[2] levels of stored water in Barney Reservoir and Scoggins Dam (Hagg Lake) that may fall below the historical 10th percentile in the peak season. Forecasts of drought conditions for the peak season.
Stage 3 Mandatory Severe Water Shortage (Long-Term Mandatory)	One of JWC's summer supplemental sources (Barney Reservoir and Scoggins Dam/Hagg Lake) are 50% of full capacity at the start of release season, resulting in a significant reduction[3] of JWC's water supply capacity; High demands result in drawdown of reservoir supplies at a rate indicative that supplies will not last the duration of release season; Loss by any partner agency of an alternate supply source for an entire peak season; or Failures in the pumping facilities, treatment plant or transmission mains that require a lengthy repair time.

Curtailment Stages	Potential Initiating Conditions
Stage 4 Emergency Critical Water Shortage (Critical Mandatory Restrictions)	Extensive damage to transmission, pumping or treatment processes caused by natural disaster (i.e. earthquake) or terrorist act; Both of JWC's summer supplemental sources (Barney Reservoir and Scoggins Dam (Hagg Lake) are below 50% of full capacity, resulting in a severe reduction of the JWC's water supply capacity; Interruption of electrical service to the WTP for an unknown or extended period of time. Localized transmission line break resulting in supply disruption. Unplanned water quality or other treatment issue that slows JWC WTP production below partner demands in which the timeline for recovery from the condition is uncertain and the risk of total reservoir depletions, at projected rates of production and demand, is high. Short-term increase in total partners' demand beyond JWC WTP production capabilities, due to an unforeseen circumstances such as extreme hot weather conditions, fire, or loss of a secondary supply. (This condition would be for acute short-term shortages, and not long-term shortages, such as one caused by drought.)

[1] "Short-term" interruption means an interruption with an expected end. For example, a power outage expected to last one week would be probable cause for Stage 1 curtailment. The decision to initiate curtailment would depend on the time of year, likelihood that power will be restored in the predicted timeframe, and the likelihood that the JWC can maintain backup power for the duration of the outage. In this case, the JWC could avoid curtailment by using the back-up generators at the water treatment plant, backup fuel supplies, and the JWC Member Agency storage.

[2] "Below normal" levels means that water levels fall slightly outside the normal drawdown curve. However, the JWC could avoid curtailment if alternate supplies are made available that put source supplies back into normal ranges. For example, the reservoirs were between the 25th and 10th percentile in the 2015-2016 release season, but curtailment was not necessary. In addition, if alternate supplies are expensive, the JWC may choose to promote voluntary curtailment in order to reduce dependency on alternative supplies and to reduce costs.

[3] "Significant Reduction" means that the JWC's water supply capacity cannot be made up through alternative means, so mandatory curtailment is necessary to reduce demand levels to ensure that water supplies don't run out. However, the JWC could avoid mandatory curtailment if alternate supplies are made available that put source supplies back into normal ranges.

4.2.5. Curtailment Plan Implementation

OAR 690-086-0160(4)

Curtailment Response

It is important to note that curtailment response includes a range of options. It does not necessarily mean that reductions in demand on the JWC system will be required for all partners. Utilizing available JWC assets or other alternative water supply sources are the agreed-upon first choice for managing source and peak capacity issues. A coordinated curtailment response that provides sufficient water to all JWC partners may be achievable without the need for individual partner agencies to impose voluntary or mandatory restrictions on their customers. Measures that impact customers will only need to be implemented if JWC partners cannot meet one or more partners' needs through negotiation and sharing of resources.

Objectives

JWC will do the following to ensure a coordinated response in a curtailment trigger situation:

- Present member agencies with information about the status of WTP capacity limitations, individual agency ownership percentages, and agencies' current demands on capacity.
- Present member agencies with information about the status of source water availability and releases from stored water.
- Present member agencies about the current physical and chemical water quality parameters, as well as notify member agencies when water quality parameters exceed decided upon trigger levels relevant to operational decisions.
- Provide a forum for negotiation of alternative or shared supply sources between JWC members.
- Require each JWC member agency to develop and adopt a customer curtailment plan and submit it to the JWC for inclusion in the JWC Water Management and Curtailment Plan (WMCP), in accordance with ORS 690-086.
- Coordinate unified public messaging related to curtailment and conservation measures and requirements. If curtailment is only needed by some of the partners, messages will still be coordinated to minimize confusion and/or impacts to customers of the JWC partners not implementing curtailment.
- Meet State requirements for curtailment when the Governor issues a drought declaration and orders curtailment plan implementation in accordance with ORS 536.720. See the Drought Declaration discussion at the end of Section 4 for details.

JWC System Components

There are a variety of emergency situations that could cause the need for curtailment, and the method for determining curtailment percentage for each JWC partner will be based on the system component affected. It is important to remember that JWC partners have agreed to always try and avoid curtailment through partner negotiation of assets, but formal curtailment methodology will be helpful in determining how much additional water one partner may need to negotiate with other partners.

- Source Water Curtailment (Curtailment caused by lack of source water):
  - As previously described in Summary of 2001 Drought section, supply reductions in Hagg Lake are stipulated in BOR contracts.
- Water Treatment Plant Curtailment (Curtailment caused by decrease in treatment capacity severe enough to be less than demands on the system for a prolonged period that Fern Hill Reservoirs and in-town storage facilities may not be able to cover.)
  - Curtailment will be based on ownership percentage in the Water Treatment Plant
- Electrical Power Failure Curtailment (Curtailment due to power failure for a prolonged duration that Fern Hill Reservoirs and in-town storage facilities may not be able to cover)
  - If curtailment is necessary to meet partner water demands, it will be based on percentage ownership of the back-up power generator
- Transmission Line Failure (Service from one or more transmission line is disrupted, and any remaining transmission line(s) still in service are unable to meet partner demands.)
  - Curtailment percentage will be based on percentage of ownership in the remaining transmission line(s) in operation.

Curtailment Stages

Stage 1: Advisory - Temporary Water Shortage Alert

Supply Disruption and Capacity Limitations – Short-Term

1. The JWC Managing agency will notify the member agencies of the expected duration of the event and available finished water in storage, as soon as that information is known. The JWC will also notify wholesale customers if they are affected by the event.
2. The JWC Managing agency will request projected water demands from each member agency for the projected duration of the event.
3. JWC staff will optimize available JWC assets and utilize Fern Hill storage to the extent practical.

4. The JWC Managing agency may request JWC member agencies to voluntarily reduce or shift their demands to other supplies. If these actions result in costs to those agencies, compensation for those costs may be negotiated between the agencies.
5. Member agencies shall keep the other JWC agencies apprised of activities and messaging for their individual agency curtailment efforts. Affected agencies may request assistance and coordination for public messaging and outreach efforts from the JWC Events and Education Committee (EEC).
6. The JWC shall notify and potentially coordinate with Washington County Public Health and Oregon Health Authority.
7. If disruption is caused by a transmission line break, and the break does not affect all partners, and if curtailment by other partners does not improve the situation for the partner that is affected by the line break, partners do not have to curtail to assist the affected partner. However, if the affected partner requests assistance, the Managing agency will assist affected partner(s) with alternate supply and/or curtailment efforts, and will also make the emergency water distribution system available to affected partner(s), upon request.

Drought Conditions and/or Source Water Scarcity – Peak Season

1. Source water scarcity issues that affect Barney Reservoir will be coordinated through the Barney Reservoir Joint Ownership Commission (BRJOC), which includes all the JWC partners and Clean Water Services (CWS). Any decisions regarding curtailment of Barney Reservoir source water must include all BRJOC partners. Although CWS is not normally part of the JWC EEC, if curtailment is necessary due to Barney source scarcity, a CWS representative will be invited to participate with the EEC in any coordinated messaging and outreach efforts. Any outside coordination and possible curtailment negotiation with Oregon Department of Fish and Wildlife will also be handled by the BRJOC Managing Agency.
2. Source water scarcity issues that affect Hagg Lake will be primarily coordinated through the Joint Water Commission, although secondary coordination with the Tualatin Valley Irrigation District (TVID), Clean Water Services, and the Federal Bureau of Reclamation may be required. Curtailment due to Scoggins' Dam future remediation or seismic improvements will be coordinated through Clean Water Services and a working group partnership, and may be done as a separate agreement from what is outlined in this curtailment plan – assuming such curtailment is pre-organized as part of the improvement project.
3. JWC staff will continue to participate in, and coordinate through, the Tualatin River Flow Management Committee. This committee discusses operations that could impact flows, flow monitoring, and share information to proactively manage storage, instream flows, and diversions. Its members include the Oregon Water Resources Department's local Watermaster, JWC, CWS, TVID, Lake Oswego Corporation, Washington County Parks and Recreation, and Washington County Emergency Management.

4. The JWC Managing agency will notify the member agencies of the expected duration of the event and available stored water supplies and available finished water in storage.
5. The JWC Managing agency will request projected water demands from each member agency for the projected duration of the event.
6. The JWC Managing agency will develop stored water use scenarios based on various estimated peak season demand levels.
7. JWC staff will optimize available JWC assets and utilize Fern Hill storage capacity to the extent practical.
8. The JWC Managing agency may request JWC member agencies to voluntarily reduce or shift their demands to alternate sources. If these actions result in costs to those agencies, compensation for those costs may be negotiated between the agencies.
9. Partners that have available excess stored water and/or capacity may receive requests from partners needing water to lease excess stored water and/or additional capacity to other partners in need. Leasing protocols are found in the JWC Water Service Agreement.
10. Member agencies shall keep the other JWC agencies apprised of activities and messaging for their individual agency curtailment efforts. Affected agencies may request assistance and coordination for public messaging and outreach efforts from the JWC Events and Education Committee (EEC).
11. Communication efforts will be coordinated by the JWC Public Information Officer (PIO) if mandatory curtailment is required of all JWC partners. The JWC EEC will provide a summary and schedule of any proposed cooperative public outreach campaign and schedule to the Operations and Management Committees for review and approval. JWC maintains an emergency communications budget that covers short-term communication efforts, but each agency may be requested to provide additional funds for a longer-term, peak-season public outreach campaign, depending on the elements of the proposed campaign.
12. The JWC shall notify and potentially coordinate with Washington County Public Health and Oregon Health Authority.

Stage 2: Voluntary - Long-Term Water Shortage Alert

Supply Disruption and Capacity Limitations – Short-Term

The same actions described under Stage 1 apply to this stage, as well.

Drought Conditions and/or Source Water Scarcity – Peak Season

The same actions described under Stage 1 apply to this stage, as well.

Stage 3: Mandatory - Severe Water Shortage

Supply Disruption and Capacity Limitations – Short-Term

Actions described in the previous stages may apply to this stage, as well. The following actions may also be taken.

1. The JWC Managing agency may order mandatory curtailment from all partners if voluntary efforts do not solve JWC supply or capacity issues.
2. Communication efforts will be coordinated by the JWC Public Information Officer (PIO) if mandatory curtailment is required of all JWC partners.
3. The JWC shall notify and potentially coordinate with Washington County Public Health and Oregon Health Authority.

Drought Conditions and/or Source Water Scarcity – Peak Season

Actions described in the previous stages may apply to this stage, as well. The following action may also be taken.

1. The JWC may order mandatory curtailment from all partners if voluntary efforts do not solve JWC supply or capacity issues.
2. Communication efforts will be coordinated by the JWC Public Information Officer (PIO) if mandatory curtailment is required of all JWC partners.

The JWC shall notify and coordinate with Washington County Public Health and Oregon Health Authority.

Stage 4: Emergency - Critical Water Shortage

Supply Disruption and Capacity Limitations – Short-Term

Actions described under previous stages of curtailment may apply to this stage, as well. The following action may also be taken.

The JWC General Manager may declare an emergency if all partners and wholesale customers are affected. The JWC can require individual member agencies and/or wholesale customers to reduce demand on the JWC system if those members are exceeding their percentage of supply/capacity availability.

Drought Conditions and/or Source Water Scarcity – Peak Season

Actions described in the previous stages may apply to this stage, as well. The following actions may also be taken.

The JWC General Manager may declare an emergency if all partners and wholesale customers are affected. The JWC may request individual member agencies and wholesale customers to reduce demand on the JWC system if those members are exceeding their percentage of supply/capacity availability. Curtailment amounts are based on percentage of ownership in the JWC component that is causing the scarcity issue.

Extreme Supply Disruption

After an extreme event such as a severe natural disaster (earthquake, flooding, landslides, etc.) or terrorist act, JWC will take the following actions:

1. The JWC Managing agency will invoke its Emergency Response Plan, and procedures in that plan supersede procedures in this plan if they are in conflict.
2. JWC will follow procedures 4-12 listed above under the Stage 1 “Drought Conditions” section.
3. JWC will initiate activation of the JWC Department Operations Center (DOC), and of the Hillsboro Emergency Operations Center (EOC) if it has not already been activated, within the Incident Command System. (The General Manager may declare a State of Emergency at this point as well.)
4. JWC will notify the member agencies of the expected duration of the event (if known) and the status of supply.
5. JWC will complete a damage assessment as soon as possible and provide critical information on facility damage and treatment capacity to member agencies and Hillsboro EOC. Resources will be requested through the Hillsboro EOC.
6. JWC will coordinate with the Washington County Office of Consolidated Emergency Management for regional support in extreme events, and implement any needed support from the Oregon Water/Wastewater Agency Response Network mutual aid agreements, and seeking federal aid from the Federal Emergency Management Agency and the National Guard.
7. Communication efforts between JWC member agencies, wholesale customers, basin partners, regional partners (RWPC members), and Washington County emergency communicators (including a Joint Information Center, if one is set up by the county) will be coordinated by the JWC Public Information Officer (PIO).
8. Recovery from an extreme event will be directed by the JWC Disaster Recovery Plan, outlined in the JWC Emergency Response Plan.

Aquifer Storage and Recovery (ASR) Wells

For ASR wells operating under the JWC Limited License, the following curtailment language that was included in the Agreement regarding ASR Management (dated 2013) will apply:

> *“The Parties agree that the production of potable water, storage and transmission by the JWC System, as defined in the Water Services Agreement, is primarily for the direct and immediate needs of all members of the JWC and will have priority over production storage and transmission of water for ASR purposes. If the JWC System experiences an emergency, construction, or maintenance event where by water production by the JWC System is interrupted, reduced or otherwise curtailed, then the JWC Managing Agency may suspend provision of water for the ASR Program until the circumstances are resolved.”*

ASR wells not licensed through the JWC Limited License Agreement and instead licensed by individual JWC partners with the State, will operate at the complete discretion of the owner. The JWC Managing Agency will coordinate with individual ASR owners, as needed, on potential impacts of injection if curtailment is a consideration during non-peak (injection) season, but does not have authority to require individual partner action regarding such ASRs.

Authority and Protocols

Actions of this plan that are handled by system optimization and agreements between the member agencies can be taken under direction of the JWC General Manager. Emergency response will be coordinated by the JWC General Manager and the Senior Program Manager in charge of JWC treatment processes at the Water Treatment Plant.

If a decision or emergency declaration must be made immediately, the JWC General Manager has authority to make emergency response decisions as Incident Commander. The JWC Operations Committee will be notified and consulted as soon as possible when a potential curtailment situation develops. The JWC will consult the Curtailment Decision Tree and will make operational recommendations to the JWC General Manager, who will then consult the JWC Management Committee for approval on the recommended approach. The General Manager may convene an emergency meeting of the Commission if needed.

The JWC's Water Service Agreement gives the JWC General Manager the authority to impose mandatory reductions in treated water supply from the JWC WTP to partner agencies and wholesale customers in an emergency situation that affects one or all partners.

After a declaration of emergency by the JWC General Manager, and approval by the JWC Management Committee, all partner agencies will be informed of any mandatory curtailment action required by the JWC, along with a timeline to achieve such reduction. Individual partner agencies are responsible for decisions and implementation of mandatory curtailment for their customers.

Mandatory curtailment actions will remain in effect until the emergency declaration is ended by the JWC General Manager. The JWC General Manager is responsible for execution of the plan provisions once an emergency has been declared.

Enforcement of the Curtailment Plan, along with remedies and penalties for overuse are addressed in the JWC's Water Service Agreement, which is being updated to include crisis curtailment enforcement and agreement on the use and ownership of the back-up power generator. Disagreements on curtailment actions that cannot be settled through collaborative effort will be settled as outlined by the JWC's Water Service Agreement.

Voluntary curtailment messaging can be coordinated and/or implemented by the JWC EEC, or by individual agencies, depending on agreed upon preference. JWC partners should notify other member agencies prior to implementation of curtailment actions.

The Operations Committee will exercise the Curtailment Plan as part of their exercises for the JWC Emergency Response Plan.

Drought Declaration

If a declaration of a drought is declared for Washington County by the Governor per ORS 536.720, the Oregon Water Resources Commission may order political subdivisions within any drainage basin or subbasin to implement a water conservation or curtailment plan or both, approved under ORS 536.780. The conservation and curtailment elements of this WMCP meet these requirements.

If the JWC and its member agencies are within a drought area declared by the Governor, the JWC and its member agencies will consider whether curtailment measures are needed to meet system demands. If ordered to implement a water conservation or curtailment plan during a declared drought, the JWC and its member agencies would comply by implementing the water conservation and curtailment provisions of this WMCP. Alternatively, the JWC could petition for a State exemption from implementing its curtailment plan if it can demonstrate to the State (using historic and current data) that the JWC is not experiencing a water shortage that impacts the ability of its partner agencies to meet the demands of their customers (e.g. JWC has adequate stored water supply at Barney Reservoir and Hagg Lake, or partners are able to tap additional supply availability from ASR or from other sources). Regardless of whether curtailment is needed, the JWC and its member agencies will encourage customers to conserve water.

4.2.6. Curtailment Decision Tree

The Joint Water Commission (JWC) water system is producing water, but cannot meet full water demands, either due to supply disruption or lack of capacity in water infrastructure.

Are any partners exceeding their rightful available capacities? (Yes/No)

Yes – Exceeding partner(s) must take action to address deficiency. Options include using an alternative source if one is available, negotiating for a lease (water supply or infrastructure capacity) or another acceptable arrangement with a JWC partner, or go into some form of customer curtailment. Actions related to “Supply Disruption and Capacity Limitations” of the Protocol section in the Curtailment Plan are triggered for impacted partner(s) only.

No – All partners must reduce their JWC demand to a sustainable amount through crisis. Curtailment plan is triggered for protocol section regarding “Supply Disruption and Capacity Limitations” for all partners.

Are alternative supplies available to one or more JWC partner(s) that will allow them make additional water/infrastructure capacity available to another partner? (Yes / No)

Yes – Partners without alternative supplies may be able to negotiate with JWC partners that have alternative supplies for additional water or infrastructure capacity in the JWC system. Negotiations will likely include financial compensation for use of asset.

No – All partners must reduce JWC demand to a sustainable amount and customer curtailment must be considered by partner(s) with no alternative method to meet demand. Curtailment plan is activated for all partners under protocol section titled, “Supply Disruption and Capacity Limitations.”

The JWC water system has been incapacitated in some way and the ability to serve water to a part or all of the JWC service population has been severed.

Is it possible to serve the system from an alternative source through an interconnection with another water system?

Yes – Partners will work together to get water into the system as quickly and efficiently as possible, using whatever means at their disposal. Negotiations for financial compensation will be handled as quickly as possible, but the emergency need of the community takes precedence. The Curtailment Plan is activated, and mandatory actions under “Extreme Supply Disruption” are enacted. Other actions will be considered and implemented if necessary.

No – JWC can dispatch its emergency water distribution system to the area without water service, or to a designated area which is accessible by the majority affected population. JWC will also call and request additional water supplies from ORWARN, if warranted by the situation. The Curtailment Plan is activated using protocols under “Extreme Supply Disruption.”

Either one or both of JWC’s summer supplemental sources (Barney Reservoir and Hagg Lake) do not fill, resulting in a reduction of JWC’s water supply capacity. Or, weather conditions cause transfer to supplemental sources at an early date.

Looking at historical demand scenarios, how likely is it that JWC does not have enough water to meet summer season demands?

Likely – Historic demand records indicate that summer source water will run out before an average release season would end. Curtailment Plan is triggered and protocol for mandatory actions under “Source Water Scarcity Protocol” are activated.

Not Likely – Historic demand records indicate that summer source water is adequate for an average release season length. If demands escalate changing the supply forecast, staff alerts General Manager who can decide if Curtailment Plan should be triggered.

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5. Water Supply

This section satisfies the requirements of OAR 690-086-0170.

This rule requires descriptions of the JWC's current and future water delivery areas and population projections, demand projections for 10 and 20 years, and the schedule for when the JWC expects to fully exercise its water rights. The rule also requires comparison of the JWC's projected water needs and the available sources of supply, an analysis of alternative sources of water, and a description of required mitigation actions.

5.1. Delineation of Service Areas

OAR 690-086-0170(1)

Exhibit 2-2 shows the JWC's current and future water service area during this WMCP 20-year planning period. The future water service area is the area between the current water service area boundaries and both the Metro Urban Growth boundary and Urban Reserve boundary for Washington County, which is an area that will be served by various JWC Member Agencies. Although the Metro UGB boundary and Urban Reserve boundary for Washington County account for growth beyond the 20-year planning period of this WMCP, these boundaries provide the best representation of the area where the JWC Member Agencies need to be prepared to serve water within the next 20 years given that near-term JWC Member Agency future service areas are in flux and the water providers do not make the decisions regarding what areas will be opened to expansion. Additional information about the anticipated future service areas of individual JWC Member Agencies is available in the 2017 City of Hillsboro WMCP, 2018 City of Beaverton WMCP, and 2015 TVWD WMCP.

5.2. Population Projections

OAR 690-086-0170(1)

Exhibit 5-1 presents population projections for each JWC Member Agency, and the JWC's wholesale customers, North Plains and Western Lutheran School. The JWC projects that its entire service area population will reach 505,609 in 2030 and 559,472 in 2040. The analyses used to develop the population projections are described below.

Exhibit 5-1. JWC Population Projections

Year	Hillsboro	Forest Grove	Beaverton	TVWD	Wholesale	Total
2020	104,043	25,379	91,338	218,514	3,682	442,956
2021	104,964	25,877	92,238	222,218	3,858	449,155
2022	105,901	26,375	93,153	225,957	4,043	455,429
2023	106,847	26,880	94,085	229,739	4,238	461,789
2024	107,810	27,387	95,028	233,558	4,442	468,225
2025	108,785	27,901	95,988	237,418	4,657	474,749
2026	109,642	28,384	96,849	241,023	4,883	480,780
2027	110,517	28,871	97,717	244,655	5,120	486,879
2028	111,391	29,360	98,597	248,323	5,369	493,040
2029	112,287	29,853	99,492	252,027	5,631	499,290
2030	113,190	30,350	100,399	255,763	5,907	505,609
2031	113,978	30,818	101,207	259,237	6,197	511,437
2032	114,772	31,286	102,021	262,734	6,501	517,314
2033	115,549	31,747	102,817	266,177	6,821	523,111
2034	116,273	32,197	103,574	269,516	7,157	528,717
2035	117,003	32,651	104,340	272,875	7,510	534,379
2036	117,573	33,055	104,955	275,835	7,882	539,299
2037	118,151	33,462	105,579	278,806	8,272	544,270
2038	118,731	33,869	106,210	281,795	8,682	549,287
2039	119,317	34,278	106,849	284,794	9,113	554,352
2040	119,911	34,688	107,498	287,809	9,566	559,472

As shown in Exhibit 5-2, the City of Hillsboro's projected service area population consists of the populations projected within the City's In-Town service area, the City's Upper System service area, and the wholesale customer service area of the LA Water Cooperative, and the Cities of Gaston and Cornelius. The population projections within the City's In-Town service area, the City's Upper System, and the City of Cornelius are based on forecasts developed by the Portland State University Population Research Center (PRC) completed June 2019 (based on 2019 water service area boundaries). LA Cooperative's population projections are based on its annual growth rate from 2010 through 2016 of 0.5% applied to the 2018 estimated population of 2500. The City of Gaston's population projections are based on its average annual growth rate from 2010 through 2018 of approximately 2.8% applied to the 2018 estimated populations of 655, according to the 2018 PRC Report.

Exhibit 5-2. City of Hillsboro Population Projections

Location	Projected	
	2030	**2040**
City of Hillsboro (In-Town)	96,467	101,690
Hillsboro Upper System	1,937	1,935
LA Water Co-Op	2,655	2,791
Gaston	891	1179
Cornelius	11,240	12,316
Total	113,190	119,911

The projected populations for the City of Forest Grove, the City of Beaverton, and TVWD are based on the forecasts developed by the Portland State University Population Research Center (PRC) completed June 2019.

The City of North Plain's projected populations utilize an average annual growth rate of approximately 4.97% and a 2019 baseline population estimate of 3,285. Westside Lutheran School currently has an estimated population of 230 students and teachers.

5.3. Demand Projections and Water Supplies To Meet Projected Demands Approach

As described in Section 2, the JWC has natural flow water rights for municipal water supply from the Tualatin River and its tributaries, water rights for the use of stored water from Barney Reservoir and Scoggins Reservoir, and ASR. JWC Member Agencies also have non-JWC water rights for municipal water supply from the Clear Creek watershed (Forest Grove), groundwater (Beaverton and TVWD), ASR (TVWD, Beaverton and Hillsboro), and the Willamette River (Hillsboro, Beaverton, and TVWD). To reiterate, the Willamette River is not a JWC source, and will not serve all JWC Member Agencies. The JWC water supply will remain the largest available source for the Cities of Hillsboro, Beaverton, and Forest Grove.

The JWC water supply year has two seasons, the peak season (May-October) and the non-peak season (November-April), with different demands and available sources of supply during each season. As a result, two separate demand projections need to be developed, 1) maximum day demand (MDD) projections that represent the greatest demands anticipated in the peak season and 2) average day demand (ADD) projections that represent the typical demands anticipated in the non-peak season. The MDD for the peak season and the ADD for the non-peak season. Water supplies needed to meet those two demand projections need to be addressed for both seasons listed above.

5.4. Demand Forecast

OAR 690-086-0170(3)

5.4.1. JWC Demand Projections

To develop the JWC's demand projections, each JWC Member Agency developed its own demand projections and provided them to the JWC, which the JWC then compiled. Each JWC Member Agency determines which of its water sources to use to meet that demand.

MDD Projections in the Peak Season

The JWC's MDD considers the MDD of each JWC Member Agency and wholesale customers from all sources, not just demand on the JWC system. The JWC's MDD occurs during the peak season of May through October. Exhibit 5-3 presents the MDDs of the individual JWC Member Agencies, wholesale customers, and their combined total, which is 210.26 cfs (135.91 mgd) in 2030 and 237.94 cfs (153.8 mgd) in 2040. The JWC calculated MDDs as described under Demand Projections Methodology below.

Exhibit 5-3. MDD Projections, 2030 and 2040

	2030		2040	
	MDD (mgd)	**MDD (cfs)**	**MDD (mgd)**	**MDD (cfs)**
Hillsboro	49.08	75.92	58.26	90.12
Forest Grove	11.03	17.07	13.13	20.31
Beaverton	19.99	30.93	21.13	32.69
TVWD	54.25	83.92	58.72	90.84
Wholesale	1.56	2.42	2.57	3.98
Total	**135.91**	**210.26**	**153.8**	**237.94**

Adjusted ADD Projections in the Non-peak Season

To determine the demand that the JWC must be prepared to meet in the non-peak season of November through April, the JWC considered: ADD, water demands for ASR injections, variability in non-peak season demand, and the JWC's daily diversions at the SHPP Intake. The ADD of each JWC Member Agency and its wholesale customers, as described under Demand Projections Methodology below, was summed. That ADD total was added to the maximum injection rate authorized for ASR LL-002, ASR LL-019, and ASR LL-027. Next, a multiplier of 0.9 was applied to reflect the fact that maximum day demand from December through April historically has occurred in December and has been approximately 90 percent of the ADD. Finally, a peaking factor of 1.15 was applied to reflect the variability of the JWC's diversions at the SHPP Intake throughout the course of a day, which was based on an analysis of the diversion data. Between the 0.9 and 1.15 multipliers, the maximum demand anticipated during the non-peak season is 1.035 times the ADD. Exhibit 5-4 presents the factors accounted for when calculating the adjusted ADD anticipated during the non-peak season and the estimated adjusted ADD total, which is 162.61 cfs (105.11 mgd) in 2030 and 178.79 cfs (115.57 mgd) in 2040.

Exhibit 5-4. Adjusted Average Day Demand (ADD), 2030 and 2040

Demand Factors	2030		2040	
	ADD (mgd)	**ADD (cfs)**	**ADD (mgd)**	**ADD (cfs)**
Hillsboro	28.73	44.44	34.51	53.39
Forest Grove	5.52	8.53	6.56	10.15
Beaverton	10.52	16.28	11.12	17.21
TVWD	26.41	40.86	28.62	44.28
Wholesale	0.71	1.10	1.17	1.81
User Total	**71.89**	**111.21**	**81.99**	**126.84**
ASR LL-002 Max Injection	12.50	19.34	12.50	19.34
ASR LL-019 Max Injection	11.66	18.04	11.66	18.04
ASR LL-027 Max Injection	5.51	8.52	5.51	8.52
ASR Total	**29.67**	**45.90**	**29.67**	**45.90**
User + ASR Totals (Total ADD)	**101.56**	**157.11**	**111.66**	**172.74**
90% of Total ADD (Dec)	**91.40**	**141.40**	**100.50**	**155.47**
Total with WTP Daily PF (1.15)	**105.11**	**162.61**	**115.57**	**178.79**

5.4.2. Demand Projections Methodology

Hillsboro

The City of Hillsboro Water Department (City) prepared a 2018 update to its water demand projections (Demand Projections Update Report, April 2018). The objectives of this update were to:

- Reflect changes in water usage characteristics associated with recent development;
- Capture the range of potential growth related to economic development; and,
- Identify the factors that most impact demand and analyze the sensitivity of demand to those variables.

The demand projection update used statistical analysis of historical water usage to define relationships between customer demand and influencing variables, such as temperature, precipitation, and rates (i.e., price). These relationships were then used to project future demands per account based on potential changes to the influencing variables. This approach was taken where feasible and then complemented by traditional methods for projecting components of demands for which the historical relationships were not as relevant (e.g., future industrial use, which depends more upon type of development rather than other influencing variables). Traditional methods included land use based techniques, where water usage factors (e.g., in gallons per acre per day) were applied to projected future growth in land area to be served by the City. This approach also accounted for demands of wholesale customers and included a water loss factor.

The 2018 water demand projection update incorporates future demands associated with redevelopment of Downtown Hillsboro, the development of South Hillsboro (SoHi) over the coming 20 years, the anticipated development of North Hillsboro (NoHi) and, further in the future, additional Future Growth Areas (FGA) on the outskirts of the City (See Exhibit 2-2).

Forest Grove

Forest Grove is currently beginning the process to update its Water Master Plan, which will produce updated demand projections within the next couple of years. In the meantime, Forest Grove based the demand projections in this WMCP on the demand projections developed for the 2010 JWC WMCP, which were based on Forest Grove's 2000 WMP with updated water demand trends, population forecasts, and per capita demand factors.

As stated in the 2010 JWC WMCP, water use projections for the 2000 WMP included both land use analyses and population projections. Key forecasting factors in the WMP included an annual population growth rate of 2.23 percent and an average day per capita water demand of 199 gpcd. Master plan demand projections were updated using the same methodology but using a revised growth rate of 2.65 percent and a lower per capita demand of 160 gpcd. That reduction in per capita demand was attributed to successful conservation efforts. Demand forecasting included approximately 160 residential water customers outside Forest Grove's city limits. Buildout for Forest Grove's service area was estimated to occur in 2034. Based on historical trends, the MDD to ADD peaking factor was 2.0. In this WMCP, the ADD and MDD projections also include the demand that could be met by Forest Grove's Clear Creek water supply (which is not managed by the JWC); the JWC must plan to provide supply in case this source becomes unavailable.

Beaverton

Beaverton's demand projections come from its 2018 Water System Master Plan and align with its 2018 WMCP, but were extended for two years to synchronize with the planning period of this WMCP. The demand projections considered the following variables and made assumptions about each:

- **Growth Scenario and Schedule.** Of the three growth scenarios that the City considered, the City selected the Medium scenario to represent service area future growth and the schedule of this growth. This scenario was selected on the basis of the City's knowledge of growth trends and regional and local plans for land development.
- **Average Day Demand (ADD).** To forecast ADD, the City applied a per capita demand figure to future population estimates. The City estimated future ADD based on an average per capita demand of 103 gpcd.
- **Per Capita Use.** The City's per capita usage of 103 gpcd was based on historical usage from all customer classes and was used to estimate future ADD. It is assumed that this per capita usage will remain the same over the planning period.
- **Peaking Factor.** Peaking factors were estimated and applied to ADD over time to estimate future MDDs through the planning period. The WSMP applied unique peaking factors to each of the City's current and future pressure zones over the planning period, with an average value of 1.9. Note that a peaking factor of 2.0 is assumed for areas anticipated to be served in the final years of the WMCP planning period (2037/2038 and thereafter), and was applied to the Tile Flats (west and north of Urban Reserve 6B) area. However, given that the Tile Flats area is anticipated to add to demand only in the last years of the City's planning period, the effects of this peaking factor of 2.0 are negligible on overall demand.
- **Customer Make-Up.** Beaverton utilized the percent of customers in each billing class for fiscal year 2014/15 (single family residence with 41.4 percent, apartment and multifamily with 28 percent, commercial with 21.1 percent, fire and irrigation with 8.5 percent and public facility with 0.9 percent), and assumed that these percentages are still current and will remain the same during the planning period.

Additional details, including service area development assumptions, are available in Beaverton's 2018 WMCP.

TVWD

TVWD's demand projections come from its 2018 Water Master Plan (WMP) Update, which made updates to the 2015 Water Master Plan, including adjusting demand curves to begin in 2018 while keeping the trendline the same as the 2015 WMP. For the 2015 WMP, TVWD developed low-, medium-, and high-demand scenarios to: 1) account for the uncertainty that is inherent in demand projections as a result of the numerous factors and assumptions involved, and 2) better depict the range of possible future demands. TVWD considered the following variables and made assumptions for each: demographic growth scenarios, Equivalent Dwelling Units (EDUs) per account, EDU water use, water loss, MDD/ADD peaking factors, and a large water user demand. TVWD selected a medium demand projection to account for uncertainties associated with future growth and water demand including, but not limited to demographic growth, EDUs per account, EDU water use, water loss, long-range weather forecasts, and large user demand projections. TVWD's projected MDD decreases in 2025 and again towards the end of the planning horizon due to customers being transferred to City of Beaverton water service.

5.5. Meeting Projected Demands with JWC and ASR Sources (Schedule to Exercise Permits and Comparison of Projected Need to Available Sources)

OAR 690-086-0170(2) and (4)

Non-peak Season Water Sources and Projected Adjusted Average Day Demands

As described in Section 2 and shown in Exhibit 2-63 (Typical Water Right Use), during November through April the JWC typically does not use its secondary rights for use of stored water. This calculation excludes recovery of ASR water given that water is injected into the aquifer rather than withdrawn during the non-peak season. Thus, the non-peak water sources must also meet the ASR injection demands.

Currently, the JWC has access to up to 26 cfs under Permit S-54737 under the final order approving the 2010 JWC WMCP. The JWC has determined that it will need access to an additional 18 cfs under Permit S-54737, for a total of 44 cfs, during the planning period of this WMCP. This calculation does not consider the JWC's pending Application S-88506, which would authorize use of up to 44 cfs from the Tualatin River from December through April, because it has not yet been approved by OWRD and it would not provide additional water supply (i.e.; it will not be additive to the amount of water used under Permit S-54737).

The JWC's Water Treatment Plant Facility Plan (updated April 2018) described expanding the WTP from 131.5 cfs (85 mgd) to 163 cfs (105 mgd) within approximately 20 years, which is similar to the planning horizon for this WMCP. Therefore, the JWC is seeking access to 44 cfs of "green light water" under Permit S-54737, the difference between the estimated expanded JWC WTP capacity of 163 cfs and the 119.46 cfs of JWC natural flow surface water rights currently accessible for use in the non-peak season. The 44 cfs of "green light water" under Permit S-54737 would enable the JWC to meet up to 163 cfs out of 178.8 cfs of the projected adjusted ADD in the non-peak season in 2040. (As previously described, the 178.8 cfs incorporates the WTP Daily PF of 1.15.) Over the next 10 years, the JWC will monitor actual and projected demands in order to determine if additional non-peak season supplies are needed. The JWC and JWC Partner Agencies could also coordinate to reduce ASR injections during high demand periods in the non-peak season, thereby lowering total demand to be within the JWC existing water supplies.

Peak Season Water Supply Sources and Projected Maximum Day Demands

As described in Section 2 and shown in Exhibit 2-63 (Typical Water Right Use), most of the JWC's natural flow water rights are typically regulated off in the peak season (June through October), and as a result, the JWC largely relies on the use of stored water to meet MDDs in the peak season.

In a typical year, the JWC's combination of available natural flow rights and secondary rights for the use of stored water provide up to 152.7 cfs (98.69 mgd) of surface water during the peak season. In addition, the JWC's ASR LL-019 authorizes the recovery of stored water at a rate of up to 62.3 cfs (40.3 mgd), Beaverton/TVWD's ASR LL-02 authorizes the recovery of stored water at a rate of up to 22.3 cfs (14.4 mgd), and Hillsboro's ASR LL-027 authorizes the recovery of stored water at a rate of up to approximately 11.5 cfs (7.5 mgd). These natural flow and secondary rights, in combination with the ASR limited licenses, authorize the use of up to 248.8 cfs (160.8 mgd).

For planning purposes, the JWC is not including the following sources of supply as being available to meet the peak season MDD: the City of Hillsboro's, City of Beaverton's, and TVWD's Willamette River water supply; Forest Grove's water supply from the Forest Grove WTP; and the City of Hillsboro's water supply from the Cherry Grove WTP. Excluding these sources from the analysis ensures the JWC can provide sufficient water supply if the Member Agencies' other sources become unavailable. Furthermore, the infrastructure to develop the Willamette River water supply is not in place, TVWD's groundwater rights are only used as an emergency or backup water supply, so are not considered a water source to meet MDDs, and Beaverton's native groundwater rights are not considered additional sources to ASR given that the native groundwater rights are appropriated from the same wells used for Beaverton's ASR operations. Thus, the JWC has 248.8 cfs (160.8 mgd) of water rights and ASR limited license authorizations that can be used and developed to meet MDDs in the peak season, as shown in Exhibit 5-5.

The projected MDD of 237.94 cfs in 2040 is less than the 248.8 cfs of water rights and ASR limited licenses described above. Additional water conservation measures could also augment water supplies, which will be discussed in the Alternatives Analysis later in Section 5.

Exhibit 5-5. Water Sources to Meet Maximum Day Demands in the Peak Season

Water Sources	Rate (cfs)	Rate (mgd)
JWC surface water rights	152.7	98.7
JWC ASR	62.3	40.3
TVWD/Beaverton ASR	22.3	14.4
Hillsboro ASR	11.5	7.5
Total	248.8	160.8

Willamette River as a Future Water Source for the City of Hillsboro, City of Beaverton, and TVWD

Hillsboro, Beaverton and TVWD are working toward obtaining water from the Willamette River as a future water source to help meet MDDs in the peak season, to provide TVWD with a replacement source for its PWB water supply, and to provide redundant water supplies. Hillsboro, Beaverton, and TVWD determined that a redundant source is crucial given that several of the Tualatin River natural flow water rights are regularly not available, leaving primarily stored water for use. The JWC is experiencing much longer and more frequent periods when only stored water is available due to very low streamflows. In 2019, the JWC supplemented natural flow water rights with stored water into mid-December. Thus, the reliability of the JWC's Tualatin River natural flow water rights is being negatively affected by climate change and more frequent and prolonged droughts, making the need for redundant water supply critical. In addition, the Willamette River will provide a redundant source of water supply during seismic upgrades to the JWC water system. More information about plans for Hillsboro, Beaverton, and TVWD to use the Willamette River as a water source are described in their individual WMCPs.

Schedule to Develop JWC Permits

The JWC anticipates that Permit S-54737 will be put to full beneficial use by approximately 2071, the development deadline for Permit S-54737. As described above, based on the assumption that other JWC member agency water sources are not available during the non-peak season, the JWC is seeking access to 44 cfs of the undeveloped portion of *extended permit* S-54737. The JWC anticipates that Permit S-55219 will be put to full beneficial use by July 26, 2039 in accordance with the permit's development deadline.

5.6. Alternative Sources

OAR 690-086-0170(5)

OAR 690-086-0170(5) requires an analysis of alternative sources of water if any expansion or initial diversion of water allocated under existing permits is necessary to meet future water demand. The JWC plans to initiate diversion of water under Permit S-54737.

5.6.1. Conservation Measures

OAR 690-086-0170(5)(c) requires an analysis of the extent to which the projected water needs can be satisfied through implementation of conservation measures identified under OAR 690-086-0150.

Given that Permit S-54737 authorizes use during the non-peak season, an analysis of water conservation from November through April is most pertinent. Relevant measures are primarily indoor water conservation. Each JWC Member Agency has its own water conservation program that includes numerous indoor and outdoor water conservation measures and strives to increase water use efficiency. The water conservation programs of each JWC Member Agency are described in detail in Section 3. If the JWC's Member Agencies collectively managed to achieve additional water conservation savings of 5% annually, they would reduce the projected 2040 non-peak season ADD by approximately 2 cfs. Thus, the JWC would still need access to approximately 42 cfs under Permit S-54737 by 2040. In addition, that level of water conservation savings would likely be challenging to achieve given that the JWC Member Agencies have various indoor water conservation measures already in place and have very low per capita water use, and the three largest JWC Member Agencies had water losses of 10 percent or less as of 2019.

Therefore, water savings from conservation measures cannot eliminate the JWC's need for additional water supply to meet its future demands in the non-peak season within its entire service area. With that said, the JWC will continue to strive to be a water conservation and management leader among water providers in the State of Oregon.

5.6.2. Interconnections

OAR 690-086-170(5)(b) requires an analysis of the extent to which the projected water needs can be satisfied through interconnection with other municipal supply systems and cooperative regional management.

The JWC's water supply agreements between multiple water supply systems exemplifies regional cooperation. JWC Member Agencies are interconnected and have cooperative water management agreements that allow a given Member Agency to make use of another Member Agency's unused water supply.

In 2011 and 2012, the City of Hillsboro and TVWD conducted evaluations of water supply options to meet their future water demands, and the City of Beaverton participated in both.

The City of Hillsboro's evaluation considered the following supply options: the Portland Water Bureau, the Willamette River, the Tualatin Basin Water Supply Project (which involved raising the dam at Hagg Lake), JWC ASR, treated effluent, and a groundwater source. TVWD's evaluation considered four water supply options: the Portland Water Bureau, the Willamette River, the Tualatin Basin Water Supply Project, and obtaining groundwater supply from a well field in the Scappoose area.

The evaluations considered such factors as: cost, source reliability, source redundancy, ownership, operational complexity, implementation risk, source water quality, treated water quality, environmental impacts, and responsiveness to demand growth of each of these sources. Other considerations included public acceptance, community impacts, economics, and impacts to rates.

Based on their evaluations, the City of Hillsboro and TVWD concluded that the Willamette River was the best water supply source option because it offers benefits such as year-round reliability, source redundancy, ownership and control of supply, excellent finished water quality, cost-effectiveness, and reduced environmental impacts compared to other options. According to OWRD's water availability analysis, water is available in the reaches of the Willamette River below the McKenzie River confluence at 80 percent exceedance every month of the year. The ability of the City of Hillsboro, City of Beaverton, and TVWD to partner to create the WWSP made the Willamette River water supply option more feasible and preferable, as well.

Subsequently, the City of Hillsboro and TVWD began a partnership to develop the Willamette River option under the WWSP. The City of Beaverton participated in the WWSP preliminary design process from 2013 to 2015. Under the preliminary design, the City evaluated its demands and source options and concluded that buying into the WWSP provided the most reliable and cost-effective significant source of additional water supply. More detailed descriptions about the water supply evaluations can be found in TVWD's 2014 WMCP, the City of Hillsboro's 2017 WMCP, and the City of Beaverton's 2018 WMCP.

The WWSP is a cooperative water management effort between the City of Hillsboro, TVWD, and the City of Beaverton to use water from the Willamette River to meet projected water demands, provide water supply redundancy, and in the case of TVWD, replace an existing water supply source (PWB). However, for this evaluation, the JWC is focusing on its ability to meet the needs of its member agencies in the event their individual water supplies are not available, and in that circumstance, the JWC would need to rely on Permit S-54737 to meet water demands.

5.6.3. Cost Effectiveness

OAR 690-086-170(c) requires an assessment of whether the projected water needs can be satisfied through other conservation measures that would provide water at a cost that is equal or less than the cost of other identified sources.

Existing infrastructure is capable of diverting and distributing the water to which the JWC is requesting access to under Permit S-54737, such that conservation measures would not provide water at a cost equal to or lower than the cost of using water under the permit. In addition, water conservation measures alone, regardless of the cost, cannot meet the projected adjusted ADDs in the non-peak season under the above-described assumptions in this WMCP. Nevertheless, the JWC and its member agencies will continue to implement and promote their water conservation programs.

5.7. Quantification of Projected Maximum Rate and Monthly Volume

OAR 690-086-0170(6)

OAR 690-086-0170(6) requires a quantification of the maximum rate of withdrawal and maximum monthly use if any expansion or initial diversion of water allocated under an existing permit is necessary to meet demands in the 20-year planning horizon. Within the next 20 years, the JWC is planning to need access of up to 44.0 cfs (28.4 mgd) under Permit S-54737. Assuming that the water right is used at 28.4 mgd, 24 hours per day for 31 days during a non-peak season month (likely December or March), the maximum monthly volume for the water right would be approximately 880.4 MG.

5.8. Mitigation Actions under State and Federal Law

OAR 690-086-0170(7)

Under OAR 690-086-0170(7), for expanded or initial diversion of water under an existing permit, the water supplier is to describe mitigation actions it is taking to comply with legal requirements of the Endangered Species Act, Clean Water Act, and other applicable state or federal environmental regulations.

The JWC currently is not required to take any mitigation actions under state or federal law. However, the final order approving an extension of time for Permit S-54737 (formerly Permit S-50879) included “fish persistence” conditions, which are described above in Section 2. The JWC is aware of the conditions.

In addition, the JWC has proposed a mitigation project to ODFW that will allow the agency to grant a fish screen exemption for the Bureau of Reclamation fish screens at the SHPP. (Permits S-55219 and S-54737 include fish screening conditions and if OWRD issues a permit for Application S-88506, it will also have a fish screening condition.)

5.9. New Water Rights

OAR 690-086-0170(8)

Under OAR 690-086-0170(8), if a municipal water supplier finds it necessary to acquire new water rights within the next 20 years in order to meet its projected demand, an analysis of alternative sources of the additional water is required. The analysis must consider availability, reliability, feasibility and likely environmental impacts and a schedule for development of the new sources of water.

The JWC does not need to acquire new water rights within the next 20 years to meet its projected demands. The JWC does have a pending permit application (Application S-88506) for up to 44 cfs from the Tualatin River, which is intended to increase the reliability of the JWC's water supply during a portion of the non-peak season (December 1 through April 30), but does not provide additional water supply, because use of water under the requested permit in combination with use of the 75 cfs authorized by Permit S-54737, will be limited to a total of 75 cfs. Since Application S-88506 is not requesting additional supply, the provisions of this section are not applicable.

Appendix A

Letters to Local Governments and Comments

August 7, 2020

Colin Cooper
City of Hillsboro Planning Department
Civic Center, 4th Floor
150 E Main Street
Hillsboro, OR 97123
Colin.Cooper@hillsboro-oregon.gov

Subject: Water Management and Conservation Plan for the Joint Water Commission

Dear Mr. Cooper:

The Joint Water Commission (JWC) has developed a draft Water Management and Conservation Plan (WMCP) to fulfill the requirements of Oregon Administrative Rule Chapter 690, Division 86 of the Oregon Water Resources Department.

Under these rules, the water supplier shall make its draft WMCP available for review by affected local governments and seek comments relating to consistency with the local governments' comprehensive land use plans. Attached you will find a copy of the JWC's draft WMCP for your review.

Please provide comments to me within 30 days from the date of this letter. If the plan appears consistent with your Comprehensive Land Use Plan, a letter response to that effect would be appreciated. You may send your comments to me by email at sdeszoeke@gsiws.com.

If you have any questions, please feel free to contact me at 541-224-4588. Thank you for your interest.

Sincerely,
GSI Water Solutions Inc.

Suzanne de Szoeke

Suzanne de Szoeke, Water Resources Consultant

Enclosure

GSI Water Solutions, Inc.

August 7, 2020

Anna Slatinsky
City of Beaverton Planning Division
Beaverton City Hall
4755 SW Griffith Dr.
P.O. Box 4755
Beaverton, OR 97076
aslatinsky@BeavertonOregon.gov

Subject: Water Management and Conservation Plan for the Joint Water Commission

Dear Ms. Slatinsky:

The Joint Water Commission (JWC) has developed a draft Water Management and Conservation Plan (WMCP) to fulfill the requirements of Oregon Administrative Rule Chapter 690, Division 86 of the Oregon Water Resources Department.

Under these rules, the water supplier shall make its draft WMCP available for review by affected local governments and seek comments relating to consistency with the local governments' comprehensive land use plans. Attached you will find a copy of the JWC's draft WMCP for your review.

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If you have any questions, please feel free to contact me at 541-224-4588. Thank you for your interest.

Sincerely,
GSI Water Solutions Inc.

Suzanne de Szoeke

Suzanne de Szoeke, Water Resources Consultant

Enclosure

Water Solutions, Inc.

August 7, 2020

Bryan Pohl, Director
City of Forest Grove Community Development: Planning
City Hall
1924 Council Street
P.O. Box 326
Forest Grove, OR 97116-0326
bpohl@forestgrove-or.gov

Subject: Water Management and Conservation Plan for the Joint Water Commission

Dear Mr. Pohl:

The Joint Water Commission (JWC) has developed a draft Water Management and Conservation Plan (WMCP) to fulfill the requirements of Oregon Administrative Rule Chapter 690, Division 86 of the Oregon Water Resources Department.

Under these rules, the water supplier shall make its draft WMCP available for review by affected local governments and seek comments relating to consistency with the local governments' comprehensive land use plans. Attached you will find a copy of the JWC's draft WMCP for your review.

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If you have any questions, please feel free to contact me at 541-224-4588. Thank you for your interest.

Sincerely,
GSI Water Solutions Inc.

Suzanne de Szoeke

Suzanne de Szoeke, Water Resources Consultant

Enclosure

Water Solutions, Inc.

August 7, 2020

Andy Back
Washington County Public Services Building
Land Use & Transportation Division
Planning and Development Services, Long Range Planning
155 N 1st Avenue, Suite 350
Hillsboro, Oregon 97124-3072
lutdir@co.washington.or.us

Subject: Water Management and Conservation Plan for the Joint Water Commission

Dear Mr. Back:

The Joint Water Commission (JWC) has developed a draft Water Management and Conservation Plan (WMCP) to fulfill the requirements of Oregon Administrative Rule Chapter 690, Division 86 of the Oregon Water Resources Department.

Under these rules, the water supplier shall make its draft WMCP available for review by affected local governments and seek comments relating to consistency with the local governments' comprehensive land use plans. Attached you will find a copy of the JWC's draft WMCP for your review.

Please provide comments to me within 30 days from the date of this letter. If the plan appears consistent with your Comprehensive Land Use Plan, a letter response to that effect would be appreciated. You may send your comments to me by email at sdeszoeke@gsiws.com.

If you have any questions, please feel free to contact me at 541-224-4588. Thank you for your interest.

Sincerely,
GSI Water Solutions Inc.

Suzanne de Szoeke

Suzanne de Szoeke, Water Resources Consultant

Enclosure

GSI Water Solutions, Inc.

August 7, 2020

Chris Neamtzu
City of Wilsonville Planning Division
29799 SW Town Center
Loop E
Wilsonville, OR 97070
neamtzu@ci.wilsonville.or.us

Dear Mr. Neamtzu:

The Joint Water Commission (JWC) has developed a draft Water Management and Conservation Plan (WMCP) to fulfill the requirements of Oregon Administrative Rule Chapter 690, Division 86 of the Oregon Water Resources Department.

Under these rules, the water supplier shall make its draft WMCP available for review by affected local governments and seek comments relating to consistency with the local governments' comprehensive land use plans. Attached you will find a copy of the JWC's draft WMCP for your review.

Please provide comments to me within 30 days from the date of this letter. If the plan appears consistent with your Comprehensive Land Use Plan, a letter response to that effect would be appreciated. You may send your comments to me by email at sdeszoeke@gsiws.com.

If you have any questions, please feel free to contact me at 541-224-4588. Thank you for your interest.

Sincerely,
GSI Water Solutions Inc.

Suzanne de Szoeke

Suzanne de Szoeke
Water Resources Consultant

Enclosure

GSI Water Solutions, Inc.

August 7, 2020

Andy Varner, City Manager
City of North Plains
31360 NW Commercial Street
North Plains, OR 97133
andy.varner@northplains.org

Subject: Water Management and Conservation Plan for the Joint Water Commission

Dear Mr. Varner:

The Joint Water Commission (JWC) has developed a draft Water Management and Conservation Plan (WMCP) to fulfill the requirements of Oregon Administrative Rule Chapter 690, Division 86 of the Oregon Water Resources Department.

Under these rules, the water supplier shall make its draft WMCP available for review by affected local governments and seek comments relating to consistency with the local governments' comprehensive land use plans. Attached you will find a copy of the JWC's draft WMCP for your review.

Please provide comments to me within 30 days from the date of this letter. If the plan appears consistent with your Comprehensive Land Use Plan, a letter response to that effect would be appreciated. You may send your comments to me by email at sdeszoeke@gsiws.com.

If you have any questions, please feel free to contact me at 541-224-4588. Thank you for your interest.

Sincerely,
GSI Water Solutions Inc.

Suzanne de Szoeke
Water Resources Consultant

Enclosure

GSI Water Solutions, Inc.

August 7, 2020

Multnomah County Planning Department
1600 SE 190th Avenue
Portland, OR 97233
Land.use.planning@multco.us

Subject: Water Management and Conservation Plan for the Joint Water Commission

Dear Multnomah County Planning Department:

The Joint Water Commission (JWC) has developed a draft Water Management and Conservation Plan (WMCP) to fulfill the requirements of Oregon Administrative Rule Chapter 690, Division 86 of the Oregon Water Resources Department.

Under these rules, the water supplier shall make its draft WMCP available for review by affected local governments and seek comments relating to consistency with the local governments' comprehensive land use plans. Attached you will find a copy of the JWC's draft WMCP for your review.

Please provide comments to me within 30 days from the date of this letter. If the plan appears consistent with your Comprehensive Land Use Plan, a letter response to that effect would be appreciated. You may send your comments to me by email at sdeszoeke@gsiws.com.

If you have any questions, please feel free to contact me at 541-224-4588. Thank you for your interest.

Sincerely,
GSI Water Solutions Inc.

Suzanne de Szoeke
Water Resources Consultant

Enclosure

1600 SW Western Blvd., Suite 240 Corvallis, OR 97333 P: 541.753.0745 F: 541.754.4211 info@gsiws.com www.gsiws.com

GSI Water Solutions, Inc.

August 7, 2020

Elissa Gertler, Director
Metro, Planning and Development
Metro Regional Center
600 NE Grand Ave
Portland, OR 97232-2736
elissa.gertler@oregonmetro.gov

Subject: Water Management and Conservation Plan for the Joint Water Commission

Dear Ms. Gertler:

The Joint Water Commission (JWC) has developed a draft Water Management and Conservation Plan (WMCP) to fulfill the requirements of Oregon Administrative Rule Chapter 690, Division 86 of the Oregon Water Resources Department.

Under these rules, the water supplier shall make its draft WMCP available for review by affected local governments and seek comments relating to consistency with the local governments' comprehensive land use plans. Attached you will find a copy of the JWC's draft WMCP for your review.

Please provide comments to me within 30 days from the date of this letter. If the plan appears consistent with your Comprehensive Land Use Plan, a letter response to that effect would be appreciated. You may send your comments to me by email at sdeszoeke@gsiws.com.

If you have any questions, please feel free to contact me at 541-224-4588. Thank you for your interest.

Sincerely,
GSI Water Solutions Inc.

Suzanne de Szoeke

Suzanne de Szoeke
Water Resources Consultant

Enclosure

August 7, 2020

Andrea Durbin, Director
City of Portland
Bureau of Planning and Sustainability
1900 SW 4th Avenue, Suite 7100
Portland, OR 97201-5380
andrea.durbin@portlandoregon.gov

Subject: Water Management and Conservation Plan for the Joint Water Commission

Dear Ms. Durbin:

The Joint Water Commission (JWC) has developed a draft Water Management and Conservation Plan (WMCP) to fulfill the requirements of Oregon Administrative Rule Chapter 690, Division 86 of the Oregon Water Resources Department.

Under these rules, the water supplier shall make its draft WMCP available for review by affected local governments and seek comments relating to consistency with the local governments' comprehensive land use plans. Attached you will find a copy of the JWC's draft WMCP for your review.

Please provide comments to me within 30 days from the date of this letter. If the plan appears consistent with your Comprehensive Land Use Plan, a letter response to that effect would be appreciated. You may send your comments to me by email at sdeszoeke@gsiws.com.

If you have any questions, please feel free to contact me at 541-224-4588. Thank you for your interest.

Sincerely,
GSI Water Solutions Inc.

Suzanne de Szoeke

Suzanne de Szoeke, Water Resources Consultant

Enclosure

Water Solutions, Inc.

August 7, 2020

City of Gaston
116 Front St
PO Box 129
Gaston, Oregon 97119
wenonahb@cityofgaston.com

Subject: Water Management and Conservation Plan for the Joint Water Commission

Dear City of Gaston:

The Joint Water Commission (JWC) has developed a draft Water Management and Conservation Plan (WMCP) to fulfill the requirements of Oregon Administrative Rule Chapter 690, Division 86 of the Oregon Water Resources Department.

Under these rules, the water supplier shall make its draft WMCP available for review by affected local governments and seek comments relating to consistency with the local governments' comprehensive land use plans. Attached you will find a copy of the JWC's draft WMCP for your review.

Please provide comments to me within 30 days from the date of this letter. If the plan appears consistent with your Comprehensive Land Use Plan, a letter response to that effect would be appreciated. You may send your comments to me by email at sdeszoeke@gsiws.com.

If you have any questions, please feel free to contact me at 541-224-4588. Thank you for your interest.

Sincerely,
GSI Water Solutions Inc.

Suzanne de Szoeke

Suzanne de Szoeke
Water Resources Consultant

Enclosure

GSI Water Solutions, Inc.

August 7, 2020

Ryan A. Wells, AICP
Community Development Department
City of Cornelius
1355 N. Barlow Street,
Cornelius, OR 97113
rwells@ci.cornelius.or.us

Subject: Water Management and Conservation Plan for the Joint Water Commission

Dear Mr. Wells:

The Joint Water Commission (JWC) has developed a draft Water Management and Conservation Plan (WMCP) to fulfill the requirements of Oregon Administrative Rule Chapter 690, Division 86 of the Oregon Water Resources Department.

Under these rules, the water supplier shall make its draft WMCP available for review by affected local governments and seek comments relating to consistency with the local governments' comprehensive land use plans. Attached you will find a copy of the JWC's draft WMCP for your review.

Please provide comments to me within 30 days from the date of this letter. If the plan appears consistent with your Comprehensive Land Use Plan, a letter response to that effect would be appreciated. You may send your comments to me by email at sdeszoeke@gsiws.com.

If you have any questions, please feel free to contact me at 541-224-4588. Thank you for your interest.

Sincerely,
GSI Water Solutions Inc.

Suzanne de Szoeke

Suzanne de Szoeke, Water Resources Consultant

Enclosure

1600 SW Western Blvd., Suite 240 Corvallis, OR 97333 P: 541.753.0745 F: 541.754.4211 info@gsiws.com www.gsiws.com

GSI Water Solutions, Inc.

August 7, 2020

City of Tigard
Community Development Department
13125 SW Hall Blvd
Tigard, OR 97223
tigardplanneronduty@tigard-or.gov

Subject: Water Management and Conservation Plan for the Joint Water Commission

Dear Community Development Department:

The Joint Water Commission (JWC) has developed a draft Water Management and Conservation Plan (WMCP) to fulfill the requirements of Oregon Administrative Rule Chapter 690, Division 86 of the Oregon Water Resources Department.

Under these rules, the water supplier shall make its draft WMCP available for review by affected local governments and seek comments relating to consistency with the local governments' comprehensive land use plans. Attached you will find a copy of the JWC's draft WMCP for your review.

Please provide comments to me within 30 days from the date of this letter. If the plan appears consistent with your Comprehensive Land Use Plan, a letter response to that effect would be appreciated. You may send your comments to me by email at sdeszoeke@gsiws.com.

If you have any questions, please feel free to contact me at 541-224-4588. Thank you for your interest.

Sincerely,
GSI Water Solutions Inc.

Suzanne de Szoeke

Suzanne de Szoeke, Water Resources Consultant

Enclosure

Water Solutions, Inc.

August 7, 2020

Scot Siegel
City of Lake Oswego
PO Box 369
Lake Oswego, OR 97034
planning@lakeoswego.city

Subject: Water Management and Conservation Plan for the Joint Water Commission

Dear Mr. Siegel:

The Joint Water Commission (JWC) has developed a draft Water Management and Conservation Plan (WMCP) to fulfill the requirements of Oregon Administrative Rule Chapter 690, Division 86 of the Oregon Water Resources Department.

Under these rules, the water supplier shall make its draft WMCP available for review by affected local governments and seek comments relating to consistency with the local governments' comprehensive land use plans. Attached you will find a copy of the JWC's draft WMCP for your review.

Please provide comments to me within 30 days from the date of this letter. If the plan appears consistent with your Comprehensive Land Use Plan, a letter response to that effect would be appreciated. You may send your comments to me by email at sdeszoeke@gsiws.com.

If you have any questions, please feel free to contact me at 541-224-4588. Thank you for your interest.

Sincerely,
GSI Water Solutions Inc.

Suzanne de Szoeke

Suzanne de Szoeke
Water Resources Consultant

Enclosure

August 7, 2020

LA Water Cooperative
23055 NE Albertson Road
Gaston, Oregon
lawater.cooperative@gmail.com

Subject: Water Management and Conservation Plan for the Joint Water Commission

Dear LA Water Cooperative:

The Joint Water Commission (JWC) has developed a Draft Water Management and Conservation Plan (WMCP) to fulfill the requirements of Oregon Administrative Rule Chapter 690, Division 86 of the Oregon Water Resources Department. Under these rules, the water supplier shall make its Draft WMCP available for review by affected local governments and seek comments relating to consistency with the local governments' comprehensive land use plans.

As a courtesy, the Joint Water Commission is providing you with a copy of the Draft WMCP via email. If you have any questions, please feel free to contact me at 541-224-4588 or sdeszoeke@gsiws.com.

Sincerely,
GSI Water Solutions Inc.

Suzanne de Szoeke

Suzanne de Szoeke
Water Resources Consultant

Enclosure

Water Solutions, Inc.

August 7, 2020

Tom Hickman
Tualatin Valley Water District
1850 SW 170th Avenue
Beaverton, OR 97003
tom.hickman@tvwd.org

Subject: Water Management and Conservation Plan for the Joint Water Commission

Dear Mr. Hickman:

The Joint Water Commission (JWC) has developed a Draft Water Management and Conservation Plan (WMCP) to fulfill the requirements of Oregon Administrative Rule Chapter 690, Division 86 of the Oregon Water Resources Department. Under these rules, the water supplier shall make its Draft WMCP available for review by affected local governments and seek comments relating to consistency with the local governments' comprehensive land use plans.

As a courtesy, the Joint Water Commission is providing you with a copy of the Draft WMCP via email. If you have any questions, please feel free to contact me at 541-224-4588 or sdeszoeke@gsiws.com.

Sincerely,
GSI Water Solutions Inc.

Suzanne de Szoeke

Suzanne de Szoeke
Water Resources Consultant

Enclosure

Water Solutions, Inc.

August 7, 2020

David Kraska
Willamette River Water Coalition
1850 SW 170th Avenue
Beaverton, OR 97003
david.kraska@tvwd.org

Subject: Water Management and Conservation Plan for the Joint Water Commission

Dear Mr. Kraska:

The Joint Water Commission (JWC) has developed a Draft Water Management and Conservation Plan (WMCP) to fulfill the requirements of Oregon Administrative Rule Chapter 690, Division 86 of the Oregon Water Resources Department. Under these rules, the water supplier shall make its Draft WMCP available for review by affected local governments and seek comments relating to consistency with the local governments' comprehensive land use plans.

As a courtesy, the Joint Water Commission is providing you with a copy of the Draft WMCP via email. If you have any questions, please feel free to contact me at 541-224-4588 or sdeszoeke@gsiws.com.

Sincerely,
GSI Water Solutions Inc.

Suzanne de Szoeke
Water Resources Consultant

Enclosure

Department of Community Services
Land Use Planning Division
www.multco.us/landuse

Multnomah County

1600 SE 190th Avenue, Portland OR 97233-5910 • PH. (503) 988-3043 • Fax (503) 988-3389

September 3, 2020

Suzanne de Szoeke
Water Resources Consultant
sdeszoeke@gsiws.com
GSI Water Solutions, Inc.
1600 SW Western Blvd., Suite 240
Corvallis, OR 97333

RE: Comment on Draft Water Management and Conservation Plan for the Joint Water Commission

Suzanne,

Thank you for the opportunity to review the draft Water Management and Conservation Plan developed by the Joint Water Commission to fulfill requirements of OAR Chapter 690, Division 86 of the Oregon Water Resources Department.

Our land use planning office manages unincorporated lands in Multnomah County. Although the majority of the Plan's project area is located outside of our jurisdiction, a few areas along the county's northwest boarder are identified within the Plan and which are served by the Tualatin Valley Water District.

It appears from my review that the Joint Water Commission concludes on page 202 that *"The JWC does not need to acquire new water rights within the next 20 years to meet its projected demands."* Therefore, I do not find any areas of the draft Water Management and Conservation Plan that appear inconsistent with relevant policies of the Multnomah County Comprehensive Land Use Plan which is available online: https://multco.us/file/55870/download

Please let me know if you have any questions or need anything further from Multnomah County.

Sincerely,

Adam Barber

Adam Barber,
Deputy Planning Director

Letter sent by email

Appendix B

Intergovernmental Agreements

APPENDIX B
Summary of Intergovernmental Agreements

Title	Date	Parties	Scope
Repayment contract between the United States of America and the City of Hillsboro, Contract No. 14-06-100-7180	11/11/1971	Hillsboro, BOR	Hillsboro enters into contract with BOR for construction and repayment of costs of the Tualatin Federal Reclamation Project. Provides Hillsboro with 4,500 ac-ft per year of municipal and industrial water supply from the project.
Repayment contract between the United States of America and the Tigard Water Distrct, Contract No. 14-06-100-7182	11/18/1971	Tigard Water District, BOR	Provides Tigard Water District with 2,500 ac-ft per year of M&I water from the Tualatin Federal Reclamation Project.
Repayment Contract between the United States of America and the City of Forest Grove, Contract No. 14-06-100-7197	12/17/1971	Forest Grove, BOR	Provides Forest Grove with 4,500 ac-ft per year of M&I water from the Tualatin Federal Reclamation Project.
Repayment contract between the United States of America and the City of Beaverton, Contract No. 14-06-100-7969	11/6/1973	Beaverton, BOR	Provides Beaverton with 1,500 ac-ft per year of M&I water from the Tualatin Federal Reclamation Project.
Supplemental contract between the United States of America and the City of Hillsboro, Contract No. 14-06-100-8069	3/8/1974	Hillsboro, BOR	Adds construction of the Spring Hill Pumping Plant to the Tualatin Federal Reclamation Project.
Joint Water Commission Water Service Agreement	2/1/1976	Hillsboro, Forest Grove	Establish a joint operation for the pumping, treatment and transmission of Municipal and Industrial Water, Creating a Joint Water Commission.
Joint Water Commission Water Service Agreement	4/17/1979	Hillsboro, Forest Grove, Beaverton	"Establish joint operations for the supply, pumping, treatment and transmission of municipal and industrial waters." Adds Beaverton as member of Joint Water Commission
Assignment of repayment contract No. 14-06-100-7182	8/21/1980	Tigard Water District, Hillsboro, BOR	Transfers Contract No. 14-06-100-7182 from Tigard Water District to Hillsboro.
Spring Hill Pump Plant Bypass Construction Agreement	2/28/1984	Hillsboro, Forest Grove, Beaverton Joint Utilities Commission, TVID, BOR	Springhill Pump Station Construction, JWC providing an advance of funds ($91,000) to construst the bypass to reduce sediment accumulation.
Repayment contract between the United States of America and the City of Hillsboro, Contract No. 2-07-10-W0867	12/26/1991	Hillsboro, BOR	Provides Hillsboro with 500 ac-ft per year of M&I water from the Tualatin Federal Reclamation Project.
Interim Water Conservation Plan Resolution No. 3230	7/16/1993	Hillsboro, Forest Grove, Beaverton, TVWD	"Committing to an Interim Water Conservation Plan." Conserving to comply with Barney Reservoir Expansion Project
By-Laws of the Columbia-Willamette Water Conservation Coalition	between 1993 and 1997	Municipal water providers of the Portland Metropolitan area	Establish the Conservation Coalition, establish goals, objectives, outline powers, duties and committees.
Joint Water Commission Water Service Agreement Amendment	6/30/1994	Hillsboro, Forest Grove, Beaverton, TVWD	Adds TVWD as member of Joint Water Commission
Joint Ownership Agreement- Barney Project (Rev 6-08-94) (AKA the "Original Barney Agreement")	7/19/1994	Hillsboro, Forest Grove, Beaverton, TVWD, United Sewerage Agency	"Establish joint ownership [and management] of a proposed expanded water reservoir commonly known as 'J.W. Barney Reservoir'." Includes Warranty Deed for land ownership in Yamhill (June 19, 1968) and Washington Counties (April 29, 1968).
Hillsboro-Beaverton-TVWD Joint Water Transmission Agreement	9/21/1994	Hillsboro, Forest Grove, Beaverton, TVWD	Amends Joint Water Service Agreement of April 17, 1979, by adding TVWD as part owner of the joint transmission line system.
Northside Water Transmission Agreement	4/11/1997	Hillsboro, Forest Grove, Beaverton, TVWD	Construction of Phase I of Northside Transmission Line
Proposed Bylaw Revision	7/17/1997	Columbia-Willamette Water Conservation Coalition	Adds new section of Finance Manager, establishes standing coalition committees
Northside Water Transmission Agreement- Phase II	1/14/2000	TVWD, Hillsboro, JWC	Construction of Phase II of Northside Transmission Line
Transmission Line Intergovernmental Agreement	1/14/2000	JWC, Hillsboro, TVWD, Cornelius	To coordinate the design and construction of replacement 72-inch water line that runs from the slow sand filter plant to Forest Grove and Cornelius and from which Cornelius has obtained doemstic water service pursuant to a contract between HIllsboro and Cornelius.

APPENDIX B

Summary of Intergovernmental Agreements

Title	Date	Parties	Scope
Joint Funding Agreement IWRM Water Supply Feasibility Study	5/14/2001	United Sewerage Agency, TVWD, Hillsboro, Beaverton, Forest Grove, Tigard, Sherwood, Tualatin, North Plains, Cornelius, Banks	Enters parties into an agreement under which they shall jointly fund a feasibility study of two alternatives and a 'no action' alternative to increasing the water supply for users within the Tualatin Basin. The two alternatives are Scoggins Dam Raise and Willamette River Exchange Pipeline. (IWRM = Integrated Water Resource Management)
Tualatin Basin Water Supply Agreement Memorandum of Understanding	5/18/2001	JWC, Tigard	Memorandum of Understanding outlining cooperation in planning for the developent or expansion of water sources in the Tualatin River Basin and water supply facilities.
Ordinance No. 1-03	2/19/2003	TVWD	TVWD authorizing an Intergovernmental Agreement Continuing the JWC - Hillsboro, Forest Grove, Beaverton and Tualatin Valley Water District.
Authorizing Ordinances	3/1/2003	Hillsboro, Forest Grove, Beaverton, TVWD	Each city authorizing an intergovernmental agreement titled "Joint Ownership Agreement Barney Project" which continues the Barney Reservoir Joint Ownership Commission.
Ordinance No. 5239	3/4/2003	Hillsboro	City of Hillsboro authorizing an Intergovernmental Agreement Titled "Joint Water Commission - Hillsboro, Forest Grove, Beaverton and Tualatin Valley Water District Water Service Agreement".
Agenda Bill #03072	3/31/2003	Beaverton	City of Beaverton authorizing the Mayor to Sign the JWC - Hillsboro, Forest Grove, Beaverton and Tualatin Valley Water District Water Service Agreement
Ordinance No. 2003-06	4/14/2003	Forest Grove	City of Forest Grove authorizing an Intergovernmental Agreement Continuing the JWC - Hillsboro, Forest Grove, Beaverton and Tualatin Valley Water District.
Joint Ownership Agreement- Barney Project	10/27/2003	Hillsboro, Forest Grove, Beaverton, TVWD, CWS	Terminates and Replaces the "Original Barney Agreement" (Rev 6-08-94).
Joint Water Commission Water Service Agreement (JWC IGA)	10/27/2003	JWC	Terminates and Replaces the Water Service Agreement, the Amended Water Service Agreement, the Transmission Agreement, the Amended Transmission Agreement, the Northside Water Transmission Agreement and the Northside Water Transmission Agreement Phase II.
Ordinance No. 5348	2/3/2004	Hillsboro	Authorizing a first amendement to the water service agreement and joinder agreement relating to the Joint Water Commission.
First Amendment to Joint Water Commission Water Service Agreement and Joinder Agreement	3/1/2004	JWC, Tigard	Adds Tigard as a JWC member, and places membership stipulation that Tigard must make Capital Contributions in the Hagg Lake expansion.
Ordinance No. 1-04	4/1/2004	TVWD	Authorizing a first amendement to the water service agreement and joinder agreement relating to the Joint Water Commission.
City of Cornelius Water Supply Agreement	1/1/2005	Hillsboro, Cornelius	City of Hillsboro wholesale water supply agreement with City of Cornelius, expires in December 31, 2014.
City of Gaston Water Supply Agreement	1/24/2005	Hillsboro, Gaston	City of Hillsboro wholesale water supply agreement with City of Gaston, expires in December 31, 2014.
City of North Plains Water Supply Agreement	1/14/2005	JWC, North Plains	Joint Water Commission wholesale water supply agreement with City of North Plains, expires in December 31, 2014.
Project Management Plan Agreement	07/2018	JWC, US Fish & Wildlife, and Clean Water Institute	Project Management Plan Agreement
Cyanotoxin Analysis Services IGA	07/2019	JWC and Oregon Department of Environmental Quality	Cyanotoxin Analysis Services IGA
Mutual Aid and Assistance Agreement Addendum	08/2019	JWC and Oregon Water/Wastewater Agency Response Network	Mutual Aid and Assistance Agreement Addendum
	2/3/2015	City of Beaverton, TVWD	JWC South Transmission Line temporary water supply
	4/12/2019	JWC, City of Forest Grove, TVWD	Lease of stored raw water

APPENDIX B
Summary of Intergovernmental Agreements

Title	Date	Parties	Scope
	4/12/2019	Joint Water Commission - City of Hillsboro, City of Beaverton, TVWD	Lease of North Transmission Line facilities capacity
	10/16/1996	Tualatin Valley Water District, City of Beaverton, Canby Utility Board, Clackamas River Water, City of Gladstone, Damascus Water District, City of Fairview, City of Gresham, City of Hillsboro Utilities Commission, City of Forest Grove, City of Lake Oswego, Metro, City of Milwaukie, Mt Scott Water District, Oak Lodge Water District, City of Portland, Raleigh Hills Water District, Rockwood Water, City of Sandy, City of Sherwood, South Fork Water Board, City of Oregon City, City of West Linn, City of Tigard Water Department, City of Troutdale, City of Tualatin, West Slope Water District, City of Wilsonville, City of Wood Village	Regional Water Providers Consortium
	10/27/2003	Tualatin Valley Water District, Joint Water Commission - City of Hillsboro, City of Beaverton, City of Forest Grove	Water service agreement
	10/27/2003	City of Hillsboro, City of Forest Grove, City of Beaverton, Clean Water Services	Barney Reservoir Joint Ownership Commission
	7/1/2013	Tualatin Valley Water District, Joint Water Commission - City of Hillsboro, City of Beaverton	Allocation and management of aquifer storage and recovery water and costs if the Cooper Mountain Area sites (or any future ones) are used in the JWC ASR system
	8/20/2013	Tualatin Valley Water District, Joint Water Commission, City of Hillsboro	Aquifer storage and recovery project design, construction, operation and property ownership

Appendix C

Non-Municipal Water Rights of JWC Member Agencies

Source	Priority Date	Application	Permit	Certificate	Claim, Transfer, Instream Lease	Entity Name on Water Right	Type of Beneficial Use	Authorized Rate (cfs)	Authorized Volume (ac-ft)	Maximum Rate of Withdrawal to Date		Average Daily Diversion (mgd)		Average Monthly Diversion (MG)		Authorized Date of Completion	Expiration of Instream Lease
										Instantaneous (cfs)	Annual (MG)	2015	5-year	2015	5-Year		
McKay Creek	8/16/1957	S-31801	S-25056	26358		Edward H Sahlfeld	Irrigation of 9.4 Acres	0.12		0.12	ND	ND	ND	ND	ND		
McKay Creek	4/29/1960	S-33916	S-26747	34822	Il-1325	La Vern William Buelet	Irrigation of 13.6 Acres	0.17		0.17	ND	ND	ND	ND	ND		10/1/2017
A Spring (tributary to McKay Creek)	7/11/1950	S-24975	S-19699	23481		Claire A and Marjorie E Richardson	Irrigation of 2.0 Acres	0.025		0.025	ND	ND	ND	ND	ND		
A Well	3/3/2003	~~G-15937~~	~~G-15550~~ CANCELLED			Carol Curl	Irrigation	0.02		NA	NA	NA	NA	NA	NA		
A Well	1/28/1997	G-14450	G-13463			Benchmark Land Co.; Jones Farm Single Family LLC	Irrigation of 85.7 Acres	1.07		ND	ND	ND	ND	ND	ND	10/1/2020	
Glencoe Swale	10/31/1994	R-74833	R-11641	84669		Intel Corp.	Wildlife		0.9		0.29	ND	ND	ND	ND		
Beaverton Creek	4/26/1965	R-40798	R-4568	35688		Gladys Smith	Fish Culture		2.8		0.91	ND	ND	ND	ND		
Beaverton Creek and a Reservoir Constructed Under Application No R-40798	4/26/1965	S-40799	S-30398	35689		Gladys Smith	Irrigation of 0.7 Acres and Fish Culture	0.06 (being 0.05 from Creek and Reservoir for Fish Culture and 0.01 from Creek for Irrigation)		0.06	ND	ND	ND	ND	ND		
Bronson Creek	4/20/1939	S-17913	S-13599	15402		E.J. Meihoff	Irrigation of 4.6 Acres	0.06		0.06	ND	ND	ND	ND	ND		
Bronson Creek	2/1/1945	S-20665	S-16166	16748		Erwin Springer	Irrigation of 2.5 Acres	0.031		0.031	ND	ND	ND	ND	ND		
Bronson Creek	11/30/1949	S-24303	S-19058	22749		Erwin Springer	Irrigation of 3.5 Acres	0.04		0.04	ND	ND	ND	ND	ND		
Rock Creek	4/7/1952 5/22/1952	S-27055	S-21221	23068	Il-1438	Derrell E Brown	Irrigation of 36.8 Acres	0.46		0.46	ND	ND	ND	ND	ND		9/30/2019
Bronson Creek	4/18/1940	S-18670	S-14301	14497		F.J. Meihoff	Irrigation of 5 acres	0.0625		0.0625	ND	ND	ND	ND	ND		
Beaverton Creek	1/22/1953	S-28021	S-22050	23621		Earl L Horning	Irrigation of 9.2 Acres	0.12		0.12	ND	ND	ND	ND	ND		
Dairy Creek	8/2/1966	S-42578	S-31814	35409		Laura Currin By Ruth Spaniol, Guardian	Irrigation of 264.3 Acres	1.04		1.04	ND	ND	ND	ND	ND		
Unnamed Stream, Tributary of Rock Creek	4/20/1967	R-43509	R-4876	40486		William Wallace	Storage		0.41		0.13	ND	ND	ND	ND		
Unnamed Stream, Tributary of Rock Creek	8/23/1967	R-43998	R-5072	40834		A.V. and Ida B Peterson	Storage		2.5		0.82	ND	ND	ND	ND		
Unnamed Spring Branch of Rock Creek	9/28/1932	S-14749	S-10743	12088	Il-1325	Edith S and Robert Couch	Irrigation of 16.5 Acres	0.22		0.22	ND	ND	ND	ND	ND		10/1/2017
Little Rock Creek	8/23/1966	S-42690	S-31900	38900		Joe Stroeder	Irrigation of 4 Acres	0.05		0.05	ND	ND	ND	ND	ND		
Sain Creek (and Scoggins Reservoir); Tualatin River	NA[1]			94896	PC-907	City of Hillsboro	Hydroelectric production of 67 theoretical horsepower	5[1]		ND	ND	ND	ND	ND	ND		

ND = No Data Available; NA = Not Applicable

Units: cfs = cubic feet per second; MG = million gallons; ac-ft = acre-feet

[1]This hydropower water right does not have a priority date. Use of this water right is only allowed when the underlying water rights (Certificates 67891, 81026, and 81027) are used. This water right is limited by the rate, duty, season, and any other limitations of Certificates 67891, 81026, and 81027.

Source	Priority Date	Application	Permit/ Instream Lease	Certificate	Claim, Transfer, Instream Lease	Entity Name on Water Right	Type of Beneficial Use	Authorized Rate (cfs)	Authorized Volume (ac-ft)	Maximum Rate of Withdrawal to Date		Average Daily Diversion (mgd)		Average Monthly Diversion (MG)		Authorized Date of Completion	Expiration of Instream Lease
										Instantaneous (cfs)	Annual (MG)	2015	5-year	2015	5-Year		
Unnamed Stream, a Tributary of Rock Creek, in Wetland Enhancement Reservoir appropriated under Permit S-50702	5/15/1989	R-69904	R-11133	65057		Keith and Ann Jansen	Wildlife		0.61		0.2	ND	ND	ND	ND		
Unnamed Stream and Wetland Enhancement Reservoir constructed under Permit R-11133, a Tributary of Rock Creek	5/15/1989	S-69905	S-50702	65058		Keith and Ann Jansen	Wildlife	0.012		0.012		ND	ND	ND	ND		
Rock Creek, a tributary of Tualatin River	6/10/1958	S-32385	S-25574	28514		Syver O. Ruud	Irrigation	0.02		0.02		ND	ND	ND	ND		
Wells 2 through 10 in the Tualatin River Basin	6/17/1991	~~G-12577~~	~~G-13059~~ CANCELLED			Oregon Roses Inc	Supplemental Agricultural Use and Irrigation of 30.2 acres	0.226		NA		NA	NA	NA	NA		
An Unnamed Drainage Channel and Teufel Reservoir constructed under Permit R-5805, Tributaries of Tualatin River	6/17/1991	~~S-71702~~	~~S-51627~~ CANCELLED			Oregon Roses Inc	Agriculture and Irrigation on 30.2 Acres	0.223	6.4 AF	NA		NA	NA	NA	NA		
Wastewater from Hillsboro West Wastewater Treatment Plant and Effluent Holding Pond, Constructed Under Permit R-8396	2/23/1982	S-63318	S-46641	83206		United Sewerage Agency of Washington County	Irrigation of 150 Acres	1.88 (of Wastewater from the Hillsboro West WTP)	120.0 (Water from the Effluent Holding Pond)	1.88 (of Wastewater from the Hillsboro West WTP)		ND	ND	ND	ND		
Runoff, Tributary to Jackson Slough	6/16/2011	R-87729	R-14953			City of Hillsboro	Storage for Wetland Enhancement		72.1 AF		ND	ND	ND	ND	ND	5/14/2017	
No. 1 Well	3/7/1961	G-1945	G-1788	33209		Glenn A. Walters	Irrigation of 8.2 Acres	0.07		0.07		ND	ND	ND	ND		
Walters Well	9/18/1973	G-6299	G-5922	47772		Amfac Nurseries Inc.	Irrigation of 6.3 Acres	0.08		0.08		ND	ND	ND	ND		
Wells in the Tualatin River Basin	12/13/1990	G-12343	G-12247	87500		Oregon Garden Products	Nursery Operations on 19.4 Acres	0.71 cfs, being 0.28 cfs from Well NE1, 0.005 cfs from Well NE2, 0.10 cfs from NE4, 0.045 cfs from Well NE7, 0.03 cfs from Well NW3, 0.22 cfs from Well NW4, and 0.03 cfs from Well NW5		0.71 cfs, being 0.28 cfs from Well NE1, 0.005 cfs from Well NE2, 0.10 cfs from NE4, 0.045 cfs from Well NE7, 0.03 cfs from Well NW3, 0.22 cfs from Well NW4, and 0.03 cfs from Well NW5		ND	ND	ND	ND		

ND = No Data Available; NA = Not Applicable

Units: cfs = cubic feet per second; MG = million gallons; ac-ft = acre-feet

[1]This hydropower water right does not have a priority date. Use of this water right is only allowed when the underlying water rights (Certificates 67891, 81026, and 81027) are used. This water right is limited by the rate, duty, season, and any other limitations of Certificates 67891, 81026, and 81027.

Source	Priority Date	Application	Permit	Certificate	Claim, Transfer, Instream Lease	Entity Name on Water Right	Type of Beneficial Use	Authorized Rate (cfs)	Authorized Volume (ac-ft)	Maximum Rate of Withdrawal to Date		Average Daily Diversion (mgd)		Average Monthly Diversion (MG)		Authorized Date of Completion	Expiration of Instream Lease
										Instantaneous (cfs)	Annual (MG)	2015	5-year	2015	5-Year		
Waste Water from Hillsboro West Wastewater Treatment Plant, and Effluent Holding Pond	2/23/1982	R-63317	R-8396	83205		United Sewerage Agency of Washington County	Storage of Wastewater to be appropriated under Permit 466414 Irrigation		120		39.1	ND	ND	ND	ND		
Tualatin River, Tributary of Willamette River	4/20/1967	R-43511	R-5022	43325		Delane Fry	Storage for Supplemental Irrigation		97.9		31.9	ND	ND	ND	ND		
A Well	8/24/1970	G-5294	G-5127	43693		Glenn A Walters	Supplemental Irrigation of 8.2 Acres	0.1		0.1		ND	ND	ND	ND		
Rock Creek	1/4/1951	S-25550	S-20063	22925	Il-1325	C E Hawkinson	Irrigation of 19.2 Acres	0.24		0.24		ND	ND	ND	ND		10/1/2017
An Unnamed Stream, Tributary of Rock Creek	11/25/1994	R-75046	R-11692	87499		City of Hillsboro, Water Department	Wetlands Creation and Enhancement		1.71		0.56	ND	ND	ND	ND		
Treated Effluent from Rock Creek Advanced Wastewater Treatment Facility, Discharged to Tualatin River	10/18/2006	S-86704	S-54476			Clean Water Services	Instream	10.4		ND		ND	ND	ND	ND	10/1/2025	
Lower Pond, Constructed Under Permit R-14774	1/20/2009	S-87381	S-54667	89671		City of Hillsboro, Parks And Recreation Department	Aesthetics		6.3		2.1	ND	ND	ND	ND		
Lower Pond, tributary to Tualatin River	1/20/2009	R-87379	R-14773	88492		City of Hillsboro, Parks And Recreation Department	Multi-Purpose Storage		0.3		0.1	ND	ND	ND	ND		
Runoff, Tributary to Tualatin River	1/20/2009	R-87380	R-14774	89670		City of Hillsboro, Parks And Recreation Department	Multiple-Purpose Storage		6.0		2.0	ND	ND	ND	ND		
Dairy Creek	10/9/1939	S-18415	S-14050	49086	Il-1325	Eva Bailey Lynch	Irrigation of 34.5 Acres	0.43		0.43		ND	ND	ND	ND		10/1/2017
Sain Creek, a tributary to Scoggins Creek and the waters of the Tualatin River, a tributary to the Willamette River	NA [1]			87842	PC-896	City of Hillsboro	Hydroelectric Production of 137 theoretical horsepower	3.8[1]		3.8		ND	ND	ND	ND		

ND = No Data Available; NA = Not Applicable

Units: cfs = cubic feet per second; MG = million gallons; ac-ft = acre-feet

[1]This hydropower water right does not have a priority date. Use of this water right is only allowed when the underlying water rights (Certificates 67891, 81026, and 81027) are used. This water right is limited by the rate, duty, season, and any other limitations of Certificates 67891, 81026, and 81027.

Appendix D

DEQ's 303(d) listings applicable to municipal and non-municipal water rights held by the JWC and JWC Member Agencies

Water quality issues by source for JWC sources.

Basin Name	Watershed	Water Body (Source)	River Miles	Parameter	Season	Status	Assessment Year
Willamette	Tualatin	Gales Creek	4.5 to 27.7	Chromium	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Gales Creek	0 to 27.7	Copper	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Gales Creek	0 to 23	Dissolved Oxygen	October 15 - May 15	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Gales Creek	0 to 11	E. Coli	FallWinterSpring	Cat 4A: Water quality limited, TMDL approved	2004
Willamette	Tualatin	Gales Creek	0 to 11	E. Coli	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	Gales Creek	11 to 20.6	E. Coli	FallWinterSpring	Cat 4A: Water quality limited, TMDL approved	2004
Willamette	Tualatin	Gales Creek	0 to 27.7	Iron	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Gales Creek	0 to 27.7	Lead	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Gales Creek	0 to 11	Phosphorus	June 1 - September 30	Cat 4A: Water quality limited, TMDL approved	1998
Willamette	Tualatin	Gales Creek	0 to 11	Temperature	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Northern Oregon Coastal	Wilson-Trask-Nestucca	North Fork Trask River	0 to 4.4	Temperature	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	Scoggins Creek	0 to 5.1	Ammonia	June 1 - September 30	Cat 4A: Water quality limited, TMDL approved	1998
Willamette	Tualatin	Scoggins Creek	0 to 14	Biological Criteria	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2010
Willamette	Tualatin	Scoggins Creek	0 to 5.1	Dissolved Oxygen	October 15 - May 15	Cat 4A: Water quality limited, TMDL approved	2012
Willamette	Tualatin	Scoggins Creek	5.1 to 18	Dissolved Oxygen	January 1 - May 15	Cat 4A: Water quality limited, TMDL approved	2012
Willamette	Tualatin	Scoggins Creek	0 to 18	Iron	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Scoggins Creek	0 to 5.1	Phosphorus	June 1 - September 30	Cat 4A: Water quality limited, TMDL approved	1998
Northern Oregon Coastal	Wilson-Trask-Nestucca	Trask River	4.1 to 10.2	Dissolved Oxygen	September 15 - May 31	Cat 5: Water quality limited, 303(d) list, TMDL needed	2002
Northern Oregon Coastal	Wilson-Trask-Nestucca	Trask River	0 to 10.2	Fecal Coliform	Year Round	Cat 4A: Water quality limited, TMDL approved	2004
Northern Oregon Coastal	Wilson-Trask-Nestucca	Trask River	0 to 18.6	Temperature	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	Tualatin River	0 to 44.7	Ammonia	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Tualatin River	0 to 10.5	Aquatic Weeds Or Algae	Undefined	Cat 4A: Water quality limited, TMDL approved	2010
Willamette	Tualatin	Tualatin River	0 to 80.7	Biological Criteria	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2010
Willamette	Tualatin	Tualatin River	0 to 44.7	Chlorophyll a	FallWinterSpring	Cat 4A: Water quality limited, TMDL approved	2004
Willamette	Tualatin	Tualatin River	0 to 44.7	Chlorophyll a	Summer	Cat 4A: Water quality limited, TMDL approved	2004
Willamette	Tualatin	Tualatin River	44.7 to 69.9	Chlorophyll a	Summer	Cat 4A: Water quality limited, TMDL approved	1998
Willamette	Tualatin	Tualatin River	0 to 80.7	Copper	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Tualatin River	0 to 65.8	Dissolved Oxygen	Year Round (Non-spawning)	Cat 4A: Water quality limited, TMDL approved	2012
Willamette	Tualatin	Tualatin River	0 to 44.7	E. Coli	FallWinterSpring	Cat 4A: Water quality limited, TMDL approved	2012
Willamette	Tualatin	Tualatin River	0 to 44.7	E. Coli	Summer	Cat 4A: Water quality limited, TMDL approved	2012
Willamette	Tualatin	Tualatin River	0 to 80.7	Iron	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Tualatin River	0 to 44.7	Lead	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Tualatin River	55.9 to 80.7	Lead	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Tualatin River	0 to 80.7	Mercury	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Tualatin River	0 to 44.7	Phosphorus	June 1 - September 30	Cat 4A: Water quality limited, TMDL approved	1998
Willamette	Tualatin	Tualatin River	44.7 to 69.9	Phosphorus	June 1 - September 30	Cat 4A: Water quality limited, TMDL approved	1998
Willamette	Tualatin	Tualatin River	0 to 44.7	Temperature	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	Tualatin River	0 to 44.7	Zinc	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012

Water quality issues by source for Non-JWC sources.

Basin Name	Watershed	Water Body (Source)	River Miles	Parameter	Season	Status	AssessmentYear
Willamette	Tualatin	Beaverton Creek	0 to 9.8	Dissolved Oxygen	January 1 - May 15	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Beaverton Creek	0 to 2.1	Dissolved Oxygen	May 1 - October 31	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	Beaverton Creek	0 to 2.1	Fecal Coliform	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	Beaverton Creek	0 to 2.1	Fecal Coliform	Year Round	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	Beaverton Creek	0 to 2.1	Phosphorus	June 1 - September 30	Cat 4A: Water quality limited, TMDL approved	1998
Willamette	Tualatin	Beaverton Creek	0 to 9.8	Arsenic	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Beaverton Creek	0 to 9.8	Biological Criteria	Year Round	Cat 4: Water quality limited, TMDL not needed	2002
Willamette	Tualatin	Beaverton Creek	0 to 9.8	Dissolved Oxygen	Year Round (Non-spawning)	Cat 4A: Water quality limited, TMDL approved	2012
Willamette	Tualatin	Beaverton Creek	0 to 9.8	E. Coli	FallWinterSpring	Cat 4A: Water quality limited, TMDL approved	2004
Willamette	Tualatin	Beaverton Creek	0 to 9.8	E. Coli	Summer	Cat 4A: Water quality limited, TMDL approved	2004
Willamette	Tualatin	Beaverton Creek	0 to 9.8	Iron	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Beaverton Creek	0 to 9.8	Lead	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Beaverton Creek	0 to 9.8	Phosphorus	June 1 - September 30	Cat 4A: Water quality limited, TMDL approved	1998
Willamette	Tualatin	Beaverton Creek	0 to 9.8	Temperature	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	Bronson Creek	0 to 6.5	Biological Criteria	Year Round	Cat 4: Water quality limited, TMDL not needed	2002
Willamette	Tualatin	Bronson Creek	0 to 6.5	Chlorophyll a	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	Bronson Creek	0 to 5	Dissolved Oxygen	January 1 - May 15	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Bronson Creek	0 to 6.5	Dissolved Oxygen	Year Round (Non-spawning)	Cat 4A: Water quality limited, TMDL approved	2012
Willamette	Tualatin	Bronson Creek	5 to 6.5	Dissolved Oxygen	January 1 - May 15	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Bronson Creek	0 to 6.5	E. Coli	FallWinterSpring	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	Bronson Creek	0 to 6.5	E. Coli	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	Bronson Creek	0 to 6.5	Lead	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Bronson Creek	0 to 6.5	Phosphorus	June 1 - September 30	Cat 4A: Water quality limited, TMDL approved	1998
Willamette	Tualatin	Bronson Creek	0 to 6.5	Temperature	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	Dairy Creek	0 to 10.1	Ammonia	June 1 - September 30	Cat 4A: Water quality limited, TMDL approved	1998
Willamette	Tualatin	Dairy Creek	0 to 10.1	E. Coli	FallWinterSpring	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	Dairy Creek	0 to 10.1	E. Coli	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	Dairy Creek	0 to 10.1	Iron	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Dairy Creek	0 to 10.1	Lead	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Dairy Creek	0 to 10.1	Phosphorus	June 1 - September 30	Cat 4A: Water quality limited, TMDL approved	1998
Willamette	Tualatin	Dairy Creek	0 to 10.1	Temperature	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	East Fork Dairy Creek	0 to 21.5	Biological Criteria	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2010
Willamette	Tualatin	East Fork Dairy Creek	2.9 to 20	Dissolved Oxygen	October 15 - May 15	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	East Fork Dairy Creek	0 to 13.5	pH	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	East Fork Dairy Creek	0 to 13.5	Phosphorus	June 1 - September 30	Cat 4A: Water quality limited, TMDL approved	1998
Willamette	Tualatin	East Fork Dairy Creek	0 to 13.5	Temperature	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	McKay Creek	0 to 15.8	Ammonia	June 1 - September 30	Cat 4A: Water quality limited, TMDL approved	1998
Willamette	Tualatin	McKay Creek	0 to 22.7	Arsenic	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012

Willamette	Tualatin	McKay Creek	0 to 15.7	Dissolved Oxygen	January 1 - May 15	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	McKay Creek	0 to 15.7	Dissolved Oxygen	Year Round (Non-spawning)	Cat 4A: Water quality limited, TMDL approved	2012
Willamette	Tualatin	McKay Creek	0 to 15.8	E. Coli	FallWinterSpring	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	McKay Creek	0 to 15.8	E. Coli	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	McKay Creek	0 to 22.7	Iron	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	McKay Creek	0 to 15.8	Phosphorus	June 1 - September 30	Cat 4A: Water quality limited, TMDL approved	1998
Willamette	Tualatin	McKay Creek	15.8 to 22.7	Phosphorus	June 1 - September 30	Cat 4A: Water quality limited, TMDL approved	1998
Willamette	Tualatin	McKay Creek	0 to 15.8	Temperature	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	Rock Creek	0 to 5.7	Biological Criteria	Year Round	Cat 4: Water quality limited, TMDL not needed	2002
Willamette	Tualatin	Rock Creek	0 to 18.2	Ammonia	June 1 - September 30	Cat 4A: Water quality limited, TMDL approved	1998
Willamette	Tualatin	Rock Creek	0 to 18.2	Arsenic	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Rock Creek	0 to 18.2	Biological Criteria	Year Round	Cat 4: Water quality limited, TMDL not needed	2002
Willamette	Tualatin	Rock Creek	0 to 18.2	Chlorophyll a	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	Rock Creek	0 to 12.6	Dissolved Oxygen	January 1 - May 15	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Rock Creek	0 to 18.3	Dissolved Oxygen	Year Round (Non-spawning)	Cat 4A: Water quality limited, TMDL approved	2012
Willamette	Tualatin	Rock Creek	0 to 18.2	E. Coli	FallWinterSpring	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	Rock Creek	0 to 18.2	E. Coli	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	Rock Creek	0 to 18.2	Iron	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Rock Creek	0 to 18.2	Lead	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Tualatin	Rock Creek	0 to 18.2	Phosphorus	June 1 - September 30	Cat 4A: Water quality limited, TMDL approved	1998
Willamette	Tualatin	Rock Creek	0 to 18.2	Temperature	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	West Fork Dairy Creek	0 to 23.7	Dissolved Oxygen	June 1 - September 30	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	West Fork Dairy Creek	0 to 23.7	E. Coli	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Tualatin	West Fork Dairy Creek	0 to 23.7	Phosphorus	June 1 - September 30	Cat 4A: Water quality limited, TMDL approved	1998
Willamette	Tualatin	West Fork Dairy Creek	0 to 23.7	Temperature	Summer	Cat 4A: Water quality limited, TMDL approved	2002
Willamette	Middle Willamette	Willamette River	24.8 to 54.8	Aldrin	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2002
Willamette	Middle Willamette	Willamette River	24.8 to 54.8	Biological Criteria	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2004
Willamette	Middle Willamette	Willamette River	24.8 to 54.8	DDE 4,4	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2002
Willamette	Middle Willamette	Willamette River	24.8 to 54.8	DDT 4,4	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2002
Willamette	Middle Willamette	Willamette River	24.8 to 54.8	Dieldrin	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2002
Willamette	Middle Willamette	Willamette River	24.8 to 54.8	Dioxin (2,3,7,8-TCDD)	Year Round	Cat 4A: Water quality limited, TMDL approved	1998
Willamette	Middle Willamette	Willamette River	24.8 to 54.8	Iron	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Middle Willamette	Willamette River	24.8 to 54.8	Polychlorinated Biphenyls (PCBs)	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2002
Willamette	Middle Willamette; Lower Willamette	Willamette River	0 to 54.8	Chlorophyll a	Summer	Cat 5: Water quality limited, 303(d) list, TMDL needed	2010
Willamette	Middle Willamette; Lower Willamette	Willamette River	0 to 50.6	Temperature	Year Round (Non-spawning)	Cat 4A: Water quality limited, TMDL approved	2010
Willamette	Upper Willamette; Middle Willamette	Willamette River	24.8 to 186.6	Lead	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012
Willamette	Upper Willamette; Middle Willamette; Lower Willamette	Willamette River	0 to 186.4	E. Coli	FallWinterSpring	Cat 4A: Water quality limited, TMDL approved	2010
Willamette	Upper Willamette; Middle Willamette; Lower Willamette	Willamette River	0 to 186.6	Mercury	Year Round	Cat 5: Water quality limited, 303(d) list, TMDL needed	2012

Appendix E

City of Hillsboro Water Rates

City of Hillsboro Utilities Commission

Water Rate Schedule Resolution #235-W effective January 1, 2020

CUSTOMER CLASS - C-1A Single Family Residential-SINGLE FAMILY DWELLING UNIT

Meter Size	Monthly Base Inside	Monthly Base Outside
5/8"x3/4"	$ 16.58	$ 24.87
3/4"	16.58	24.87
1"	27.63	41.45
1-1/2	55.21	82.82
2"	88.37	132.56

*1 ccf = 100 cubic feet or 748 gallons of water

Volume Charge			
Billing Frequency	Block One 0-8 ccf	Block Two 9-18 ccf	Block Three 19+ ccf
Inside City	$2.43	$3.79	$5.14
Outside City	$3.65	$5.70	$7.72

C-1 Singe Family Residential Service - Water service to a single family dwelling unit, duplex or triplex using water primarily for personal or domestic accommodation, including a group home. Other multi-unit developments with separate meters billed by the City to each individual residence is single family residential for each individual residence. Legally established home occupation businesses may utilize single family residential service if the primary use of the structure is maintained as residential.

Example calculation of monthly bill for 8 ccf: $16.58 (base charge) + (8 ccf x $2.43) = $36.02 total water bill.

CUSTOMER CLASS - C-1B Single Family Residential-DUPLEX

Meter Size	Monthly Base Inside	Monthly Base Outside
5/8"x3/4"	$ 16.58	$ 24.87
3/4"	16.58	24.87
1"	27.63	41.45
1-1/2	55.21	82.82
2"	88.37	132.56

Volume Charge			
Billing Frequency	Block One 0-16 ccf	Block Two 17-36 ccf	Block Three 37+ ccf
Inside City	$2.43	$3.79	$5.14
Outside City	$3.65	$5.70	$7.72

* See definition of C-1. Served by one meter.

CUSTOMER CLASS - C-1C Single Family Residential-TRIPLEX

Meter Size	Monthly Base Inside	Monthly Base Outside
5/8"x3/4"	$ 16.58	$ 24.87
3/4"	16.58	24.87
1"	27.63	41.45
1-1/2	55.21	82.82
2"	88.37	132.56

Volume Charge			
Billing Frequency	Block One 0-24 ccf	Block Two 25-54 ccf	Block Three 55+ ccf
Inside City	$2.43	$3.79	$5.14
Outside City	$3.65	$5.70	$7.72

* See definition of C-1. Served by one meter.

CUSTOMER CLASS - C-8 Multi-Family Residential

Meter Size	Monthly Base Inside	Monthly Base Outside
5/8"x3/4"	$ 29.25	$ 43.87
1"	48.75	73.12
1-1/2"	97.49	146.24
2"	155.99	233.98
3"	312.00	467.99
4"	487.48	731.24
6"	974.97	1,462.45
8"	2,729.91	4,094.86
10"	4,094.86	6,142.30

Inside City Volume Charge	
Winter Volume ($/ccf)	Use over Winter Volume $/ccf
$2.93	$3.44

Outside City Volume Charge	
Winter Volume ($/ccf)	Use over Winter Volume $/ccf
$4.39	$5.17

C-8 Multi-Family Residential Service-Water service to multifamily dwelling unit on one parcel of land using water primarily for personal or domestic accommodation with four or more separate living units or spaces, i.e. mobile home parks, trailer courts, apartment complexes, condominiums, and group homes in which all living units are billed by the City of their water service as a single utility bill. This classification also includes homeowner association clubhouses. This category does not include hotels or motels.

CUSTOMER CLASS - C-2 Commercial

Meter Size	Monthly Base Inside	Monthly Base Outside
5/8"x3/4"	$ 35.95	$ 53.92
1"	59.92	89.86
1 1/2"	119.82	179.70
2"	191.72	287.53
3"	383.45	575.07
4"	599.13	898.54
6"	1,198.25	1,797.07
8"	3,355.12	5,031.79
10"	5,032.68	7,547.69

Inside City Volume Charge	
Winter Volume ($/ccf)	**Use over Winter Volume** $/ccf
$3.16	$4.45

Outside City Volume Charge	
Winter Volume ($/ccf)	**Use over Winter Volume** $/ccf
$4.74	$6.68

C-2 Commercial Service-Water service to a business or businesses engaged in the manufacture and/or sale of a commodity or commodities, or the rendering of a service. This category includes stores, offices, manufacturing and industry office, restaurants, daycare facilities, dairies, warehouses, private schools, private colleges, hospitals, hotels, motels, and other entities. This category also includes Bulk Water.

CUSTOMER CLASS - C-9A Small Industrial

Meter Size	Monthly Base Inside	Monthly Base Outside
5/8"x3/4"	$ 55.00	$ 82.50
1"	91.66	137.49
1-1/2"	183.31	274.98
2"	293.31	439.96
3"	586.62	879.94
4"	916.60	1,374.89
6"	1,833.18	2,749.76
8"	5,132.92	7,699.34
10"	7,699.38	11,549.00

Inside City Volume Charge	
Usage Under 4 MG $/ccf	$2.96

Outside City Volume Charge	
All usage $/ccf	$4.44

C-9 Industrial Service - Water service to a business enterprise engaged in the manufacture of products, materials, equipment, machinery or supplies where water is primarily used in the manufacturing process and not used for personal or domestic accommodation. Wineries where water is primarily used in the manufacturing of wine and not for irrigation. Water usage is relatively constant between winter and summer months.

CUSTOMER CLASS - C-9B Large Industrial

Meter Size	Monthly Base Inside	Monthly Base Outside
6" & 4 MGD	$ 6,966.00	-
8" & 4 MGD	19,505.00	-
10" & 4 MGD	29,257.00	-

Inside City Volume Charge	
Usage Over 4 MG $/ccf	$2.65

C-9B Large Industrial rate is the same as C-9A plus a volume usage exceeding four million gallons per day (MGD).

CUSTOMER CLASS - C-11 Irrigation

Meter Size	Monthly Base Inside	Monthly Base Outside
5/8"x3/4"	$ 43.87	$ 65.81
1"	73.12	109.68
1-1/2"	146.24	219.36
2"	233.99	350.98
3"	467.96	701.95
4"	731.20	1,096.80
6"	1,462.40	2,193.60
8"	4,094.72	6,142.08
10"	6,142.08	9,213.12

Inside City Volume Charge	
All usage $/ccf	$5.93

Outside City Volume Charge	
All usage $/ccf	$8.89

C-11 Irrigation Service - Water service to a public park or irrigation user with seasonal use for recreational, landscaping and horticultural purposes or other similar uses, but not primarily for personal or domestic accommodation. Vineyards and other operations primarily growing vegetation. Irrigation includes outdoor residential and commercial sprinkler services when on separate meters. Irrigation customers may shut off and restart service each growing season, subject to the applicable service fee.

CUSTOMER CLASS - C-6 Public Entities

Meter Size	Monthly Base Inside	Monthly Base Outside
5/8"x3/4"	$ 34.96	$ 52.43
1"	58.25	87.38
1-1/2"	116.50	174.75
2"	186.41	279.61
3"	372.81	559.23
4"	582.52	873.79
6"	1,165.05	1,747.57
8"	3,262.13	4,893.20
10"	4,893.20	7,339.80

Inside City Volume Charge	
Winter Volume ($/ccf)	**Use over Winter Volume** $/ccf
$3.47	$4.87

Outside City Volume Charge	
Winter Volume ($/ccf)	**Use over Winter Volume** $/ccf
$5.20	$7.31

C-6 Public Entities Service - Water service to publicly owned or leased land or building, under city, district, county, state, or federal ownership including public schools, public colleges, and post offices.

CUSTOMER CLASS - C-10 Nonprofit

Meter Size	Monthly Base Inside	Monthly Base Outside
5/8"x3/4"	$ 31.45	$ 47.17
1"	52.41	78.62
1-1/4"	102.84	154.25
1-1/2"	104.83	157.24
2"	167.73	251.59
3"	335.44	503.17
4"	524.13	786.21
6"	1,048.28	1,572.42
8"	2,935.18	4,402.76
10"	4,402.76	6,604.14

Inside City Volume Charge	
Winter Volume ($/ccf)	**Use over Winter Volume** $/ccf
$2.76	$3.89

Outside City Volume Charge	
Winter Volume ($/ccf)	**Use over Winter Volume** $/ccf
$4.14	$5.83

C-10 Nonprofit Service - Water service to a nonprofit entity that is organized as a public benefit corporation or religious corporation as those terms are defined under ORS 65.001.

C-4 Private Fire Protection and C-5 Public Fire Protection

Meter Size	Monthly Base
1"	$ 6.03
2"	12.06
3"	18.09
4"	24.12
6"	36.18
8"	48.24
10"	60.30
12"	72.36

C-4 Private Fire Protection and C-5 Public Fire Protection - Water service for fire suppression with minimal average usage.

City of Hillsboro Water Rates

Service Type	Rate	Volume
C-7 City of Hillsboro Wholesale - Cornelius	$1.66	per ccf
C-7 City of Hillsboro Wholesale - Gaston	$1.60	per ccf
C-7 City of Hillsboro Wholesale - LA Water Co-op	$1.60	per ccf
Bulk Water	$4.22	per 1,000 gallons volume rate

Appendix F

City of Forest Grove Water Rates

Published on *Forest Grove Oregon* (https://www.forestgrove-or.gov)

Utility Service Rates

WATER SERVICE RATES
Established by Resolution No. 2019-26, Effective July 1, 2019

Single-Family Residential Water Service Rates

Water Meter Size	Monthly Fixed Rate	Tier 1 0 to 7 kgal	Tier 2 7 to 15 kgal	Tier 3 15 kgal & over
3/4" and less	$25.67	$1.94	$4.11	$5.96
1"	$35.93	$1.94	$4.11	$5.96
1.5"	$52.98	$1.94	$4.11	$5.96
2"	$73.47	$1.94	$4.11	$5.96

Multi-Family Residential Water Service Rates

Water Meter Size	Monthly Fixed Rate	Plus Usage Rate per kgal
3/4" and less	$25.67	$2.79
1"	$35.93	$2.79
1.5"	$52.98	$2.79
2"	$73.47	$2.79
3"	$94.32	$2.79
4"	$139.10	$2.79
6"	$263.37	$2.79
8"	$412.55	$2.79

Commercial & Industrial Water Service Rates

Water Meter Size	Commercial Monthly Fixed Rate	Plus Usage Rate per kgal	Industrial Monthly Fixed Rate	Plus Usage Rate per kgal
3/4" and less	$25.67	$2.96	$25.67	$2.57
1"	$35.93	$2.96	$35.93	$2.57
1.5"	$52.98	$2.96	$52.98	$2.57
2"	$73.47	$2.96	$73.47	$2.57
3"	$116.76	$2.96	$134.45	$2.57
4"	$190.39	$2.96	$201.78	$2.57
6"	$337.63	$2.96	$388.79	$2.57
8"	$530.95	$2.96	$613.17	$2.57

Appendix G

City of Beaverton Water Rates

WATER RATES

Monthly Fixed Water Rates

New rates starting July 1, 2019.

The consumption or water use charge is $3.57 per unit. As a guide, one unit of water equals approximately 748 gallons or 100 cubic feet. The monthly fixed charge or meter charge is based on the size of the meter. A 5/8" meter serves most residences. Fixed rates for meters are as follows:

- 5/8" meter: $16.00 / month
- 1" meter: $25.21 / month
- 1 1/2" meter: $40.51 / month
- 2" meter: $58.97 / month
- 3" meter: $101.93 / month
- 4" meter: $163.35 / month
- 6" meter: $316.87 / month
- 8" meter: $388.57 / month
- 10" meter: $613.73 / month

Water Rate Resolution No. 4593.

Monthly water fees are used to maintain and update the water distribution system, including repair and installation of water mains, maintenance of individual water services and meters, as well as construction and upkeep of reservoir and well sites.

Additional Information

- Sewer Rates
- Surface Water Management Rates

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Appendix H

TVWD Water Rates

Monthly Base Charges for All Customer Categories

Meter Size (inches)	November 2019 Base Charge	November 2020 Base Charge
5/8	$16.40	$16.99
3/4	$18.06	$18.71
1	$22.26	$23.06
1 ½	$29.91	$30.99
2	$44.12	$45.71
3	$122.85	$127.27
4	$164.60	$170.53
6	$265.28	$274.83
8	$383.19	$396.98
10	$630.23	$652.92

Block volume charges apply to all customer categories based on bi-monthly usage:

- For residential customers, Block 1 charges are $5.42 per hundred cubic feet (CCF) up to 28 CCF and Block 2 charges are $7.73 per each CCF above 28 CCF;
- For multi-family, commercial non-production, production processes, and irrigation customers, Block 1 charges are $5.42 per CCF up to 140 percent of the customer's yearly average water usage (calculated by multiplying the customer's 12 month moving average by 1.4). Block 2 charges of $7.73 per CCF apply to water use that exceeds the Block 1 threshold.
- All consumption on firelines in charged at the Block 1 rate of $5.42 per CCF.

Appendix I

City of Hillsboro In-Town System Curtailment Plan

Hillsboro In-Town Curtailment Plan

This section satisfies the requirements of OAR 690-086-0160.

This rule requires a description of past supply deficiencies and current capacity limitations. It also requires inclusion of stages of alert and the associated triggers and curtailment actions for each stage.

Introduction

The City of Hillsboro (Hillsboro) (OR 4101513) currently obtains the majority of its water supply from the Joint Water Commission (JWC); therefore, Hillsboro’s curtailment planning is intrinsically linked to JWC curtailment. Hillsboro's water source is treated surface water, the winter water source is the upper Tualatin River and in summer when the river level drops too low for municipal use, so Hillsboro relies upon water stored in Barney Reservoir and Hagg Lake to meet customer needs. The water is delivered to Hillsboro and beyond via two large transmission lines. There are approximately 250-miles of distribution lines in the city of Hillsboro that are fed by the transmission lines. These lines provide water to over 24,000 business and residential customers who live west of Cornelius Pass Road. The Tualatin Valley Water District serves Hillsboro residents living east of Cornelius Pass Road. While the JWC Curtailment Plan creates processes for coordination and negotiation of water supplies for the JWC partners, the City’s Curtailment Plan establishes measures to reduce its water demands when water supplies aren’t enough to meet the needs of the City and its customers. Non-peak curtailment versus peak season has different challenges – higher demand but the ability to curtail outdoor use versus lower demand but little customer use diminish.

This curtailment plan will focus on supply constraints during the peak season, non-peak season and during an emergency event. Triggers are identified – including equipment failure, water system infrastructure damage and supply-limiting events – for four different curtailment stages. Next, specific actions to reduce demands, voluntary and mandatory, are described for each curtailment stage.

Because the City operates three water systems with separate treatment plants and points of diversions, one of the supply systems may be impacted by curtailment conditions while the other system is not, each system has its own Curtailment Plan.

- Hillsboro water supply comes from two surface water sources: the Tualatin River including its tributaries Sain Creek and Scoggins Creek, and the Middle Fork of the North Fork of the Trask River. In addition to diverting water directly from these sources (“direct diversion” or “natural live flow”), in the summer months Hillsboro uses water from storage supplies in Barney Reservoir, on the Middle Fork of the North Fork of the Trask River, and Scoggins Reservoir (Hagg Lake) on Scoggins Creek, a tributary of the Tualatin River.

- The Upper System customers are served water from both the JWC Water Treatment Plant and the Slow Sand Filter Plant.

- Butternut Creek is supplied by TVWD which has three sources: JWC, Portland Water Bureau (PWB), and Aquifer Storage and Recovery. PWB has two sources, a surface water source: the Bull Run Watershed, and a ground water source: the Columbia South Shore Wellfields – this is used to supplement flows from the Bull Run.

Hillsboro may enact curtailment actions for the systems separately or in combination, depending on the nature of the event and the capacity of supplies. Wholesale customers of Hillsboro are required to adhere to Hillsboro's curtailment actions as stipulated through their wholesale contracts.

History of System Curtailment Incidents

OAR-690-086-0160(1)

Assessment of Water Shortages & Limitations

Despite several JWC supply shortages in the past, Hillsboro has not had to implement mandatory curtailment to date. Those supply incidents are described in greater detail below, but all were addressed by operational adjustments and negotiations for alternative supplies with JWC partners. Hillsboro and its partners excel at working together to find alternatives to curtailment, while being able to meet the water supply needs of all partners. While curtailment is considered a last resort to achieve decreased demand, Hillsboro has a plan to employ restrictions if necessary. Summaries of JWC water supply incidents that nearly called for Hillsboro to implement curtailment protocols are detailed below.

Summary of Incidents from 1990 to 1999

During the 1990s, the JWC Water Treatment Plant (WTP) experienced incidents that impacted supply/capacity, including: loss of power due to a car hitting a power pole near the WTP, loss of power due to a windstorm, severe raw water quality impacts due to the 1996 floods which affected numerous regions in Oregon, and disruption of deliveries to partners due to a transmission line leak on the WTP site. The incidents all reduced the ability of the JWC to supply water. At that time, there was only one reservoir on Fern Hill with 20 MG available storage, less stored water for emergency backup supply than is available today.

These power supply disruptions led to new JWC response agreements with PGE, and construction of a second finished water pumping station with a supporting power transformer station. In March 2016, a backup power facility was brought online at the WTP. The generators are capable of running the WTP at 50% of current peak capacity, which would be able to fully serve the partners for a large portion of the year, based on average demands.

Drought Incident in 2001

The JWC experienced its first source water shortage in the summer of 2001. This experience is described in brief here and in full detail in the JWC's 2010 WMPC. JWC is generally regulated off its natural flow water rights on the Tualatin River beginning in late May to early June until mid-

October. JWC relies primarily on stored water releases from Hagg Lake and Barney Reservoir during this period.

For the first time since construction of Scoggins Dam was completed in 1977, Hagg Lake did not fill in 2001, reaching only 54 percent of its storage capacity. Several JWC member agencies (the Cities of Hillsboro, Beaverton, and Forest Grove) hold contracts with the Bureau of Reclamation (BOR) for the use of stored water in Hagg Lake that also specify curtailment measures. Based on BOR contract conditions, the JWC partner cities of Hillsboro, Beaverton, and Forest Grove received only about 76% of their normal water allocations from Hagg Lake in 2001. Clean Water Services (CWS) and Tualatin Valley Irrigation District received only 27% and 47%, respectively, of their normal water allocations. Discharge changes at Scoggins Dam were made twice a day, seven days a week to closely match the timing of water orders, avoid waste, and maintain natural flow in the Tualatin River.

In the same year, Barney Reservoir only reached 55% of its storage capacity. After accounting for dead pool storage and releases for fish flows to the Trask River (15% of the available storage), the Barney Reservoir Joint Ownership Commission partners (Hillsboro, Forest Grove, Beaverton, TVWD, and CWS) were allotted only 54% of normal full pool allocations.

The JWC and Barney Reservoir Joint Ownership Committee (BRJOC) partners used a combination of leasing, alternative source options and agreements, and voluntary curtailment to meet summer 2001 demands on the JWC water system. Portland Water Bureau (PWB) had full supplies in both Bull Run and the Columbia River Wellfield. They offered assistance with coordination of regional supply, and provided an alternate source for Tualatin Valley Water District and the City of Beaverton. TVWD allowed Clean Water Services (CWS) to use some of its allocated water in the Barney Reservoir to meet streamflow demands, and CWS paid TVWD the difference between the cost of JWC water and the more expensive PWB water in exchange. It also helped that the summer weather of 2001 was cooler and wetter than usual. No mandatory curtailment was necessary.

Summer Supply Incident in 2015

An abnormal onset of early summer weather, with a record number of days exceeding 90 degrees, caused customer demands to skyrocket. In anticipation of possible shortages for the City and TVWD, the JWC approved leases of stored water and treatment plant capacity at its July 2015 meeting. The summer continued hot and dry, and demands on the WTP were often near its maximum capacity, but all agencies were able to supply their customers without needing curtailment measures.

Winter Supply Incident in 2015

Western Oregon received a record amount of rain from December 7 to 11, 2015. The heavy rain flooded the Tualatin River, and in some places, the flooding was worse than the flood of 1996. This flooding raised water turbidity and changed the chemistry of the raw water entering the WTP, creating significant challenges for treating the water to safe drinking water standards. The more intense treatment required a slower WTP process; production declined to under 20 mgd.

During this time, demands on the WTP were over 20 mgd. Based on the decreased WTP production capacity, the demands of some partners exceeded their ownership percentage of the available capacity. Throughout the week, as the WTP continued to experience treatment challenges, and Fern Hill Reservoirs and the Cities' in-town storage continued to deplete, it became unclear if the City of Hillsboro would continue to meet demands without some measure of mandatory curtailment since the City of Hillsboro does not currently have any alternate supply sources. City of Beaverton voluntarily turned on one ASR well the first day of the event to reduce demands on the WTP and provide more water to the partners, especially the City of Hillsboro. As the event continued, it appeared that the City of Hillsboro might need to curtail its own customers' water usage. On the third day, TVWD shifted demand onto to its PWB supply and ASR well, and the City of Beaverton agreed to turn on a second ASR well, to further lessen their JWC system demand. (The City of Beaverton and TVWD used ASR wells developed under LL #002, not the JWC's ASR LL #019.)

TVWD and the City of Beaverton were meeting their customer demands with these alternate sources, and the City of Forest Grove was still able to meet its customer demands with its share of the reduced JWC WTP capacity that was available. As raw water quality improved, the WTP increased production levels, and by the fourth day of the event, the WTP was again producing enough water to begin refilling the storage reservoirs. The City of Hillsboro did not need to curtail. The event was over by the beginning of the following week, with normal WTP production capacity restored and all partners returning to their normal demand levels at the WTP.

Storm Event in 2018

Similar to December 2015's event an "atmospheric river" dropped an enormous amount of water into the Tualatin Watershed. Rainwater is notoriously hard to treat to drinking water standards because of its naturally low pH and alkalinity. To add to the problematic water chemistry, this was also the first large rainstorm of fall, which is referred to as a "flush" because a large amount of organic material is swept into the river. The entire "flush" happened in a 24-48 hour period. To further complicate matters, due to the low levels of Hagg Lake and Barney Reservoir after the long dry summer there was no release from either reservoir to supplement river flows. This meant that all river flow increase was directly the result of rainfall and rainfall runoff. On December 19th, a 70 cfs release from Hagg Lake (Scoggins Reservoir) was requested to mitigate overflowing commercial holding ponds downstream.

The rapid and extreme changes to the incoming water chemistry impacted treatment plant operations. JWC operators, concerned that water would soon not meet drinking water standards turned off the Water Treatment Plant (WTP) while they worked to figure out the correct treatment chemistry. Meanwhile, Fern Hill Reservoir supplemented demands for all partners except TVWD. Over the course of the 3-day emergency event, reservoir levels dropped to the lowest ever (less than 13 feet). Furthermore, the JWC requested that partners curtail demands and switch sources if possible, which led to the JWC Member Agencies taking the following curtailment actions:

- Hillsboro relied on in-system storage reservoirs to minimize demand on JWC, eliminated inspection and construction flushing, asked industrial customers to voluntarily reduce their demands, and closely monitored fire events.
- Forest Grove used their WTP and in-system storage to minimize demand on JWC.
- Beaverton stopped ASR injection and mobilized their ASR system to significantly decrease their demand on JWC.
- TVWD relied on Portland supply, and did not take JWC supply during the event.

Immediate remedial actions taken at the WTP included turning on a caustic soda feed to the rapid mix, which had solved a similar chemistry problem in a similar December 2015 storm event. However, staff saw very limited improvement from this measure this time around, and so continued to look for solutions. Incoming raw water was reduced to a single pipeline from the raw water intake. Staff had to keep pumping and treating water until filterable water was produced. Until that time, staff sent flume water directly to the drying beds and overflow, instead of treating the highly turbid water with the filters. A large diesel pump, which was purchased after the 2015 event, was utilized during this time (continuously for days) to minimize the amount of overflow.

<u>Algae Bloom Event in 2019</u>

In the spring of 2019, JWC water quality staff first observed an algae bloom at Hagg Lake near Scoggins Dam while conducting routine sampling. Immediately, staff began ramping up monitoring per the JWC Algal Response Plan and determined that the dominant species was *Aphanizomenon flos aquae*, a species of potentially toxin cyanobacteria. Based on the JWC Algal Response Plan, as well as recommendations by the Oregon Health Authority (OHA), JWC staff collected samples for toxic analysis, and determined that there were low levels of the toxin microcystin present at two of the four locations sampled in the reservoir, but no toxins were present in Scoggins Creek downstream of the reservoir outlet or in the JWC raw water. Continued sampling of algal speciation, enumeration, and associated toxins showed a brief increase in enumeration of *Aphanizomenon flos aquae*, followed by a steady decline over the course of the following weeks. All subsequent toxin samples in the reservoir were either at the detection limit or non-detects and toxins were never detected in Scoggins Creek downstream of the reservoir or in the JWC raw water. This event lasted approximately 5 weeks from the initial observation to when cell densities were observed at low enough levels to return to routine monitoring as defined by the JWC Algal Response Plan.

Although this event did not require curtailment, in the event of the detection of toxins at the JWC raw water intake it is possible that curtailment may be necessary depending on the time of year, severity of the algal bloom, and the treatment plants capabilities to properly treat raw water to remove specific toxins. The WTP has the ability to add powdered activated carbon (PAC), which is effective at removing cyanotoxins. For example, if cyanotoxins are detected in the source water and at the JWC intake operators at the WTP may initiate the addition of PAC as a precaution. Dosing of PAC to effectively remove cyanotoxins often requires large amounts of PAC, which may require the WTP to decrease production. This may result in curtailment, depending on demand, storage, and the dose of PAC needed.

Curtailment Actions

JWC requested partners to curtail demands, and switch sources if possible.

1. **City of Hillsboro** relied on in-system storage reservoirs to minimize demand on JWC, eliminated inspection and construction flushing, asked industrial customers to voluntarily reduce their demands, and closely monitored fire events.
2. **City of Forest Grove** used their WTP and in-system storage to minimize demand on JWC.
3. **Beaverton** stopped ASR injection and mobilized their ASR system to significantly decrease their demand on JWC.
4. **TVWD** relied on PWB's supply, and did not take JWC supply during the event.
5. **Fern Hill Reservoir's** supplemented demands for all partners except TVWD. Over the course of the three-day event, reservoir levels dropped to the lowest ever (less than 13 feet) during an emergency event.

Shortage Capability Assessment

OAR-690-086-0160(1)

The City of Hillsboro's current capacity limitation is its ownership share in production capacity of the JWC WTP, which has been rated at 85 mgd for peak day capacity. Hillsboro's maximum ownership of production capacity is 41.75 mgd. Hillsboro's storage capacity in JWC's Fernhill Reservoirs is 10.8 million gallons. The WTP's production capacity is lower during the winter season due to impacts of colder temperatures on treatment process, and capacity can further decrease during the winter season due to water quality events. Production capacity can be impacted at any time due to equipment failures.

In an event where Hillsboro cannot access its capacity in JWC, the capacity limitation is the storage volume of the City's three distribution system storage tanks totaling 31 million gallons.

In the event of a supply interruption, Hillsboro is well-positioned to meet its non-peak season customer demands for the following reasons:

- Additional finished water storage
    - Construction of a second JWC Fern Hill Reservoir was completed in 2006, adding an additional 20 MG of finished water capacity to the system for a total of 40 MG. Hillsboro's allocation is 45% or 10.8 MG of that total.
    - Hillsboro also increased in-town storage with the addition of the 10 MG Crandall Reservoir in 2013, for a total of 31 MG.
    - Hillsboro consistently follows best management practices and stores three days of average day demand (ADD) in finished water storage in the JWC and local distribution system.
- Installation of back-up electricity
    - In cooperation with PGE, the WTP added a back-up power generator system onsite in 2016.
- Improvements to water quality treatment
    - Hillsboro added chlorination feeders in 2014 to its reservoirs to increase storage time of finished water.
    - The WTP added a PAC feeder in 2008 to improve treatment of organics
    - During the WTP Expansion to 85 MGD there were a number of Water Quality improvements made. These improvements include:
        - Plate Settlers added to basins D-F.
        - Coagulation/Settling Aid feed added to the Rapid Mix.
        - Caustic and Chlorine injection moved up the Raw Water pipeline to allow proper mixing prior to the Rapid Mix.
        - Rapid Mix mixing improvements.
- Seismic reinforcement
    - The JWC's Fern Hill Reservoir 1 was seismically upgraded in 2007.
    - The construction of the second JWC Fern Hill Reservoir included seismic hardening and wrapping Reservoir 1 with rebar in 2006.
    - Hillsboro seismically reinforced the 24th Street Reservoir in 2004, and Dilley Reservoir in 2017.

Curtailment Event Triggers and Stages

OAR-690-086-0160(2) and (3)

During the peak summer demand period each year from June through September, the system is typically operating at or near its maximum capacity. An interruption to supply during this time – such as a natural disaster, mechanical failure, terrorist act, or loss of source – could present significant challenges to Hillsboro. Therefore, the following triggers and related curtailment stages in this plan are based primarily on events occurring during this time period. In addition, less critical impacts to the water supply – such as forecasted drought and minor mechanical or electrical failures – are addressed in Stages 1 and 2. Since there is also a need to plan for supply shortages in the winter, potential restrictions on indoor use are also presented. This scenario presents a unique challenge because few opportunities exist to further reduce winter-time demand to meet lowered supplies.

It is important to note that Hillsboro may be able to make alternative arrangements to meet customer demands, and that the "Initiating Conditions" described below don't always require the need to implement curtailment stages. If Hillsboro is able to make arrangements, or utilize other parts of its system to meet the demands required of its customers, no curtailment stage will be activated. When a curtailment stage is activated, staff will review the status of available supply and current and historic demands to establish a demand reduction goal. Each curtailment event will be addressed on a case-by-case basis.

This curtailment plan for Hillsboro is designed to be initiated and implemented in progressive stages. The plan has four distinct stages, as shown in **Exhibit 1**, each of which is triggered by one or more of the listed events:

Exhibit 1. Curtailment Plan Stages 1 through 4.

Curtailment Stages	Potential Initiating Conditions
Stage 1 **Advisory** Temporary Water Shortage Alert (Short-Term Voluntary)	Short-term[1] interruption of electrical service affecting water treatment and distribution affecting ability to meet customer demands short-term; Harmful algal blooms (HAB) clogs filters and impairs performance or occurrence of a cyanotoxin producing bloom; in which Powder-Activated Carbon (PAC) may need to be added, affecting ability to meet customer demands short-term; Minor mechanical or electrical malfunction in pumping facilities or treatment plant affecting ability to meet customer demands short-term; Minor damage to raw or treated water transmission mains (e.g., leaking joint requiring repair); or Below-normal[2] levels of stored water in Barney Reservoir and Scoggins Dam (Hagg Lake) that may fall below the historical 25th percentile in the peak season.
Stage 2 **Voluntary** Long-Term Water Shortage Alert (Long-Term Voluntary)	Stored water is below-normal[2] levels in Barney Reservoir and Scoggins Dam (Hagg Lake) that may fall below the historical 10th percentile in the peak season.
Stage 3 **Mandatory** Severe Water Shortage (Long-Term Mandatory)	One of JWC's summer supplemental sources (Barney Reservoir and Scoggins Dam (Hagg Lake) are 50% of full capacity at the start of release season, resulting in a significant reduction[3] of Hillsboro's water supply capacity; Failures in the pumping facilities, treatment plant or transmission mains that require a lengthy repair time.
Stage 4 **Emergency** Critical Water Shortage (Critical Mandatory Short or Long-Term Restrictions)	Extensive damage to transmission, pumping or treatment processes caused by natural disaster (i.e. earthquake); Both of JWC's summer supplemental sources (Barney Reservoir and Scoggins Dam (Hagg Lake) are below 50% of full capacity at the start of release season, resulting in a severe reduction of Hillsboro's water supply capacity; Interruption of electrical service to the WTP for an unknown or extended period of time. Localized transmission line break resulting in supply disruption. Unplanned water quality, or other treatment issue, that slows JWC WTP production below partner demands in which the timeline for recovery from the condition is uncertain and the risk of total reservoir depletions, at projected rates of production and demand, is high. Short-term increase in Hillsboro's demand beyond Hillsboro's percentage of JWC WTP production capabilities, due to an unforeseen circumstances such as extreme hot weather conditions, fire, or loss of a secondary supply. (This condition would be for acute short-term shortages, and not long-term shortages, such as one caused by drought.)

[1] "Short-term" interruption means an interruption with an expected end. For example, a power outage expected to last one week would be probable cause for Stage 1 curtailment. The decision to initiate curtailment would depend on the time of year, likelihood that power will be restored in the predicted timeframe, and the likelihood that Hillsboro can maintain backup power for the duration of the outage. In this case, Hillsboro could avoid curtailment by using the back-up generators at the water treatment plant, backup fuel supplies, and Hillsboro's in-town storage.

[2] "Below normal" levels means that water levels fall slightly outside the normal drawdown curve. However, Hillsboro could avoid curtailment if alternate supplies are made available that put source supplies back into normal ranges. For example, the reservoirs were between the 25th and 10th percentile in the 2015-2016 release season, but curtailment was not necessary. In addition, if alternate supplies are expensive, Hillsboro may choose to promote voluntary curtailment in order to reduce dependency on alternative supplies and to reduce costs.

Curtailment Stages	Potential Initiating Conditions

[3] "Significant Reduction" means that Hillsboro's water supply capacity cannot be made up through alternative means, so mandatory curtailment is necessary to reduce demand levels to ensure that water supplies don't run out. However, Hillsboro could avoid mandatory curtailment if alternate supplies are made available that put source supplies back into normal ranges. For example, Hillsboro's summer supplemental sources were at 50% full, but Hillsboro received 54% and 76% of its stored water. Mandatory curtailment wasn't needed due to availability of other supplies in the region.

Authority

Hillsboro's Water Department Director, under the authority of the City of Hillsboro Utilities Commission, will be responsible for the actions and implementation of Stages 1 and 2, with frequent updates to the City Manager and City Council. Before implementing Stages 3 or 4, the Water Department Director, under the authority of the Utilities Commission, will notify and make a recommendation to the City Manager regarding the proposed curtailment action. Actions under Stages 3 and 4 of this plan may be initiated only after a declaration of emergency is issued by the Mayor, City Council, or appropriate successor as outlined in the City's Emergency Response Plan. If an emergency declaration made by the Mayor or City Council does not impact water supply or demands, Stages 3 and 4 may not be implemented, under the authority of the Utilities Commission.

Plan provisions will remain in effect until the emergency declaration is lifted by the City Manager or appropriate successor, or until the Utilities Commission is able to demonstrate that the Water Department can meet water demands.

Curtailment measures may be applied to the entire system, or only to water use sectors, and/or in certain geographic areas, which are directly impacted as determined by City staff under the direction of the Water Department Director, or a designee such as an Acting Director or the Assistant City Manager. Different restriction levels may be placed upon the Upper System depending on the nature, severity, and location of the initiating conditions.

The Water Department Director and Water Department staff, under the authority of the Utilities Commission, are responsible for execution of the plan provisions once an emergency has been declared.

The Water Department Director and staff will keep the JWC, its partners, and its wholesale customers informed about water demands and curtailment plans during the course of any water emergency.

Curtailment Plan Implementation

OAR-690-086-0160(4)

In implementing this curtailment plan, Department staff will work closely with the JWC and other member agencies to assure consistent approaches to dealing with water shortages by coordinating stage designations, public notices, press releases, and other outreach activities. Department staff will also coordinate with its wholesale customers on curtailment efforts.

Stage 1: Advisory - Temporary Water Shortage Alert

After notifying the City Manager and the Utilities Commission, Water Department staff, under the direction of the Water Department Director, will activate an Advisory Temporary Water Shortage Alert to inform customers of the need for voluntary, temporary reductions in consumption. This will occur when the Stage 1 triggers described in **Exhibit 1** are met, and Hillsboro determines demands will not be met through alternative methods.

Stage 1 Advisory Temporary Water Shortage Alert requests for short-term voluntary reductions will be made if the Utilities Commission determines that finished water storage at the JWC or in the distribution system may not meet projected demands due to the events described in **Exhibit 1** Stage 1.

Stage 1 public information program elements may include one or more of the following actions:

1. Begin preparations for a voluntary curtailment bilingual (English and Spanish) campaign. Include components such as:
    a. Issue a general request for voluntary reductions in water use by all water users. The request will include a summary of the current water situation, the reasons for the requested reductions, and a warning that mandatory cutbacks will be required if voluntary measures do not sufficiently reduce water usage.
    b. Get the message out through multiple communication venues.
    c. Contact local media outlets, in coordination with the JWC, to inform customers about temporary interruptions to normal service delivery.
    d. Post a public service announcement on Hillsboro's webpage and Social Media (SM) outlets. Include prepared information regarding conservation tips.
2. Encourage voluntary reductions on outdoor irrigation.
3. Encourage refraining from washing vehicles except at commercial establishments that recycle or reuse water in their cleaning process. Consider offering free or discounted single-wash coupons to encourage compliance. Depending on severity of situation, car wash fundraisers may also be excluded from voluntary restriction, as decided by Water Department Director with advisement from staff.
4. Notify wholesale customers of the existence of, or potential for, water shortages and ask them to issue similar messages to their customers.
5. Provide bilingual notification, assistance, and conservation curtailment materials to wholesale customers and City departments if requested. Share materials with JWC partners on request as well, for awareness even if they are not participating in curtailment actions. Notify the Regional Water Providers Consortium (RWPC) to coordinate with other providers if needed.

Non-Peak Season (Winter) Curtailment

1. Ask industrial and commercial customers to conserve and reduce or eliminate non-essential water use.
2. Encourage customers to shut off their irrigation systems for the season.
3. Encourage repair of all known customer leaks.
4. Encourage customers to take shorter showers.
5. Encourage customers to run taps and flush toilet only when necessary.
6. Encourage customers to delay washing clothes if possible.
7. Encourage customers to eliminate all non-essential water use.

Stage 2: Voluntary - Long-Term Water Shortage Alert

A Stage 2 Voluntary Long-Term Water Shortage Alert will be issued for reduction preparations if it is projected by the JWC and BRJOC. Reasons might include; that peak season storage supplies may not reach projected peak season demand, Hillsboro determines demands will not be met or it is undesirable to do so through alternate means. The actions under this stage will include the previous actions listed above in Stage 1, but will also include the following actions requesting customers to voluntarily restrict their non-essential uses.

Stage 2 public information program elements will include one or more of the following actions:

1. Hillsboro's Water Department Director, under the authority of the City of Hillsboro Utilities Commission, will implement Stages 1 and 2, with frequent updates to the City Manager and City Council.
2. Begin preparations for an aggressive voluntary curtailment bilingual campaign to begin in April or May, before the peak season begins. Include components such as:
    a. Provide notice and press releases to local media outlets to inform customers about potential water shortages for peak season demands.
    b. Develop and provide voluntary conservation messaging through various communication venues.
    c. Encourage customers to water sparingly, by sharing information at community events and promotions. Tailor all conservation messaging at outreach events to the drought conditions and attend additional events such as neighborhood or homeowner's associations, farmer's markets, etc.
    d. Provide weekly notices and updates using the City website and other communication venues of water availability in Barney and Scoggins reservoirs.
    e. Consider purchasing additional radio or television advertisements with other affected partners such as the JWC or RWPC.

3. Advise the Industrial Users Group, Top 25 Customer Group, City departments, and wholesale customers of the water supply situation.

Staff will closely monitor the community response to Stage 2 throughout the peak season, and implement Stage 3 if response is not adequate to sustain storage supplies through the entire peak season. *(These measures proved sufficient during the 2001 curtailment campaign.)*

If the situation worsens, or warrants stricter measures, the following restrictions could also be implemented under Stage 2:

4. Encourage outdoor irrigation to only three-days per every seven-day period (including use of specific schedules imposed by the City Manager) and only between the hours of 8 pm and 5 am. This restriction and prohibition applies to all outdoor irrigation unless:
    - **a.** Grass, trees, turf or landscaping is less than one-year old;
    - **b.** Grass, trees, or turf is part of a commercial sod farm;
    - **c.** Grass, trees, or turf areas are within a high use athletic field used for organized play;
    - **d.** Grass, trees, or turf areas are used for golf tees or greens; or
    - **e.** Grass, trees, or turf areas are part of a park or recreation area deemed by the City Council or Utilities Commission to be of particular significance and value to the community.
5. Notwithstanding the exceptions to the outdoor irrigation restrictions and prohibitions noted above, all outdoor watering schedules shall be limited to only that necessary to maintain plant health and shall not allow unnecessarily irrigation. This includes:
    - **a.** Voluntary restrictions on nonessential water uses, including:
        - i. No washing of paved surfaces;
        - ii. No fountains except those using re-circulated water;
        - iii. No washing of vehicles other than in establishments that recycle water. (Depending on severity of situation, car wash fundraisers may also be excluded from voluntary restriction, as decided by Water Department Director with advisement from staff); and
        - iv. No washing of roofs, decks, or home siding unless such uses are solely to abate a potential fire hazard.
6. Water Department staff will continue to work closely with Utility Billing to identify and notify customers of unfixed leaks. Additional financial incentives may be made available to customers that fix their leaks within a short timeframe.

7. In addition, Water Department staff will work with its industrial and commercial water users to minimize their non-essential water use.

Stage 3: Mandatory - Severe Water Shortage

Conditions causing Stage 3 curtailment measures are severe enough in terms of extent and duration that significant reductions in water use must be achieved as quickly as possible in order to ensure public health, safety, and welfare. This step would take place after Hillsboro has attempted to secure additional supply through alternate means. Stage 3 builds on measures enacted through the previous stages. In a Stage 3 curtailment, all outside watering with City-served water is prohibited and any exceptions noted above for outdoor water uses are rescinded unless such uses are solely to abate public health or fire hazards (an allowance may be made by the City Manager to water sparingly in order to keep public-funded parks and outdoor areas alive). Stage 3 measures attempt to achieve reductions in residential and commercial demands of up to 20% of peak season demand. In the case of temporary water loss due to major damage to critical supply system facilities or major damage to local electrical utility systems, it may be necessary to go directly to Stage 4.

Under Stage 3 it will be expressly prohibited to use City-served/metered water to do any of the following:

1. Water or irrigate lawns, grass, landscaping, or turf unless such uses are solely to abate public health or fire hazards, as directed by the City Manager with advisement from agencies such as Washington County Public Health or Hillsboro Fire Department, or as directed by the City Manager to sustain publicly-funded outdoor areas and facilities.
2. Wash or wet down sidewalks, walkways, driveways, parking lots, open ground, or other hard-surfaced areas with water.
3. Wash vehicles, unless the City Manager or other authority, such as the Washington County Health Department, finds that the public health, safety, and welfare is contingent upon frequent vehicle cleaning such as cleaning of solid waste transfer vehicles, vehicles that transfer food and other perishables, or as otherwise required by law. An exception is that washing vehicles will be allowed at vehicle washing establishments that recycle water.
4. Flush water mains, except for water quality concerns, construction flushing, flow tests or emergency purposes.

The Water Department Director will consider exemptions on a case-by-case basis for businesses that rely on irrigation for their essential operations, such as nurseries, as well as businesses that are willing to implement requested conservations measures. Exemptions can also be appealed by the customer to the Utilities Commission. Staff, under the authority of the Utilities Commission, may also consider reducing pressure at Pressure Reducing Valve (PRV) stations for a prolonged severe water shortage event.

Additional restrictions and exemptions may be passed; as necessary, if the above measures do not adequately reduce demands.

If the Stage 3 alert is triggered within a specific geographical area with the distribution system, Hillsboro may provide bottled water or deploy the JWC Emergency Water Distribution System to the limited number of customers who are affected by loss of water service.

Stage 4: Emergency - Critical Water Shortage

Stage 4 responds to events causing an immediate and sustained loss of the source of supply or major damage to critical treatment, transmission and pumping systems, even after Hillsboro has attempted to secure additional supply through alternate means. Examples may include failure of a main transmission line, failure of an intake or water treatment plant, a contamination event in Barney or Scoggins reservoirs, or the upper Tualatin River or its tributaries, natural disaster such as an earthquake, or a malevolent attack on the system that introduces a contaminant at some point in the system.

Under the Critical Water Shortage stage, all water use may be prohibited, except that which is necessary for human consumption, fire suppression, and sanitation needs. If the emergency causes or is expected to cause a shortage of water for an extended period of time, implementing the curtailment measures of Stage 3 may be more appropriate than Stage 4 for business continuity purposes and recovery operations.

If the event causes immediate sustained loss of supply, major damage, or renders water in the system unsafe to drink (as described above), the Hillsboro Emergency Operations Center (EOC) will be activated within the Incident Command System. The Incident Commander will assume command and control of the City's response to the event. As the cause and severity of the event dictates, the Incident Commander can direct the following actions to occur, as appropriate to the response at hand:

1. Implement the appropriate response protocols of the City's Emergency Response Plan for the Hillsboro Water System.
2. Contact Washington County Emergency Management, Washington County Public Health, and the Oregon Drinking Water Program: Department of Human Services, and any other identified support agencies, to request assistance in response actions.
3. Issue media releases, and notify the local news media to solicit their assistance in notifying customers.
4. Contact county, state, and federal law enforcement officials as appropriate.
5. Contact the County Public Health Officer and local hospitals as appropriate for the nature of the event.
6. Contact JWC staff and request deployment of the Emergency Water Distribution System.
7. Hillsboro may impose fines or penalties for negligent use of water.
8. Consider contacting another Oregon Water/Wastewater Agency Response Network (ORWARN) agency requesting additional equipment and staff for emergency response operations.

Hillsboro will continue to investigate and develop specific back-up plans for curtailment emergencies. These plans may include negotiating a water purchase agreement with another water agency, designating emergency water distribution locations, securing redundancy supply through the development of the mid-Willamette River as a second source, and assessing feasibility of ASR technology.

Winter Curtailment Options

During winter months, curtailment is geared towards indoor use only. This makes reductions harder for customers to implement and for staff to enforce, due to the essential needs of water use instead of irrigation use, and that use is occurring mostly unseen. Use the following tips to reduce winter water use:

1. Request reduction in water use by the percentage determined to be the goal based on the comparable month in the prior year.
2. Ensure customers have shut their irrigation off for the season and winterized their systems to prevent leaks.
3. Encourage leak investigation and repair.
4. Encourage customers to take shorter showers.
5. Encourage customers to run taps and flush toilet only when necessary.
6. Encourage customers to delay washing clothes if possible.
7. Encourage customers to eliminate all non-essential water use.
8. Order industrial and commercial customers to conserve and reduce or eliminate non-essential water use.
9. Fire Department should discontinue training exercises that use water.
10. Stop serving water in restaurants unless requested by the customer. This action generates awareness for curtailment, and reduces use of water for washing glasses.
11. Hotels and motels shall discourage daily linen replacement by providing procedures for guests to opt for less frequent laundering.

Penalties and Enforcement

The penalties for violations of this chapter shall be cumulative in that they may be in addition to, not in lieu of, other penalties, remedies or surcharges established by this chapter.

Service may be terminated to any customer who knowingly and willfully violates any provision of the current curtailment ordinance.

Drought Declaration

If the Governor declares a drought in Washington County or in the State of Oregon, but Hillsboro has/will not activate any of the four stages outlined above, Hillsboro will inform customers of the drought declaration and the status of Hillsboro's water supply. In addition, Hillsboro will ask customers to voluntarily decrease water use through measures similar to the ones provided under Stage 1.

The public information program elements may include one or more of the following actions:

1. Issue a bilingual general request for voluntary reductions in water use by all water users:
    a. Summarize the current water situation, status of Hillsboro's water supply, and the reasons for the requested reductions.
    b. Outline measures that customers can take to reduce water use and remind customers of Hillsboro's availability as an information resource and for water-saving devices.
    c. Post a public service announcement on City's webpage and SM outlets. Include prepared information regarding conservation tips.
    d. Increase conservation promotion efforts.
2. Contact wholesale customers notifying them of the drought declaration and the status of Hillsboro's water supply. Ask them to increase their promotion of conservation programs.
3. Provide notification, assistance, and conservation/curtailment materials to wholesale customers and City departments, if requested. Share materials with JWC partners on request. Notify the RWPC to coordinate with other providers if needed.

Note: The JWC adopted an updated Curtailment Plan on January 13, 2017. The City's In-town and Upper System Curtailment Plans work in conjunction with the JWC plan.

Appendix J

City of Hillsboro Upper System

Curtailment Plan

Upper System Curtailment Element

This section satisfies the requirements of OAR 690-086-0160.

This rule requires a description of past supply deficiencies and current capacity limitations. It also requires inclusion of stages of alert and the associated triggers and curtailment actions for each stage.

Introduction

The Hillsboro-Cherry Grove Water System (OR 4100985) is also known as Hillsboro's "Upper System" and will be referred to as such in this curtailment plan to differentiate from Hillsboro's "In-town" curtailment plan. The Cherry Grove Slow Sand Filter Plant (SSFP) – located outside unincorporated Cherry Grove – is one of two sources for 1,456 people and the wholesale customers of City of Gaston and L.A. Water Cooperative. The Upper System is supplemented by Dilley Reservoir fed from the Joint Water Commission (JWC) Water Treatment Plant. This curtailment plan establishes measures to reduce water demands when water supplies aren't enough to meet Upper System demands.

This curtailment plan focuses on supply constraints during peak season, non-peak season and emergency events. Triggers are identified such as equipment failure, water system infrastructure damage, and supply-limiting events for four different curtailment stages. Next, specific actions to reduce demands voluntarily and by mandate are described for each curtailment stage.

Because Hillsboro operates three water systems with separate treatment plants and points of diversions, one of the supply systems may be impacted by curtailment conditions while the other system is not, each system has its own Curtailment Plan. Wholesale customers are required to adhere to Hillsboro's curtailment actions as stipulated through their wholesale contracts.

- Hillsboro water supply comes from two surface water sources: the Tualatin River including its tributaries Sain Creek and Scoggins Creek, and the Middle Fork of the North Fork of the Trask River. In addition to diverting water directly from these sources ("direct diversion" or "natural flow"), in the summer months Hillsboro uses water from storage supplies in Barney Reservoir, on the Middle Fork of the North Fork of the Trask River, and Scoggins Reservoir (Hagg Lake) on Scoggins Creek, a tributary of the Tualatin River.
- The Upper System customers are served water from both the JWC Water Treatment Plant and the Slow Sand Filter Plant.
- Butternut Creek is supplied by TVWD which has three sources: JWC, Portland Water Bureau (PWB), and Aquifer Storage and Recovery. PWB has two sources, a surface water source: the Bull Run Watershed, and a ground water source: the Columbia South Shore Wellfields – this is used to supplement flows from the Bull Run.

History of System Curtailment Incidents

OAR-690-086-0160(1)

Assessment of Water Shortages & Limitations

Despite several incidents of Upper System supply shortages in the past, the Upper System has not had to implement mandatory curtailment to date. Curtailment is considered a last resort to achieve decreased demand, but there is a plan to employ curtailment if necessary. The SSFP has flexibility in source water. Typically, water runs from the river to a settling pond to the SSFP, but the pond can be bypassed.

Summaries of Upper System water supply incidents that resulted in supply disruptions and nearly called for curtailment protocols are detailed below.

Summary of Incidents from 2000 – 2009

- December 2007: Due to a three day heavy rain event totaling 10.65", the ditch and culverts on Lee Falls Road became flooded. This also caused landslide issues on Lee Falls Road near mile marker three. Operation crews cleared the roadway and placed rock gabions at the landslide site.
- December 2008: A series of winter snow storm events hit the coast range. Trees fell across Lee Falls Road in all directions, knocking out power for three days. PGE attempted to restore power for two days but concluded it was too dangerous for workers during the storm and waited for the storm to pass. Over 20 big fir trees came down in the settling pond that had to be air lifted and recovered by a logging company.

Summary of Incidents from 2010 – 2019

- April 2015: While contractors were connecting a new waterline to an existing line in Dilley, the connection blew apart due to not having restraints in place. Water and Public Works department staff welded the two pieces together. Operations staff shut off the valves at the intersection of Maple and Etters causing limited disruption to customers.
- September 2013: A green algae that was a type of Spirogyra was detected at the raw water intake from the pond, on the top of the filter. There was also brown algae present that was an overgrowth of diatoms. Both were harmless to customers.
- March 2014: Limited filter capacity was caused from replacing the sand in one of the filters. The wrong sand was ordered, which slowed down the filtration process.
- January 2016: The local Fire Department utilized a hydrant near the Patton valley control valve. They were unaware the connecting line was under high-pressure and created a water hammer. This resulted in supply outages to a handful of customers, due to a main break. In response Hillsboro Water trained local Fire Department staff from Gaston Fire about the high pressure zone in the area and marked all hydrants "high pressure". Hillsboro updated an outdated plan on how to shut down the Upper Systems' distribution backbone.

Shortage Capability Assessment

OAR-690-086-0160(1)

The Upper System's current capacity limitation is based on the Slow Sand Filter Plant maximum production capacity of 3 mgd, Dilley Reservoir's storage capacity of 0.65 million gallons, and Elm PRV's capacity of 4 mgd. The Elm PRV allows the Upper System to be served by Hillsboro's capacity in JWC.

In the event of a supply interruption, the Upper System has one to two days' worth of stored water for customers. Dilley Reservoir holds 575,000 gallons, and the SSFP clear well holds 225,000 gallons of treated water.

- <u>In response to vulnerability assessments and outages, Hillsboro has recently made the following improvements.</u>
    - A back-up generator was installed at the SSFP in 2015 with seven days of fuel on site.
    - Dilley Reservoir had a seismic evaluation and determined the stored water level should be 575 feet of elevation. The water is now at that elevation.
    - A list of customers affected by supply and pressure issues is maintained by Hillsboro. Hillsboro has provided those customers 50 gallon barrels and small pumps to use during supply outages.

Curtailment Event Triggers and Stages

OAR-690-086-0160(2) and (3)

During the peak summer demand period each year from June through September, the system is typically operating at or near its maximum capacity. An interruption to supply during this time – such as a natural disaster, mechanical failure, terrorist act, or loss of source – could present significant challenges to the Upper System. Therefore, the following triggers and related curtailment stages in this plan are based primarily on events occurring during this time period. In addition, less critical impacts to the water supply – such as forecasted drought and minor mechanical or electrical failures – are addressed in Stages 1 and 2. Since there is also a need to plan for supply shortages in the winter, potential restrictions on indoor use are also presented. This scenario presents a unique challenge because few opportunities exist to further reduce winter-time demand to meet lowered supplies.

A wide range of initiating conditions are represented in the following four curtailment stages. As the stages increase from 1 to 4, the severity and/or length of the outage increases. Less critical impacts to the water supply such as forecasted drought, and minor mechanical or electrical failures are addressed in Stages 1 and 2. Severe droughts, earthquakes, or major infrastructure failures are addressed in Stages 3 and 4.

It is important to note that Hillsboro may be able to make alternative arrangements to meet customer demands, and that the "Initiating Conditions" described below don't always require the need to implement curtailment stages. If Hillsboro is able to make arrangements, or utilize other parts of its system to meet the demands required of its customers, no curtailment stage will be activated. When a curtailment stage is activated, staff will review the status of available supply and current and historic demands to establish a demand reduction goal. Each curtailment event will be addressed on a case-by-case basis.

This curtailment plan for the Upper System is designed to be initiated and implemented in progressive stages. The Upper System's curtailment plan has four distinct stages, as shown in Exhibit 1, each of which is triggered by one or more of the listed events:

Exhibit 1. Upper System Curtailment Plan Stages 1 through 4

Curtailment Stages	Potential Initiating Conditions
Stage 1 **Advisory** Temporary Water Shortage Alert (Short-Term Voluntary)	Short-term[1] interruption of electrical service affecting water treatment and distribution; Harmful algal blooms (HAB) clogs filters and impairs performance or occurrence of a cyanotoxin producing bloom; Minor mechanical or electrical malfunction of treatment plant; Minor damage to raw or treated water transmission mains (e.g., leaking joint requiring repair); or Forecasts of below-normal[2] levels of stored water in Barney Reservoir that may fall below the historical 25th percentile in the peak season.
Stage 2 **Voluntary** Long-Term Water Shortage Alert (Long-Term Voluntary)	Forecasts of below-normal[2] levels of stored water in Barney Reservoir that may fall below the historical 10th percentile in the peak season; or Forecasts of drought conditions for the peak season.
Stage 3 **Mandatory** Severe Water Shortage (Long-Term Mandatory)	The summer supplemental source Barney Reservoir is 50% of full capacity at the start of release season, resulting in a significant reduction[3] of the Upper System's water supply capacity; or Any event causing the Cherry Grove WTP to be out of service for an extended period beyond the storage capacity (); up to 7 days with the Lee Road valve closed and the rest of the Upper System fed by JWC. Failures in the treatment plant or transmission main that require a lengthy repair time.
Stage 4 **Emergency**	Extensive damage to transmission, or treatment processes caused by natural disaster (i.e. earthquake);

Curtailment Stages	Potential Initiating Conditions
Critical Water Shortage (Critical Mandatory Restrictions)	Interruption of electrical service to the SSFP for an unknown or extended period of time; Localized transmission line break resulting in supply disruption; Unplanned water quality, or other treatment issue, that slows SSFP production below demands in which the timeline for recovery from the condition is uncertain and the risk of total reservoir depletion, at projected rates of production and demand, is high; or Short-term increase in demand beyond the Upper System's percentage of SSFP production capabilities, due to an unforeseen circumstance such as extreme hot weather conditions or fire. (This condition would be for acute short-term shortages, and not long-term shortages, such as one caused by drought.)

[1] "Short-term" interruption means an interruption with an expected end. For example, a power outage expected to last one week would be probable cause for Stage 1 curtailment. The decision to initiate curtailment would depend on the time of year, likelihood that power will be restored in the predicted timeframe, and the likelihood that the Upper System can maintain backup power for the duration of the outage. In this case, the Upper System could avoid curtailment by using the back-up generators at the water treatment plant, backup fuel, and increased reliance on the JWC's water treatment plant.

[2] "Below normal" levels means that water levels fall slightly outside the normal drawdown curve. However, the Upper System could avoid curtailment if alternate supplies are made available or demands are lower than anticipated. For example, the reservoirs were between the 25th and 10th percentile in the 2015-2016 release season, but curtailment was not necessary. In addition, if alternate supplies are not feasible, promoting voluntary curtailment in order to reduce dependency on alternative supplies and to reduce costs may be the selected option.

[3] "Significant Reduction" means that the Upper System's water supply capacity cannot be made up through alternative means, so mandatory curtailment is necessary to reduce demand levels to ensure that water supplies don't run out. However, the Upper System could avoid mandatory curtailment if alternate supplies are made available that put source supplies back into normal ranges, or actual demands are lower than anticipated. For example, the Upper System's summer supplemental source was at 50% full in 2001, but the Upper System received over 50% of its stored water. Mandatory curtailment wasn't needed due to availability of other supplies in the region and voluntary curtailment measures.

Authority

The Water Department Director, under the authority of the City of Hillsboro Utilities Commission will be responsible for the actions and implementation of Stages 1 and 2, with frequent updates to the City Manager and City Council. Before implementing Stages 3 or 4, the Water Department Director, under the authority of the Utilities Commission, will notify and make a recommendation to the City Manager regarding the proposed curtailment action. Actions under Stages 3 and 4 of this plan may be initiated only after a declaration of emergency is issued by the Mayor, City Council, City Manager or appropriate successor as outlined in the City's Emergency Response Plan. If an emergency declaration made by the Mayor or City Council does not impact water supply or demands, Stages 3 and 4 may not be implemented, under the authority of the Hillsboro Utilities Commission.

Plan provisions will remain in effect until the emergency declaration is lifted by the City Manager or appropriate delegate, or until the Utilities Commission is able to demonstrate that the Water Department can meet water demands.

Curtailment measures may be applied to the entire system, or only to specific types of water use, and/or in certain geographic areas, which are directly impacted depending on the nature, severity, and location of the initiating conditions. This will be determined by City staff under the direction of the Water Department Director, or a designee such as an Acting Director or the Assistant City Manager.

The Water Department Director and Water Department staff, under the authority of the Utilities Commission, are responsible for execution of the plan provisions once an emergency has been declared.

The Water Department Director and staff will keep the JWC, its partners, and its wholesale customers informed about water demands and curtailment plans during the course of any water emergency.

Curtailment Plan Implementation

OAR-690-086-0160(4)

In implementing this curtailment plan, Department staff will work closely with the JWC and other member agencies to assure consistent approaches to dealing with water shortages by coordinating stage designations, public notices, press releases, and other outreach activities. Department staff will also coordinate with its wholesale customers on curtailment efforts.

Stage 1: Advisory - Temporary Water Shortage Alert

After notifying the City Manager and the Utilities Commission, Water Department staff, under the direction of the Water Department Director, will activate an Advisory Temporary Water Shortage Alert to inform customers of the need for voluntary, temporary reductions in consumption. This will occur when the Stage 1 triggers described in **Exhibit 1** are met, and Hillsboro determines demands will not be met through alternative methods.

Stage 1 Advisory Temporary Water Shortage Alert requests for short-term voluntary reductions will be made if the Utilities Commission determines that finished water storage at the JWC or in the distribution system may not meet projected demands due to the events described in **Exhibit 1** Stage 1.

Stage 1 public information program elements may include one or more of the following actions:

1. Begin preparations for a voluntary curtailment bilingual (English and Spanish) campaign. Include components such as:
    a. Issue a general request for voluntary reductions in water use by all water users. The request will include a summary of the current water situation, the reasons for the

requested reductions, and a warning that mandatory cutbacks will be required if voluntary measures do not sufficiently reduce water usage.

   b. Get the message out through multiple communication venues.

   c. Contact local media outlets, in coordination with the JWC, to inform customers about temporary interruptions to normal service delivery.

   d. Post a public service announcement on Hillsboro's webpage and Social Media (SM) outlets. Include prepared information regarding conservation tips.

2. Encourage voluntary reductions on outdoor irrigation.

3. Encourage refraining from washing vehicles except at commercial establishments that recycle or reuse water in their cleaning process. Consider offering free or discounted single-wash coupons to encourage compliance. Depending on severity of situation, car wash fundraisers may also be excluded from voluntary restriction, as decided by Water Department Director with advisement from staff.

4. Notify wholesale customers of the existence of, or potential for, water shortages and ask them to issue similar messages to their customers.

5. Provide bilingual notification, assistance, and conservation curtailment materials to wholesale customers and City departments if requested. Share materials with JWC partners on request as well, for awareness even if they are not participating in curtailment actions. Notify the Regional Water Providers Consortium (RWPC) to coordinate with other providers if needed.

Non-Peak Season (Winter) Curtailment

1. Ask industrial and commercial customers to conserve and reduce or eliminate non-essential water use.

2. Encourage customers to shut off their irrigation systems for the season.

3. Encourage repair of all known customer leaks.

4. Encourage customers to take shorter showers.

5. Encourage customers to run taps and flush toilet only when necessary.

6. Encourage customers to delay washing clothes if possible.

7. Encourage customers to eliminate all non-essential water use.

Stage 2: Voluntary - Long-Term Water Shortage Alert

A Stage 2 Voluntary Long-Term Water Shortage Alert will be issued for reduction preparations if it is projected by the JWC and BRJOC. Reasons might include; that peak season storage supplies may not reach projected peak season demand, Hillsboro determines demands will not be met or it is undesirable to do so through alternate means. The actions under this stage will include the previous actions listed above in Stage 1, but will also include the following actions requesting customers to voluntarily restrict their non-essential uses.

Stage 2 public information program elements will include one or more of the following actions:

1. Hillsboro's Water Department Director, under the authority of the City of Hillsboro Utilities Commission, will implement Stages 1 and 2, with frequent updates to the City Manager and City Council.
2. Begin preparations for an aggressive voluntary curtailment bilingual campaign to begin in April or May, before the peak season begins. Include components such as:
    a. Provide notice and press releases to local media outlets to inform customers about potential water shortages for peak season demands.
    b. Develop and provide voluntary conservation messaging through various communication venues.
    c. Encourage customers to water sparingly, by sharing information at community events and promotions. Tailor all conservation messaging at outreach events to the drought conditions and attend additional events such as neighborhood or homeowner's associations, farmer's markets, etc.
    d. Provide weekly notices and updates using the City website and other communication venues of water availability.
    e. Consider door-to-door distribution or mailing of conservation materials.
3. Advise the wholesale customers, Stimson Lumber, Washington County, Clean Water Services, and high communication customers. Ensure Gaston notifies the Gaston School District.

    Staff will closely monitor the community response to Stage 2 throughout the peak season, and implement Stage 3 if response is not adequate to sustain storage supplies through the entire peak season. *(These measures proved sufficient during the 2001 curtailment campaign.)*

    If the situation worsens, or warrants stricter measures, the following restrictions could also be implemented under Stage 2:

4. Encourage outdoor irrigation to only three-days per every seven-day period (including use of specific schedules imposed by the City Manager) and only between the hours of 8 pm and 5 am. This restriction and prohibition applies to all outdoor irrigation unless:
    a. Grass, trees, turf or landscaping is less than one-year old;
    b. Grass, trees, or turf is part of a commercial sod farm;
    c. Grass, trees, or turf areas are within a high use athletic field used for organized play;

    d. Grass, trees, or turf areas are used for golf tees or greens; or
    e. Grass, trees, or turf areas are part of a park or recreation area deemed by the City Council or Utilities Commission to be of particular significance and value to the community.

5. Notwithstanding the exceptions to the outdoor irrigation restrictions and prohibitions noted above, all outdoor watering schedules shall be limited to only that necessary to maintain plant health and shall not allow unnecessarily irrigation. This includes:
    a. Voluntary restrictions on nonessential water uses, including:
        i. No washing of paved surfaces;
        ii. No fountains except those using re-circulated water;
        iii. No washing of vehicles other than in establishments that recycle water. (Depending on severity of situation, car wash fundraisers may also be excluded from voluntary restriction, as decided by Water Department Director with advisement from staff); and
        iv. No washing of roofs, decks, or home siding unless such uses are solely to abate a potential fire hazard.
6. Water Department staff will continue to work closely with Utility Billing to identify and notify customers of unfixed leaks. Additional financial incentives may be made available to customers that fix their leaks within a short timeframe.
7. In addition, Water Department staff will work with its industrial and commercial water users to minimize their non-essential water use.

Stage 3: Mandatory - Severe Water Shortage

Conditions causing Stage 3 curtailment measures are severe enough in terms of extent and duration that significant reductions in water use must be achieved as quickly as possible in order to ensure public health, safety, and welfare. This step would take place after Hillsboro has attempted to secure additional supply through alternate means. Stage 3 builds on measures enacted through the previous stages. In a Stage 3 curtailment, all outside watering with City-served water is prohibited and any exceptions noted above for outdoor water uses are rescinded unless such uses are solely to abate public health or fire hazards (an allowance may be made by the City Manager to water sparingly in order to keep public-funded parks and outdoor areas alive). Stage 3 measures attempt to achieve reductions in residential and commercial demands of up to 20% of peak season demand. In the case of temporary water loss due to major damage to critical supply system facilities or major damage to local electrical utility systems, it may be necessary to go directly to Stage 4.

Under Stage 3 it will be expressly prohibited to use City-served/metered water to do any of the following:

1. Water or irrigate lawns, grass, landscaping, or turf unless such uses are solely to abate public health or fire hazards, as directed by the City Manager with advisement from agencies such as Washington County Public Health or Hillsboro Fire Department, or as directed by the City Manager to sustain publicly-funded outdoor areas and facilities.
2. Wash or wet down sidewalks, walkways, driveways, parking lots, open ground, or other hard-surfaced areas with water.
3. Wash vehicles, unless the City Manager or other authority, such as the Washington County Health Department, finds that the public health, safety, and welfare is contingent upon frequent vehicle cleaning such as cleaning of solid waste transfer vehicles, vehicles that transfer food and other perishables, or as otherwise required by law. An exception is that washing vehicles will be allowed at vehicle washing establishments that recycle water.
4. Flush water mains, except for water quality concerns, construction flushing, flow tests or emergency purposes.
5. Staff, under the authority of the Utilities Commission, may also consider reducing pressure at Pressure Reducing Valves (PRV) stations for prolonged severe water shortage event.

   The Water Department Director will consider exemptions on a case-by-case basis for businesses that rely on irrigation for their essential operations, such as nurseries, as well as businesses that are willing to implement requested conservations measures. Exemptions can also be appealed by the customer to the Utilities Commission. Staff, under the authority of the Utilities Commission, may also consider reducing pressure at Pressure Reducing Valve (PRV) stations for a prolonged severe water shortage event.

Additional restrictions and exemptions may be passed; as necessary, if the above measures do not adequately reduce demands.

If the Stage 3 alert is triggered by an extended disruption at Hillsboro's Cherry Grove WTP or a specific geographical area with the distribution system, Hillsboro may provide bottled water or deploy the JWC Emergency Water Distribution System to the limited number of customers who are affected by loss of water service.

Stage 4: Emergency - Critical Water Shortage

Stage 4 responds to events causing an immediate and sustained loss of the source of supply or major damage to critical treatment, transmission and pumping systems, even after Hillsboro has attempted to secure additional supply through alternate means. Examples may include failure of a main transmission line, failure of an intake or water treatment plant, a contamination event in Barney or Scoggins reservoirs, or the upper Tualatin River or its tributaries, natural disaster such as an earthquake, or a malevolent attack on the system that introduces a contaminant at some point in the system.

Under the Critical Water Shortage stage, all water use may be prohibited, except that which is necessary for human consumption, fire suppression, and sanitation needs. If the emergency causes or is expected to cause a shortage of water for an extended period of time, implementing the curtailment measures of Stage 3 may be more appropriate than Stage 4 for business continuity purposes and recovery operations.

If the event causes immediate sustained loss of supply, major damage, or renders water in the system unsafe to drink (as described above), the Hillsboro Emergency Operations Center (EOC) will be activated within the Incident Command System. The Incident Commander will assume command and control of Hillsboro's response to the event. As the cause and severity of the event dictates, the Incident Commander can direct the following actions to occur, as appropriate to the response at hand:

1. Implement the appropriate response protocols of the City's Emergency Response Plan for the Hillsboro Water System.
2. Contact Washington County Emergency Management, Washington County Public Health, and the Oregon Drinking Water Program: Department of Human Services, and any other identified support agencies, to request assistance in response actions.
3. Issue media releases, and notify the local news media to solicit their assistance in notifying customers.
4. Contact county, state, and federal law enforcement officials as appropriate.
5. Contact the County Public Health Officer and local hospitals as appropriate for the nature of the event.
6. Contact JWC staff and request deployment of the Emergency Water Distribution System.
7. Hillsboro may impose fines or penalties for negligent use of water.
8. Consider contacting another Oregon Water/Wastewater Agency Response Network (ORWARN) agency requesting additional equipment and staff for emergency response operations.

Hillsboro will continue to investigate and develop specific back-up plans for a Stage 4 emergency. These plans may include negotiating a water purchase agreement with another water agency, designating emergency water distribution locations, and assessing feasibility of Aquifer Storage and Recovery (ASR) technology. The Willamette Water Supply System will be online in 2026 and will serve as a redundant supply for the In-Town System but may potentially be used as a source for emergency water for the Upper System.

Winter Curtailment Options

During winter months, curtailment is geared towards indoor use only. This makes reductions harder for customers to implement and for staff to enforce, due to the essential needs of water use instead of irrigation use, and that use is occurring mostly unseen. Use the following tips to reduce winter water use:

1. Request reduction in water use by the percentage determined to be the goal based on the comparable month in the prior year.
2. Ensure customers have shut their irrigation off for the season and winterized their systems to prevent leaks.
3. Encourage leak investigation and repair.
4. Encourage customers to take shorter showers.
5. Encourage customers to run taps and flush toilet only when necessary.
6. Encourage customers to delay washing clothes if possible.
7. Encourage customers to eliminate all non-essential water use.
8. Order industrial and commercial customers to conserve and reduce or eliminate non-essential water use.
9. Fire Department should discontinue training exercises that use water.
10. Stop serving water in restaurants unless requested by the customer. This action generates awareness for curtailment, and reduces use of water for washing glasses.
11. Hotels and motels shall discourage daily linen replacement by providing procedures for guests to opt for less frequent laundering.

Penalties and Enforcement

The penalties for violations of this chapter shall be cumulative in that they may be in addition to, not in lieu of, other penalties, remedies or surcharges established by this chapter.

Service may be terminated to any customer who knowingly and willfully violates any provision of the current curtailment ordinance.

Drought Declaration

If the Governor declares a drought in Washington County or in the State of Oregon, but the Upper System has/will not activate any of the four stages outlined above, Hillsboro will inform customers of the drought declaration and the status of the Upper System's water supply. In addition, Hillsboro will ask customers to voluntarily decrease water use through measures similar to the ones provided under Stage 1.

The public information program elements may include one or more of the following actions:

1. Issue a bilingual general request for voluntary reductions in water use by all water users:
    a. Summarize the current water situation, status of the Upper System's water supply, and the reasons for the requested reductions.

b. Outline measures that customers can take to reduce water use and remind customers of the Upper System's availability as an information resource and for water-saving devices.

c. Post a public service announcement on City's webpage and SM outlets. Include prepared information regarding conservation tips.

d. Increase conservation promotion efforts.

2. Contact wholesale customers notifying them of the drought declaration and the status of the Upper System's water supply. Ask them to increase their promotion of conservation programs.

3. Provide notification, assistance, and conservation curtailment materials to wholesale customers and City departments if requested. Share materials with JWC partners on request. Notify the Regional Water Providers Consortium (RWPC) to coordinate with other providers if needed.

Note: The JWC adopted an updated Curtailment Plan on January 13, 2017. The City's In-town and Upper System Curtailment Plans work in conjunction with the JWC plan.

Appendix K

City of Forest Grove
Curtailment Plan

Forest Grove

The City of Forest Grove depends on the JWC's water source for an average of 44 percent (2008 through 2018) of its water supply, so Forest Grove's curtailment planning will consider JWC curtailment as well as measures based on the City's own water supplies. As stated in the JWC's curtailment plan, the JWC does not have direct authority to regulate its member agencies. Thus, while the JWC curtailment plan creates processes for coordination, negotiation and public education, Forest Grove's curtailment plan establishes measures to reduce on-the-ground water demand.

The curtailment plan presented in this section expands on the City of Forest Grove's current city code, and is revised to comply with Division 86 requirements. In addition to the following measures, the City shall retain ordinance provisions regarding the adoption of enforcement.

History of System Curtailment Episodes

OAR 690-086-0160 (1)

During the last 10 years, the City of Forest Grove has not experienced supply deficiencies. When the City has had transmission line or power failures, it has been able to use capacity from the JWC system so that its customers have had sufficient water supply and curtailment has been unnecessary. Refer to the JWC "History of System Curtailment Episodes" at the beginning of this section for more information.

Shortage Capability Assessment

OAR 690-086-0160 (1)

The City of Forest Grove's current capacity limitation is its raw water supply if it becomes significantly reduced or unavailable for an extended period.

In the event of a supply interruption the City is well-positioned to meet its non-peak season customer demands based on the previously described upgrades to the JWC water system and the following reasons:

- Additional finished water storage
    - The City consistently follows best management practices and stores three days of average day demand (ADD) in finished water storage in the JWC and local distribution system.
- Additional Water Sources
    - The City of Forest Grove has the Clear Creek water source
    - The City of Forest Grove has an emergency intertie with the City of Cornelius

Curtailment Event Triggers and Stages

OAR 690-086-0160 (2) and (3)

The City of Forest Grove's Curtailment Plan, presented here, has four stages that increase in level of severity:

Stage 1 – Water Shortage Alert

Stage 2 – Serious Water Shortage

Stage 3 – Critical Water Shortage

Stage 4 – Emergency Water Shortage

The City of Forest Grove's curtailment plan stages will be triggered by one or more of the criteria presented in Exhibit 1.

Exhibit 1. City of Forest Grove Curtailment Stages

Curtailment Stages	Initiating Conditions
Stage 1 Water Shortage Alert	Mechanical or electrical malfunction at city's or SHPP Intake or water treatment plant anticipated to be of short duration; Interruption of local utility electrical service anticipated to be of short duration; or Abnormal weather conditions during the storage season, or other reasons, that make it unlikely that Barney Reservoir and Scoggins Dam (Hagg Lake) will fill to their full capacities preceding the peak summer supply season;
Stage 2 Serious Water Shortage	Notice of potential water shortage from the JWC as part of its Stage 2 curtailment; Water supply at or below 90 percent of demands for three or more consecutive days; or Mechanical or electrical malfunction or other incident requiring a longer duration and more extensive repairs of pumping facilities, treatment plant or water transmission mains.
Stage 3 Critical Water Shortage	Curtailment request from the JWC as part of its Stage 3 curtailment; Water supply at or below 80 percent of projected demands for three or more consecutive days; or Mechanical or electrical malfunction or other incident requiring a longer duration and more extensive repairs of pumping facilities, treatment plant or water transmission mains.
Stage 4 Emergency Water Shortage	Water supply notification from the JWC as part of its Stage 4 curtailment; Water supply at or below 70 percent of demands for three or more consecutive days;

Curtailment Stages	Initiating Conditions
	Intentional acts or fire, contamination of source or any other event resulting in an immediate, sustained deprivation of water supply; or Extensive damage to transmission, pumping or treatment processes caused by natural disaster.

Authority

Actions under Stages 2 through 4 of this plan may be initiated only after a declaration of emergency by the City Manager. Plan provisions will remain in effect until the emergency is declared ended by the initiating party, provided that the City Council may rescind an emergency declaration issued by the City Manager upon a finding that the emergency no longer exists, or that the original declaration was made in error.

Actions may be applied to the entire system or only to those water use sectors or in those geographic areas that are directly impacted by a water supply shortage.

The City Manager is responsible for execution of the plan provisions once an emergency has been declared.

Curtailment Plan Implementation and Enforcement

OAR 690-086-0160 (4)

In implementing this curtailment plan, the City will work closely with the JWC and other member agencies to assure consistent approaches to dealing with water shortages by coordinating stage designations, public notices, press releases, and other outreach activities.

Stage 1: Water Shortage Alert

Under Stage 1, the City Manager will issue a notice requesting voluntary reductions in water use by all customers upon determining in coordination with City staff that voluntary curtailment is needed based on the circumstances. The notice will include a summary of the current water situation, the reasons for the requested conservation measures, and a warning that mandatory restrictions will be implemented if voluntary measures do not sufficiently reduce water usage. Forest Grove will coordinate with the JWC to contact local media to inform customers about temporary interruptions to normal service delivery.

When Stage 1 is triggered, the City will ask customers to voluntarily comply with the following:

1. Minimize landscape watering between 10:00 a.m. and 6:00 p.m., the period of highest water loss due to evaporation.
2. Water landscapes on alternate days (even numbered addresses water on even numbered days and odd numbered addresses water on odd numbered days.)

3. Implement other conservation measures, such as those described on the Regional Water Providers Consortium website, which can be accessed from the City's website.

The goal under Stage 1 is to reduce demand by approximately 5 percent.

Stage 2: Serious Water Shortage

Stage 2 is similar to Stage 1, except that the voluntary measures regarding outdoor water use will be made mandatory by the City Manager, and additional non-essential water use will be prohibited. The goal under Stage 2 is to reduce demand by approximately 10 percent.

Under Stage 2, the City will implement the following mandatory water reduction measures:

1. Restricting outdoor irrigation to the odd/even schedule described in Stage 1, and to only the hours between 6:00 p.m. and 10:00 a.m. This restriction applies to all outdoor irrigation unless:
    a. Grass, turf or landscaping is less than 1-year old;
    b. Grass or turf is part of a commercial sod farm;
    c. Grass or turf areas are within a high use athletic field used for organized play;
    d. Grass or turf areas are used for golf tees or greens; or
    e. Grass or turf areas are part of a park or recreation area deemed by the City Manager to be of particular significance and value to the community.
2. Prohibiting washing motor vehicles, boat trailer, or other vehicles, except at a commercial washing facility that practices wash water recycling. An exception to this restriction will allow washing of vehicles that must be cleaned to maintain public health and welfare such as food carriers and solid waste transfer vehicles.
3. Prohibiting the following non-essential uses of water:
    a. Washing of paved or hard-surfaced areas such as sidewalks, driveways and parking lots;
    b. Fountains or ponds except those using re-circulated water;
    c. Water running onto streets, sidewalks, or into gutters;
    d. Washing of roofs, gutters, decks or home siding unless such uses are needed for painting, construction or to abate a potential fire hazard.
    e. Irrigating golf courses except tees and greens.

Stage 3: Critical Water Shortage

Conditions causing Stage 3 curtailment measures are severe enough in terms of extent and duration that significant reductions in water use must be achieved as quickly as possible in order to ensure public health safety and welfare. Stage 3 builds on measures enacted through the previous stages. The goal under stage 3 is to reduce demand by approximately 20 percent.

In a Stage 3 curtailment, all outside watering is prohibited and any exceptions noted above for outdoor water uses are rescinded unless such uses are solely to abate public health or fire hazards.

Under Stage 3, in addition to the prohibitions in Stage 2, it will be expressly prohibited to:

1. Irrigate lawns, grass, landscaping or turf
2. Flush water mains, except for water quality concerns or emergency purposes.
3. Filling or otherwise putting water into any swimming pool or hot tub, unless it:

    a. Is used for a neighborhood fire control supply;
    b. Has a recycling water system;
    c. Has an evaporative cover; or
    d. Is required by a medical doctor's prescription.

As part of Stage 3, the City will issue public service announcements, in coordination with the JWC, to notify customers of the severity of the conditions.

Stage 4: Emergency Water Shortage

Stage 4 responds to events causing an immediate and sustained loss of water supply or major damage to critical treatment, transmission and pumping systems. Under the Critical Water Shortage stage, all water use may be prohibited, except that necessary for human consumption, fire suppression, and sanitation needs. The goal under Stage 4 is to ensure potable water supply for public health, safety and welfare.

If the event renders water in the system unsafe to drink (e.g., chemical spill or intentional act against the system), the City Manager will direct staff to notify customers as quickly as possible. In addition, the City Manager will implement the following:

1. Contact the Oregon Drinking Water Program, Department of Human Services, and request their assistance in response actions.
2. Notify the local news media, if appropriate, to solicit their assistance in notifying customers.
3. Contact city, county, state and federal law enforcement officials as appropriate.
4. Contact the county public health officer and local hospitals, as appropriate for the nature of the event.
5. Contact the JWC staff and request deployment of the Emergency Water Distribution System.
6. Contact another Oregon Water/Wastewater Agency Response Network agency requesting additional equipment and staff for emergency response operations.

The City will continue to investigate and develop specific back-up plans for a Stage 4 emergency. These plans may include purchasing water from another JWC partner agency, directing residents to a pre-designated water distribution location, and supplying bottled water.

Drought Declaration

If a declaration of a severe drought is declared by the Governor per ORS 536.720, the Oregon Water Resources Commission may order political subdivisions within any drainage basin or subbasin to implement a water conservation or curtailment plan or both, approved under ORS 536.780. The City's conservation and curtailment elements in this WMCP meet these requirements. If the City is within a severe drought area declared by the Governor, such as Washington County, the City will consider whether it needs to implement curtailment measures to meet system demands. The City will encourage its customers to conserve water regardless of whether curtailment is needed.

Appendix L

City of Beaverton
Curtailment Plan

Beaverton

The City currently obtains most of its water supply from JWC so the City's curtailment planning is intrinsically linked to JWC curtailment. JWC adopted an updated curtailment plan on January 13, 2017. The City's curtailment plan works in conjunction with JWC's plan. While JWC curtailment plan creates processes for coordination and negotiation of water supplies for JWC partners, the City's curtailment plan establishes measures to reduce its water demands when water supplies are not enough to meet the needs of the City and its customers.

This curtailment plan focuses on supply constraints during an emergency in the peak season, although the plan is flexible enough to address non-peak season constraints. To address these constraints, the City has identified triggers, such as equipment malfunctions, infrastructure damage, and supply-limiting events for five different curtailment stages. For each of these stages, specific actions to reduce demands, voluntary and mandatory, are described.

Not only does the City's curtailment plan comply with Division 86 requirements, it also expands on Beaverton's city code and comports with its 2016 Emergency Response Plan (ERP). JWC also has an ERP, updated in 2004, which describes how the member agencies will respond to a variety of incidents, addressing the entirety of JWC infrastructure and sources of supply. The City's curtailment plan and ERP were designed to work in tandem with JWC's ERP to allow for a coordinated response among members as needed.

Availability of Emergency Supplies

In addition to water sourced from JWC, Beaverton can rely on native groundwater and water derived from its ASR program (recharged typically during non-peak seasons via JWC), and has interties with TVWD and the Cities of Tigard and Portland for use as supply during a water shortage.

History of System Curtailment Episodes

OAR 690-086-0160 (1)

Despite several incidents of JWC supply shortages in the past, the City has not had to implement mandatory curtailment within the last 10 years. Those supply incidents are described in detail in the JWC "History of System Curtailment Episodes" at the beginning of this section, but all were handled by operational adjustments, negotiations for alternative supplies with JWC partners, and use of water via interconnections with other non-JWC partner entities. The City and its partners excel at working together to meet the water supply needs of all partners if alternatives besides curtailment are available. Curtailment is considered a last resort to achieve decreased demand, but the City has a plan to employ curtailment if necessary.

Shortage Capability Assessment

OAR 690-086-0160 (1)

The City's current capacity limitation is the South Transmission Line (STL), as the City owns 18.75 mgd but can move only 14 mgd through the STL. The City is moving forward with a connection to the North Transmission Line (NTL) to make up for this gap in transmission capacity and owned treatment capacity.

In the event of a supply interruption the City is well-positioned to meet its non-peak season customer demands based on upgrades to the JWC water system and the following reasons:

- Additional finished water storage
  - The City consistently follows best management practices and stores three days of average day demand (ADD) in finished water storage in the JWC and local distribution system.
- Additional Water Sources

  The City's groundwater and ASR wells can reliably meet non-peak season demand on a temporary basis.
  - The City has interties with TVWD, PWB, and Tigard and can call on these entities for emergency supplies as needed.
  - By 2026, the City will have access to the Willamette River though Permit S-54940.

Curtailment Event Triggers

OAR 690-086-0160 (2), (3)

The following triggers and related curtailment stages in this curtailment plan are based primarily on events occurring during the peak season time period, although the triggers can be initiated at any time.

This curtailment plan is designed to be initiated and implemented in progressive stages. As shown in Exhibit 1, Beaverton's curtailment plan has five distinct stages, each of which is triggered by one or more of the listed events. The City's curtailment plan is consistent with a resolution for curtailment that adopted in 2010 with which the City is required to comply. Furthermore, City Council has authority to authorize emergency water use restrictions under City Code 4.02.180.

Exhibit 1. City of Beaverton Water Use Curtailment Plan Stages 1 through 5

Curtailment Stages	Initiating Conditions
Stage 1 Temporary Water Shortage Alert (Short-Term Voluntary)	Interruption of local utility electrical service affecting water treatment and distribution. Minor mechanical or electrical malfunction in pumping facilities or treatment plant. Minor damage to raw or treated water transmission mains (e.g., leaking joint requiring repair).
Stage 2 Long-Term Water Shortage Alert (Preparing for Long-Term Voluntary)	JWC forecasts below-normal levels of stored water in Barney Reservoir and Scoggins Dam (Hagg Lake) that may fall below City's projected peak season demand. JWC forecasts of drought conditions for the peak season.
Stage 3 Serious Water Shortage (Long-Term Voluntary)	JWC forecasts of below-normal levels of stored water in Barney Reservoir and Scoggins Dam (Hagg Lake) (storage supply at or below 90% of City's projected peak season demand). Mechanical or electrical malfunction or other incident requiring more extensive repairs of pumping facilities, treatment plant, or water transmission mains than in Stage 1.
Stage 4 Severe Water Shortage (Long-Term Mandatory)	JWC forecasts below-normal levels of stored water in Barney Reservoir and Scoggins Dam (Hagg Lake) (storage supply at or below 80% of City's projected peak season demand). Multiple failures in the pumping facilities, treatment plant, or transmission mains.
Stage 5 Critical Water Shortage (Short-Term Critical Mandatory Restrictions)	Extensive damage to transmission, pumping, or treatment processes caused by natural disaster. JWC forecasts of below-normal levels of stored water in Barney Reservoir and Scoggins Dam (Hagg Lake) (storage supply at or below 70% of City's projected peak season demand). Intentional acts, fire, contamination of source, or any other event resulting in an immediate, sustained deprivation of water supply.

Notes:

JWC = Joint Water Commission

ORS = Oregon Revised Statute

Authority

Actions under Stages 2 through 5 of the City's curtailment plan may be initiated only after a declaration of emergency by the Mayor and ratified by the City Council per City Code 2.01. Provisions of the plan will remain in effect until the emergency is declared ended by the City Council.

Curtailment measures may be applied to the entire system, or only to water use sectors, and/or in geographic area that are directly affected as determined by the Public Works Director.

The Mayor is responsible for execution of the plan provisions after an emergency has been declared and will rely on the City's emergency response team to implement appropriate measures.

Curtailment Plan Implementation and Enforcement

OAR 690-086-0160 (4)

In implementing this curtailment plan, the City will work closely with JWC and other member agencies as necessary to ensure consistent approaches to dealing with water shortages by coordinating stage designations, public notices, press releases, and other outreach activities.

Stage 1: Temporary Water Shortage Alert

A Temporary Water Shortage Alert will be activated to inform customers of the need for voluntary, temporary reductions in consumption. This will occur when the Stage 1 triggers are met as described in Exhibit 1.

For a Stage 1 Temporary Water Shortage Alert, requests for short-term voluntary reductions will be made if the Mayor determines that finished water storage at JWC or in the distribution system may not meet projected demands because of the events described in Exhibit 1 Stage 1.

Stage 1 public information program elements would include the following:

1. Issue a general request for voluntary reductions in water use by all water users. The request will include a summary of the current water situation, the reasons for the requested reductions, and a warning that mandatory cutbacks will be required if voluntary measures do not sufficiently reduce water usage.
2. Contact local media outlets, in coordination with JWC, to inform customers about temporary interruptions to normal service delivery.
3. Post pre-prepared public service announcement on City's webpage. Include prepared information regarding conservation tips.
4. Provide notice on water bills or through utility bill inserts if the timing is feasible.
5. Encourage, through public service announcements, voluntary reductions on outdoor irrigation and limit irrigation times to between the hours of 8 p.m. and 10 a.m.
6. Encourage customers to refrain from washing cars except at commercial establishments that recycle or reuse water in their cleaning process. Consider offering free or discounted single-wash coupons to encourage compliance.
7. Contact wholesale customers and notify them of the existence or potential for water shortages.
8. Provide notification, assistance, and conservation curtailment materials to wholesale customers.

Stage 2: Long-Term Water Shortage Alert

A Stage 2 Long-Term Water Shortage Alert will be issued for potential long-term voluntary reduction preparations if it is projected by JWC and BRJOC that peak season storage supplies may not reach the City's projected peak season demand and the City's ASR system cannot fully satisfy ADD or peak season demand. The actions under this stage will include the previous actions listed above in Stage 1, but also will include the following actions requesting customers to voluntarily restrict their non-essential uses.

Stage 2 public information program elements would include the following:

Follow Stage 1 program elements.

1. Begin preparations for an aggressive conservation campaign to begin before the peak season (April and May).
2. Provide notice and press releases to local media outlets to inform customers about potential water shortages for peak season demand.
3. Develop and provide billboard conservation advertisements.
4. Provide weekly updates on website and/or local newspapers of storage levels in Barney and Scoggins Dam (Hagg Lake).
5. Tailor all conservation messaging at outreach events to the drought conditions and attend additional events such as neighborhood or homeowners' associations, farmers' markets, etc.
6. Consider purchasing additional radio or television advertisements with partners such as JWC or Consortium.
7. Meet with industrial customers to review the water supply situation.

City personnel will closely monitor the citizen response to Stage 2 throughout the peak season and recommend that the Mayor implement Stage 3 if response is not adequate to sustain storage supplies through the entire peak season. These measures proved sufficient during the 2001 curtailment campaign.

Stage 3: Serious Water Shortage

A Stage 3 alert will be activated to impose a suite of mandatory prohibitions on non-essential water use when any of the initiating conditions are met. The goal of a Stage 3 alert is to achieve reductions of 10 percent of peak season demand. Under Stage 3, the City would introduce the following mandatory water reduction measures:

1. Restrict outdoor irrigation to 3 days per every 7-day period (including use of specific schedules imposed by the Mayor) and only between the hours of 8 p.m. and 10 a.m. This restriction and prohibition applies to all outdoor irrigation unless:

    a. Grass, turf or landscaping is less than 1 year old.
    b. Grass or turf is part of a commercial sod farm.
    c. Grass or turf areas are within a high use athletic field used for organized play.

d. Grass or turf areas are used for golf tees or greens.
e. Grass or turf areas are part of a park or recreation area deemed by the City Council to be of particular significance and value to the community.

Notwithstanding the exceptions to the outdoor irrigation restrictions and prohibitions noted above, all outdoor watering schedules will be limited to only those necessary to maintain plant health.

2. Restrict all water waste:

   a. No washing of paved surfaces.
   No use of fountains except those using re-circulated water.
   No water running onto streets, sidewalks, or into gutters.
   No washing of vehicles other than in establishments that recycle water.
   No washing of roofs, decks, or home siding unless such uses are solely to abate a potential fire hazard.

3. Identify and notify customers about unfixed leaks in their systems. Financial incentives will be available to customers that fix their leaks in a short time frame. Additional restrictions on notified customers with unfixed leaks will be considered.
4. Notify the City's water supply partners to activate alternative water supplies.
5. Work with large, local industrial and commercial water users to minimize their non-essential water use.

Stage 4: Severe Water Shortage

Conditions causing Stage 4 curtailment measures are severe enough in terms of extent and duration that significant reductions in water use must be achieved as quickly as possible to ensure public health safety and welfare. Stage 4 builds on measures enacted through the previous stages. In a Stage 4 curtailment, all outside watering is prohibited and any exceptions noted above for outdoor water uses are rescinded unless such uses are solely to abate public health or fire hazards. Stage 4 measures attempt to achieve reductions in residential and commercial demands of up to 20 percent of peak season demand. In the case of temporary water loss because of major damage to critical supply system facilities or major damage to local electrical utility systems, it may be necessary to go directly to Stage 5.

Under Stage 4, it will be expressly prohibited to:

1. Water, sprinkle, or irrigate lawns, grass, landscaping, or turf.
2. Wash, wet down, or sweep sidewalks walkways, driveways, parking lots, open ground, or other hard-surfaced areas with water.
3. Wash vehicles, unless the Mayor finds that the public health, safety, and welfare are contingent upon frequent vehicle cleaning, such as cleaning of solid waste transfer vehicles, vehicles that transfer food and other perishables, or as otherwise required by law. Exceptions will be required to wash vehicles at establishments that recycle water.

4. Flush water mains, except for water quality concerns or emergency purposes.

The Mayor will consider exemptions on a case-by-case basis for businesses that rely on irrigation for their essential operations, such as nurseries, and if the businesses are willing to implement requested conservations measures.

Additional restrictions and exemptions may be passed as necessary if the above measures to not adequately reduce demands.

Stage 5: Critical Water Shortage

Stage 5 responds to events causing an immediate and sustained loss of the source of supply or major damage to critical treatment, transmission, and pumping systems. Examples include failure of a main transmission line, failure of the intake or WTP, a contamination event in Barney Reservoir or Scoggins Dam (Hagg Lake), natural disaster such as an earthquake, or a malevolent attack on the system that introduces a contaminant at some point in the system.

Under Stage 5, all water use may be prohibited, except water that is necessary for human consumption, fire suppression, and sanitation needs.

The City Council also may activate the City's Emergency Operations Center (EOC) to mobilize sufficient resources to respond to the event(s) causing the need for a Stage 5 action.

If the event renders water in the system unsafe to drink (e.g., chemical spill or intentional act against the system), the EOC will be activated and the Incident Commander will assume command and control of the City's response to the event. As the cause and severity of the event dictates, the Incident Commander will:

1. Implement the appropriate response protocols of the City's ERP for the Beaverton Water System.
2. Contact the Oregon Drinking Water Program, Oregon Health Authority, and request assistance in response actions.
3. Notify the local news media to solicit assistance in notifying customers.
4. Contact county, state, and federal law enforcement officials as appropriate.
5. Contact the County Public Health Officer and local hospitals as appropriate for the nature of the event.
6. Contact the JWC staff and request deployment of the Emergency Water Distribution System.
7. Consider contacting another Oregon Water/Wastewater Agency Response Network agency requesting additional equipment and staff for emergency response operations.

The City will continue to investigate and develop specific backup plans for a Stage 5 emergency. These plans may include purchasing water from another JWC partner agency, directing residents to a pre-designated water distribution location, and supplying bottled water.

Drought Declaration

If a declaration of a severe drought is declared by the Governor per ORS 536.720, the Oregon Water Resources Commission may order political subdivisions within any drainage basin or subbasin to implement a water conservation or curtailment plan or both, approved under ORS 536.780. The conservation and curtailment elements of this WMCP meet these requirements. If the City is within a severe drought area declared by the Governor, such as Washington County, the City will consider whether curtailment measures are needed to meet system demands. Regardless of whether curtailment is needed, the City will encourage customers to conserve water.

Appendix M

Tualatin Valley Water District
Curtailment Plan

Tualatin Valley Water District

The Tualatin Valley Water District (District or TVWD) developed its water supply shortage plan to guide the Board of Commissioners and District staff in the event of a water shortage. Water supply shortage plans (i.e. curtailment plans) outline proactive measures that water suppliers may take to reduce demand and to find alternative supply during short-term water supply shortages. The intent of water curtailment plans is to minimize the impacts of water supply shortages, which may result from incidents such as: prolonged drought, equipment failure in the system, catastrophic events (e.g. flooding, landslides, earthquakes, and contamination), or events not under control of the water supplier (e.g., localized or area-wide power outages and intentional malevolent acts).

The District may undertake a variety of curtailment actions, depending on the time of year and the expected duration of any water supply shortage. Throughout any such shortage, the District will continue to pursue the following objectives:

- Maintain adequate volume of high-quality water supplies for all District customers.
- Provide clear customer communications and rapid customer service. Be consistent with public expectations based on information shared to date.
- Promote water use efficiency.
- Control costs that come with curtailed water use, such as losses in revenue, or higher-cost water supplies (e.g., the purchase of peaking water from the PWB or the lease of extra water from the JWC).
- Have an equitable impact on all users—public and private, urban and suburban, business and residential. Prioritize actions to have the least permanent negative impact.

History of System Curtailment Episodes

OAR 690-086-0160(1)

Assessment of Water Shortages & Limitations

In the past 10 years, the District has not implemented a curtailment stage beyond Stage 1: Summer Advisory, which it routinely implements every year during the summer (peak-demand) season. Nonetheless, the following is a description of earlier curtailment events that were Stage 2 or higher. These events prompted the District to develop an effective conservation program and to diversify its sources of supply.

Drought

Drought has been the principal cause of water shortages and resulting curtailment for the region in recent years.

1992 Drought Affecting the City of Portland

During 1992, PWB and its wholesale customers, including the District, experienced severe water supply shortages for five reasons: (1) the Bull Run watershed, which serves the Portland metropolitan region, had experienced the lowest spring rainfall and stream flows since the year 1899; (2) demand for water during May and June of that year was unusually high due to record-breaking temperatures that occurred in the region; (3) reservoir levels were low, as is typical in the late summer months; (4) the PWB back-up source, the Columbia South Shore wellfield, was unavailable because of concern that a contamination plume would move into the well field aquifer if those wells were used; and (5) voluntary requests to reduce water use were not effective. (Similar shortages also occurred in 1952, 1987, and 1991.)

In response to the severe water supply shortage, the PWB implemented mandatory water restrictions to reduce water use during the peak season. The District, as a wholesale customer of the City of Portland, was subject to the curtailment measures declared by the PWB. In response, the District prepared an ordinance in July 1992, declaring a water source emergency and imposing mandatory water conservation on its customers. The ordinance prohibited lawn watering (except in the case of newly seeded or sodded lawns and parks), washing of hard surfaces such as sidewalks and parking lots, and car washing. Following a warning, penalties for ordinance violations ranged from $100 for the first violation to $500 for repeat violations. The District also purchased water from the JWC to partially offset the reduced supply from the PWB and lessen the severity of water curtailment measures. In addition, the District also activated its three emergency wells and obtained additional water supply from the City of Hillsboro via an emergency connection with that city.

In the aftermath, the District formed a conservation committee and designed and installed a demonstration garden to promote the efficient use of water through innovative landscape design, construction, and maintenance principles. Furthermore, it held landscaping workshops for customers, and participated in the conservation activities of the Columbia-Willamette Water Conservation Coalition, which later merged with the Regional Water Providers Consortium. In addition, the District purchased an ownership interest in the JWC, which provides access to additional water supply from multiple sources.

2001 Drought Affecting the JWC

Refer to the JWC "History of System Curtailment Episodes" at the beginning of this section for a detailed description of this event. The District was able to meet its customers' demands by purchasing additional water from the City of Portland, thereby avoiding the need to ask customers to curtail water usage. Although the District ultimately did not need to curtail water use, this event has been mentioned because it demonstrates the ability of water providers in the region to work cooperatively to avoid curtailment.

Other Events Resulting in Supply Deficiencies

In addition to drought, numerous other events or conditions in the JWC's and PWB's sources of supply could cause the District to experience supply deficiencies. For example, water quality problems in the PWB's Bull Run watershed could reduce supply available to the District. Other conditions that could cause supply deficiencies for the District include requirements of the Endangered Species Act that reduce access to Bull Run water supplies, contamination of the PWB or JWC's water supply sources, long-term interruptions in power supplies, breaks in major transmission lines, or damage to reservoirs as the result of earthquakes or other causes.

Planning for Future Events

In the event of a future water shortage, the District plans to meet its customers' water needs by offsetting the reduced supply with water from another source, accessing its groundwater supply, utilizing emergency interconnections, and implementing curtailment.

Shortage Capability Assessment

OAR 690-086-0160 (1)

As noted above, the District's current capacity limitations are primarily related to major disruptions in its JWC and PWB sources of supply occurring at the same time. Beyond this scenario, the District is well-positioned to meet its non-peak season customer demands for the following reasons (some of which were previously mentioned under the JWC curtailment plan):

- Additional finished water storage
  - Construction of a second JWC Fern Hill Reservoir in 2006. This added an additional 20 MG of finished water capacity to the system for a total of 40 MG.
  - The District consistently follows best management practices and stores three days of average day demand (ADD) in finished water storage in its local distribution system
- Installation of back-up electricity
  - The WTP in cooperation with PGE added a back-up power generator onsite in 2016
- Improvements to water quality treatment
  - The WTP added a powdered activated carbon (PAC) feeder in 2008 to improve treatment of organics
- Seismic reinforcement
  - The JWC's Fern Hill Reservoir 1, was seismically upgraded in 2006.
  - The construction of the second JWC Fern Hill Reservoir included seismic hardening and wrapping with rebar in 2007.
- Additional Water Sources
  - The District's additional source through PWB can reliably meet most all non-peak demands on a temporary basis.

- The District's groundwater and ASR wells can reliably meet a portion of demand on a temporary basis.
- The District has interties with Beaverton, Hillsboro, PWB, and Tigard and can call on these entities for emergency supplies as needed.
- By 2026, the District will have access to the Willamette River though Permit S-54940.

Curtailment Event Triggers and Stages

OAR 690-086-0160(2) and (3)

The District has adopted a four-stage curtailment plan to be invoked in the event of a water supply shortage. These stages are designed to be initiated and implemented in progressive steps. The plan includes both voluntary and mandatory rationing, depending upon the cause, severity, and anticipated duration of the shortage.

Exhibit 1 presents the four curtailment stages, as well as their initiating conditions (i.e. triggers). Curtailment could be initiated by any of the corresponding initiating conditions.

Exhibit 1. Curtailment Stages 1 through 4

Curtailment Stages	Initiating Conditions
Stage 1: Routine Summer Advisory	PWB issues a "notice of drawdown," announcing the release of stored water in the Bull Run System. PWB activates groundwater wells as part of its supplies. Hagg Lake fails to fill 100 percent by May 1. Barney Reservoir fails to fill 100 percent by May 1. The JWC issues a "notice of drawdown," announcing the release of stored water.
Stage 2: Moderate Water Supply Shortage	PWB is operating under a warm-dry scenario [see the example diagram below under Stage 2]. Hagg Lake is filled to less than 80 percent before May 1. District customer use reaches contractual and/or facility capacity for seven consecutive days.

Curtailment Stages	Initiating Conditions
Stage 3: Severe Water Supply Shortage	PWB has only groundwater sources available. PWB cannot meet supply demands of wholesale customers. JWC reservoirs drop below 40 percent of “normal conditions”; under such circumstances JWC enacts mandatory curtailment for its members. Water supplies fail to meet U.S. Environmental Protection Agency Safe Drinking Water Act standards. The District’s distribution system experiences a significant and sustained reduction of water pressure. District customer use reaches contractual and/or facility capacity for 14 consecutive days.
Stage 4: Critical Water Supply Shortage	PWB offloads (i.e. ceases serving) the District from its system and JWC cannot meet the District’s resulting additional demands for water. JWC offloads the District from its system, and PWB supplies cannot meet the District’s resulting additional demands for water. Water supplies from the JWC or the PWB are either physically cut off or otherwise become unavailable. District customer use reaches contractual and/or facility capacity for 28 consecutive days.

Authority

The District’s Chief Executive Officer has the authority to enact the four stages of curtailment.

Enforcement

District field staff will enforce mandatory curtailment measures, if necessary.

Curtailment Plan Implementation

OAR 690-086-0160(4)

Stage 1: Routine Summer Advisory

The District predicts that it will face Stage 1 curtailment initiating conditions each summer as warm dry weather settles into the region and drawdown of the reservoirs begins. Summer water use is much greater than winter use as a result of customers irrigating their landscapes, washing cars, and using water for cooling purposes.

Water Reduction Goal

The goal of Stage 1 curtailment is for each water user to strive to maintain, and not exceed, average summer usage levels.

Triggers (any of these)

Events causing the District to activate Stage 1 curtailment include:

- PWB issues a "notice of drawdown," announcing the release of stored water in the Bull Run System.
- PWB activates groundwater wells as part of its supplies.
- The JWC issues a "notice of drawdown," announcing the release of stored water.
- Hagg Lake fails to fill 100 percent by May 1. (Hagg Lake holds 53,000 acre-feet (17.3 billion gallons).)
- Barney Reservoir fails to fill 100 percent by May 1. (The holds 20,000 acre-feet (6.5 billion gallons).)

During Stage 1 curtailment, the District will implement the following curtailment actions, including providing public messages, taking identified possible actions and working with partner agencies.

Public Message: Voluntary Conservation Measures

- Each summer, the District asks its customers to voluntarily limit water application to 1-inch of water per week for turf areas and less for areas with trees and shrubs.
- The District promotes already-existing conservation messages, such as "Use Water Wisely!" Suggested water conservation measures are posted on the District's Web site.

Possible District Actions

- Partner with Regional Water Providers Consortium and west side providers to send consistent conservation messages to the media.
- Place conservation reminders and tips in Water Words, bill message, and on the District's Web site and conservation hotline. Use various venues to distribute information. Set up public information booths where opportunities exist and look for other opportunities for public outreach, such as speaking engagements, etc.

Partners to Contact

- Work with local agencies to coordinate resources and uniform messages for water customers, and to prepare, review and/or update local water ordinances regarding curtailment enforcement.

Stage 2: Moderate Water Supply Shortage

Stage 2 curtailment may be a temporary condition lasting several days, such as a supply shortage caused by service interruptions in the region. During this time, the District may redirect supplies to areas experiencing shortages. Alternatively, Stage 2 curtailment may be an intermediate stage in an ongoing water supply shortage, such as when regional reservoirs have begun "summer drawdown," with no rain in the forecast.

Water Reduction Goal

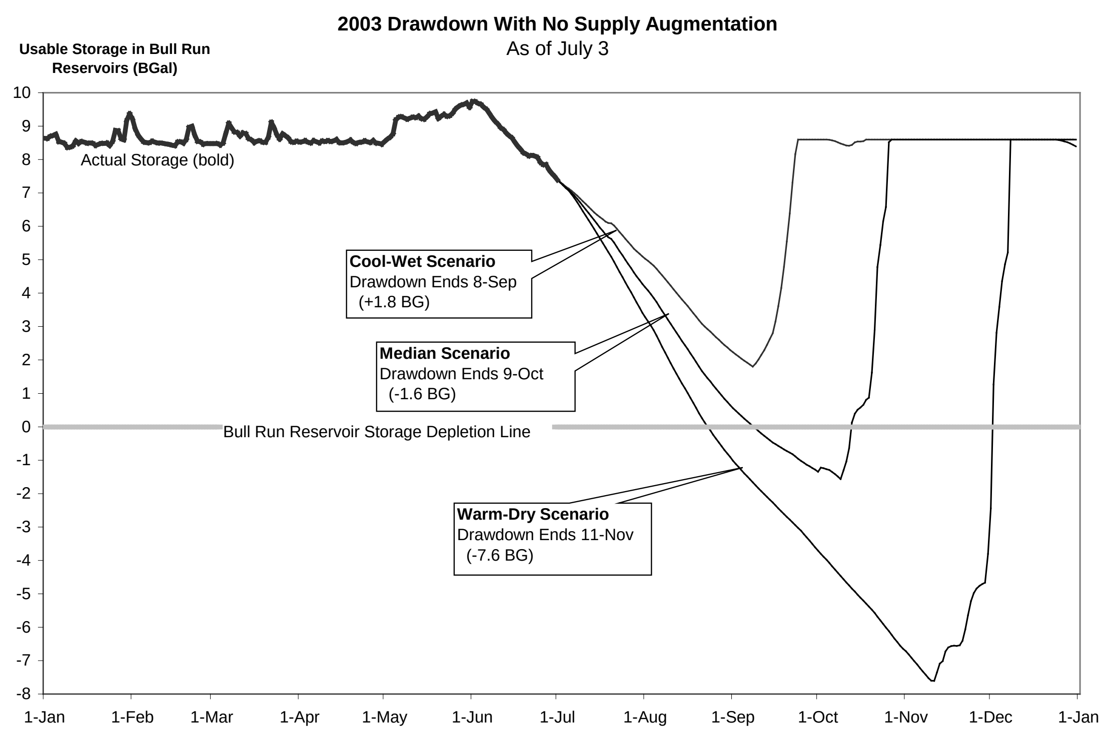
The goal of Stage 2 curtailment is to decrease overall daily water use by 10 percent. Voluntary curtailment use is intended to extend existing water supplies to last throughout the shortage.

Triggers (any of these)

Events causing the District to activate Stage 2 curtailment include:

- PWB is operating under a warm-dry scenario [see Exhibit 2 for an example Reservoir drawdown scenario, which is updated by PWB officials each year].

Exhibit 2. PWB Reservoir Drawdown Scenarios Example



- Hagg Lake fails to fill 80 percent before May 1, which equates to 42,400 acre-feet (or 13.8 billion gallons). The JWC will only make the full allotment available to municipal users if the lake fills to at least 80 percent.
- District customer use reaches contractual and/or facility capacity for seven consecutive days.

In the event of Stage 2 curtailment, the District would take the following curtailment actions.

Public Message: Voluntary Conservation Measures

- The District will provide public messages that describe the following voluntary conservation measures:
- Reduce all water use by 10 percent (as a rule of thumb, for example, residential customers in a four-person single-family household should try to reduce their use by about 20 gallons per household per day during the winter and 27 gallons per household per day during the summer).
- Limit use of water in commercial businesses (e.g., do not serve water to restaurant customers unless specifically requested).
- Reduce watering of lawns, plants, trees, gardens, shrubbery, and flora on private or public property to the minimum necessary. Conduct outdoor watering during early morning hours to reduce evaporation (preferably between 4 and 8 a.m.; must conclude by 10 a.m.).
- Eliminate all other kinds of outdoor water use, including:

  a. Washing down of hard surface areas, decks, buildings, gutters, and vehicles;
  b. Use of water in fountains, reflection ponds, and decorative water bodies for aesthetic or scenic purposes, except where necessary to support aquatic life;
  c. Filling or maintaining private swimming pools (except children's wading pools);
  d. Use of fire hydrants for any purpose other than firefighting or flushing essential to maintain water quality.

Possible District Actions

- Issue a notice to the local media that the District is in a Moderate Water Supply Shortage.
- Send postcard notification of Moderate Water Supply Shortage to District customers.
- Turn off automatic irrigation and water features in the District's Water Efficient Demonstration Garden.
- Provide reminders to non-efficient users (including customers who have been given a 30-day notice to repair one or more leaks and have failed to do so).
- Continue to encourage and educate customers to implement voluntary water conservation.
- Routinely publish in the Beaverton Valley Times, Hillsboro Argus, Tigard Times, and The Oregonian the voluntary conservation measures that the customers are requested to follow during a Moderate Water Shortage.
- Place reminder messages on in Water Words, in the bill messages and on the District Web site, as well as on billboards, signs, bus-sides, and movie theatre ads.

Partners to Contact

- Contact potential institutional partners in water conservation, including local businesses that are the most affected (e.g. landscapers/green industry, commercial carwashes, nurseries, restaurants, water-intensive manufacturers, etc.).
- Ask cities and counties to postpone enforcement of regulations that require the use of water (landscape ordinances, etc.).
- Make conservation presentations to Homeowner Associations (HOAs) and Community Planning Organizations (CPOs).

Stage 3: Severe Water Supply Shortage

Stage 3 curtailment occurs when customers still have time to prepare for and conserve water before a loss of service. Scenarios triggering Stage 3 curtailment include a protracted period of drought (similar to the drought of 1992) or multi-day disruption of service across sections of the District's service territory. Such scenarios may not affect both of the District's water sources equally.

Water Reduction Goal

The goal of Stage 3 curtailment is to decrease overall daily water use by 25 percent. Reduced water use will enable the District to re-direct unaffected water supplies without removing any customers from the system.

Triggers (any of these)

Events causing the District to activate Stage 3 curtailment include:

- PWB has only groundwater sources available.
- The PWB system cannot meet supply demands of wholesale customers.
- JWC reservoirs drop below 40 percent of "normal conditions" and JWC enacts mandatory curtailment for its members.
- Water supplies fail to meet U.S. Environmental Protection Agency Safe Drinking Water Act standards.
- The District's distribution system experiences a significant and sustained reduction of water pressure.
- District customer use reaches contractual and/or facility capacity for 14 consecutive days.

The District may take the following actions in the event Stage 3 curtailment is declared:

Public Message: Mandatory Curtailment Measures

The District will provide public messages that include the following:

- Water is in short supply.
- Reduce all water use by 25 percent (as a rule of thumb, for example, residential customers in a four-person single-family household should try to reduce their use by about 50 gallons per household per day during the winter and 70 gallons per household per day during the summer).
- The District will enforce its Water Supply Shortage Plan.
- Mandatory curtailment actions include:

  a. Eliminate all outdoor water use, including:

     a. Irrigation of established lawns (those at least six weeks old). Exceptions include commercial sod farms, high-use athletic fields that are used for organized play, and daycare providers. Residents may hand-irrigate ornamental plants, flowers, and vegetable gardens during early morning hours to reduce evaporation (preferably between 4:00 a.m. and 8:00 a.m.; must conclude by 10:00 a.m.);
     b. Irrigation of golf courses. District water cannot be used to irrigate fairways or greens on golf courses. Hand watering of ornamental plants and flowers is permitted during early morning hours to reduce evaporation (preferably between 4:00 a.m. and 8:00 a.m.; must conclude by 10:00 a.m.);
     c. Washing down of hard surface areas, decks, buildings, gutters, or vehicles. Wash-down is allowed for sanitary purposes only;
     d. Use of water in ornamental fountains, reflection ponds, and decorative water bodies for aesthetic or scenic purposes, except where necessary to support aquatic life;
     e. Filling or maintaining private swimming pools (except children's wading pools); and
     f. Use of fire hydrants for any purpose other than firefighting or flushing essential to maintain water quality.

  b. Prohibit chemical applications to lawns that require subsequent watering.
  c. Limit expanding commercial nursery facilities, placing new irrigated agricultural land in production, or planting or landscaping except when required by the permitting jurisdiction.
  d. Limit use of water in commercial businesses (e.g., do not serve water to restaurant customers unless specifically requested).
  e. Repair leaks in hoses, faucets, and couplings.

Possible District Actions

- Issue a statement that the District is experiencing a Severe Water Supply Shortage; notify the local media and send postcard notification to District customers.
- Turn off automatic irrigation and water features in the District's Water Efficient Demonstration Garden.
- Cease water service to customers who have been given a 30-day notice to repair one or more leaks and have failed to do so.
- Implement the enforcement provisions of District's Water Supply Shortage Plan.
- Routinely publish in the Beaverton Valley Times, Hillsboro Argus, Tigard Times, and The Oregonian the mandatory restrictions to be placed on the use of water supplied by the District.
- Through the media and public outreach efforts, including door hangers, publicize widely the penalties to be imposed for violations of mandatory restrictions and the procedures to be followed if a variance in the restrictions is requested.
- Place curtailment reminder messages on in Water Words, in the bill message and on the District Web site, as well as on billboards, bus-sides, TV, radio, and movie theatre ads.
- Provide and advertise a conservation hotline that provides relevant curtailment information, such as the reason for the curtailment and information to help customers comply with the curtailment stage policy.
- Update and mail a conservation brochure to customers.

Partners to Contact

- Remind business, industrial, and government (B.I.G.) customers of any letters of cooperation that the District may have signed with them to prepare for Stage 4 curtailment situations.
- Send pre-drafted letter of intent to local jurisdictions (Portland, Tigard, Hillsboro, and Beaverton) to let them know the District plans to begin issuing fines to any of their residents who are not complying with the District's mandatory restrictions.
- Inform landscape/green industry (i.e. landscape and irrigation construction professionals, landscape maintenance service providers, landscape irrigation equipment vendors, the Oregon Landscape Contractors Association, and the Oregon Landscape Contractor's Board) of prohibitions on irrigation and chemical applications that require irrigation.
- Work with Tualatin Valley Parks and Recreation to suspend irrigation of parks where applicable.

- Work with local governments and homeowners associations to temporarily suspend regulations that require the use of water (landscape ordinances, etc.).

Stage 4: Critical Water Supply Shortage

Stage 4 curtailment may be implemented in emergency conditions under which little or no water is flowing to customers (as in the case of natural disasters that result in sudden and acute water loss). It may be necessary for the District to proceed directly to Stage 4, or this stage may be the result of an extended period of time in which demand outstrips supply.

Water Reduction Goal

The goal of Stage 4 curtailment is to decrease overall daily water use by 50 percent or more, and to protect safety, health, and economic livelihood.

Triggers (any of these)

Events causing the District to activate Stage 4 curtailment include:

- Portland “offloads” (i.e. ceases serving) the District from its system and JWC cannot meet the District’s resulting demands for water.
- JWC “offloads” the District from its system, and the PWB cannot meet the District’s additional water demands.
- Water supplies from JWC or PWB are either physically cut off or otherwise become unavailable to the District.
- District customer use reaches contractual and/or facility capacity for 28 consecutive days.

Public Message: Mandatory Curtailment Measures

The District will provide its customers with public messages about the following mandatory curtailment measures:

- Water may be used for drinking, cooking, and sanitation purposes only.
- Reduce all water use by 50 percent (as a rule of thumb, for example, residential customers in a four-person single-family household should try to reduce their use by about 100 gallons per household per day during the winter and 140 gallons per household per day during the summer).
- Eliminate use of water at construction sites.
- Enforcement of the District’s Water Supply Shortage Plan including issuance of fines.

Possible District Actions

- Issue a statement that the District is experiencing a Critical Water Supply Shortage.

- Issue media releases.
- Continue to enforce Water Supply Shortage Plan with warnings, fines, and discontinued service if necessary.
- Place reminder messages in Water Words, in the bill message and on the District Web site, as well as on billboards, bus-sides, TV, radio, and movie theatre ads.
- Provide and advertise conservation hotline.
- If necessary, conduct the following emergency actions:

  a. Activate the District's Emergency Operations Center (EOC).
  b. Begin rationing water as needed.
  c. Activate any curtailment agreements previously negotiated with B.I.G. customers.
  d. Open interconnections with neighboring water suppliers.
  e. Bring emergency wells on-line.
  f. Declare emergency (per District Purchasing Policy) to allow suspension of the normal bidding process.
  g. Place a moratorium on all new water service connections and new water main extensions. Provide notice to developers of the moratorium.

- Work with partners to distribute bottled water as needed.

Partners to Contact

- Ask Tualatin Valley Fire & Rescue Fire Marshal to issue statement banning burning or construction (because these activities are possible fire hazards).
- Notify CII customers of the District's intention to activate any previously agreed upon curtailment arrangements.
- Inform developers of the moratorium on all new water service connections and water main extensions.
- Notify and work with neighboring water providers.
- Activate partnerships with bottled water manufacturers, National Guard, Red Cross or other water distributors, if needed.

Contact the Washington County Office of Consolidated Emergency Management for additional resources, as needed.

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