WATER MASTER PLAN UPDATE

CITY OF HILLSBORO WATER DEPARTMENT
HILLSBORO, OREGON

Final Report: Emergency Management / Seismic Resilience

October 18th, 2018
Revised March 18th, 2019
SEFT Project Number: B17006.00

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Table of Contents

List of Figures

List of Tables

1.0 Introduction and Background

1.1 HWD Water System Description

The City of Hillsboro Water Department (HWD) water system is divided into two interconnected subsystems. The City System uses approximately 250 miles of distribution line to provide water to over 24,000 business and residential customers within the Hillsboro city limits and west of Cornelius Pass Road [two areas in the northeast corner of the city are served by Tualatin Valley Water District (TVWD)]. The primary water supply for the City System is the Joint Water Commission (JWC) Treatment Plant which is feed by the Tualatin River and Hagg Lake. The Upper System provides water for Cherry Grove, the City of Gaston, the LA Water Cooperative, Scoggins Valley, and Dilley. The primary water supply for the Upper System is the HWD owned and operated Cherry Grove Slow Sand Water Treatment Plant (SSWTP) which is feed by the Tualatin River and Barney Reservoir. The City of Cornelius is also a wholesale customer of HWD and is supplied directly from a JWC transmission line. The current combined average day demand for both systems is approximately 17.5 million gallons per day (MGD) and summertime demands can increase to approximately 33 MGD.

1.2 Resilience Component of Water Master Plan Update

For the past several years HWD has been taking proactive steps to minimize the impact that a major earthquake will have on the HWD water system (e.g., use of restrained joint ductile iron pipe, seismic retrofit of existing reservoirs, etc.). As part of the current Water Master Plan (WMP) update, HWD has included an evaluation of the current level of seismic resilience of the HWD water system and development of recommendations for improved seismic resilience and emergency management. The objectives of this resilience assessment include:

1. Define water system level of service (LOS) goals for both the City and Upper Systems following a major seismic event;
2. Identify key backbone system components that are required to achieve these LOS goals;
3. Define performance criteria for individual system components that are required to achieve these LOS goals;
4. Conduct a limited geotechnical (Shannon & Wilson), pipeline (HDR), and structural/nonstructural (SEFT) vulnerability assessment (focused on City System backbone piping, reservoirs, pump stations, and PRV vaults but also including the Dilley Reservoir in the Upper System) to determine estimated system performance following a major earthquake;
5. Identify gaps between the LOS goals and current performance estimates; and

6. Develop recommendations to close these gaps utilizing new or retrofit infrastructure, changes to design standards, and enhancements in emergency response planning.

This report presents the recommendations related to Objectives 1 through 3 and structural/nonstructural observations and recommendations related to Objectives 4 through 6.

1.3 Resilience Planning by Other Metro Region Agencies

The resilience planning effort being undertaken by HWD is similar to the planning activities undertaken by several Portland metro region agencies. Additionally, numerous other agencies on the west coast of the United States and Canada are actively conducting resilience planning and resilience-based capital improvement projects.

Tualatin Valley Water District and Willamette Water Supply Program

TVWD has completed a water system resilience plan and is partnering with the City of Hillsboro to complete the billion-dollar Willamette Water Supply Program (WWSP) to provide an additional water supply for the region. When complete, the WWSP will greatly enhance the ability of HWD to deliver water to its customers immediately after a major earthquake by providing a resilient and reliable water supply for the region, designed to meet stringent seismic performance goals.

Clean Water Services

Clean Water Services is currently conducting a resilience planning project for the Rock Creek Advanced Wastewater Treatment Facility. One significant portion of the project has been to translate the percentage restoration goals presented in the *ORP* into specific, quantifiable treatment process based goals for the facility.

City of Portland

The Portland Water Bureau has completed a water system resilience planning project and is beginning to incorporate recommendations from the plan into their capital improvement projects. The Bureau of Environmental Services is wrapping up a wastewater system seismic resilience master plan and has already begun to incorporate early action item recommendations into practice.

City of Gresham

The City of Gresham has completed a water system resilience planning project and is beginning to incorporate recommendations from the plan into their capital improvement projects. Based on the recommendations of the *ORP* and the success of the water system resilience planning effort, the City of Gresham is currently developing a wastewater system resilience plan.

2.0 Community Resilience

Events like Hurricane Katrina in 2005, the Great East Japan M9.0 Earthquake and Tsunami in 2011, and Hurricane Sandy in 2012 have underscored the devastating impacts that natural disasters can inflict at a local, regional, state, and multi-state level. The Federal government has defined the National Preparedness Goal as: “A secure and resilient Nation with the capabilities required across the whole community to prevent, protect against, mitigate, respond to, and recover from the threats and hazards that pose the greatest risk” (FEMA, 2015).

One strategy to achieve this National Preparedness Goal is to plan for and implement programs and strategies to improve disaster resilience at the local, regional, state, and national level. Oregon is a national leader in community resilience. In February of 2013, the Oregon Seismic Safety Policy Advisory Commission submitted a report to the 77th Legislative Assembly entitled the *Oregon Resilience Plan: Reducing Risk and Improving Recovery for the Next Cascadia Earthquake and Tsunami* (OSSPAC, 2013). The report discussed the risk that is faced by the citizens of Oregon from an impending Cascadia Subduction Zone earthquake and accompanying tsunami, and the gaps that exist between the current state of Oregon’s infrastructure and where it needs to be. In addition to life safety impacts, the report also highlighted the economic vulnerabilities to individuals and communities from such an event. The *ORP* went on to outline steps that can be taken over the next 50 years to bring the state closer to resilient performance through a systematic program of vulnerability assessments, capital investments in public infrastructure, new incentives to engage the private sector, and policy changes that reflect current understanding of the Cascadia threat. While the *ORP* specifically addresses improving resilience in the aftermath of a major earthquake, implementation of the plan is also expected to improve resilience for other hazards.

A primary focus of the *ORP* goals is to minimize the long-term economic damage associated with the potential out-migration of businesses and population that would be expected to occur following a major disaster if basic services cannot be restored rapidly enough to meet the communities social and economic needs. Resilience of the water system will be key to the region’s economic recovery. For example, the fundamental goal of quickly restoring the supply of safe drinking water to homes and businesses will help to enable residents to shelter-in-place and businesses to resume operation as quickly as possible after the event. Small businesses are particularly vulnerable to being closed for an unplanned amount of time and many may not be able to re-open if closed for more than a month. Each business closing negatively impacts employment, tax revenue, and the long-term economic and social viability of the City. The more rapidly that business are able to reopen, the quicker revenue will normalize, and money will circulate within the region’s economy. At a fundamental level, the water system must be functioning at a certain level for service fees to be collected to provide revenue for HWD to sustain everyday functions and to help fund the recovery process.

2.1 Definition

In the field of community disaster planning, a common definition of "resilience" has been put forth by Presidential Policy Directive (PPD). PPD-8 [2011] defines resilience as "the ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies." PPD-21 [2013] refined the definition to "…the ability to prepare for and adapt to changing conditions and to withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents."

2.2 Planning Process

While varied forms of community disaster preparedness planning have been taking place for decades, a specific focus on community resilience has developed over about the last 10 years. In 2015, the National Institute of Standards and Technology (NIST) published NIST Special Publication 1190, *Community Resilience Planning Guide for Buildings and Infrastructure Systems* (NIST, 2015). The *Guide* outlines a consistent framework for a six-step resilience planning process (see Figure 2.1) that is designed to be conducted at a community level, involving broad representation from local and regional government, building owners, infrastructure system owner/operators, and community representatives. The *Guide* process can also be adapted to resilience planning for a specific infrastructure system (e.g. water system), with some limitations. One of the main limitations of an individual infrastructure system planning approach is that it requires assumptions to be made that can't be tested with community stakeholders and other infrastructure system providers. For instance, operation of water pump stations requires commercial electrical power or emergency generators with adequate fuel supplies. The timeline for restoration of commercial electrical power or availability of fuel for generators is largely controlled by stakeholders that aren't involved in a water system only planning scenario.

2.3 Seismic Hazard

One of the initial steps in the resilience planning process involves determining the specific hazards to be safeguarded against. HWD has selected a M9.0 Cascadia Subduction Zone scenario earthquake as the hazard to be explicitly considered in development of resilience recommendations associated with the WMP update.

The geologic and seismologic information available for identifying the potential seismicity throughout the State of Oregon is continually evolving, and large uncertainties are associated with estimates of the probable magnitude, location, and frequency of occurrence of earthquakes. The available information indicates the potential seismic sources that may affect the state can be grouped into three categories:

- Subduction zone events related to sudden slip between the upper surface of the Juan de Fuca plate and the lower surface of the North American plate,

- Subcrustal events related to deformation and volume changes within the subducted mass of the Juan de Fuca plate, and
- Local crustal events associated with movement on shallow, local faults.

A major contributor to the seismic hazard in western Oregon is the Cascadia Subduction Zone (CSZ) that lies off the coast of Oregon, Washington, Northern California, and British Columbia. The CSZ is an active plate boundary along which the remnants of the Farallon Plate (the Gorda, Juan de Fuca and Explorer plates) are being subducted beneath the western edge of the North American continent. Figure 2.2 shows that the subduction zone off the coast of Oregon is a mirror image of the subduction zone off the coast of Northern Japan that produced the deadly Magnitude 9.0 Tohoku earthquake in 2011. Seismologists anticipate that the strong shaking from a CSZ earthquake will last from 3 to 5 minutes, much longer than the 30-second strong shaking experienced in a typical California earthquake.

Seismologists' understanding of the damaging earthquakes produced by the CSZ has steadily increased over the past 25 years. Research by the Oregon Department of Geology and Mineral Industries (DOGAMI), Oregon State University, and others has provided evidence of the timeline of historic great CSZ earthquakes. The timeline of these 41 earthquakes over the last 10,000 years is provided in Figure 2.3, showing that past earthquakes have occurred at highly variable intervals, and can range widely in size and in which parts of the Pacific Northwest they affected. The rupture distance for these CSZ earthquakes varies from a short rupture along the Northern California and Southern Oregon Coast, to a rupture along the entire length of the subduction zone from Northern California to British Columbia. There is about a 37 percent chance in the next 50 years of a Magnitude 8+ earthquake originating on the southern portion of the CSZ and up to a 15 percent chance in the next 50 years of a great earthquake affecting the entire Pacific Northwest. The scenario involving rupture of the Northern Oregon portion would significantly impact all Western Oregon, including Hillsboro.

SIX-STEP PROCESS TO PLANNING FOR COMMUNITY RESILIENCE

1. FORM A COLLABORATIVE PLANNING TEAM

- Identify leader
- Identify team members
- Identify key stakeholders

2. UNDERSTAND THE SITUATION

Social Dimensions

- Characterize social functions & dependencies
- Identify support by built environment
- Identify key contacts

Built Environment

- Identify and characterize built environment
- Identify key contacts
- Identify existing community plans

Link Social Functions & Built Environment

- Define clusters

3. DETERMINE GOALS & OBJECTIVES

- Establish long-term community goals
- Establish performance goals
- Define community hazards
- Determine anticipated performance
- Summarize results

4. PLAN DEVELOPMENT

- Evaluate gaps
- Identify solutions
- Develop implementation strategy

5. PLAN PREPARATION, REVIEW, AND APPROVAL

- Document plan and strategy
- Obtain feedback and approval
- Finalize and approve plan

6. PLAN IMPLEMENTATION AND MAINTENANCE

- Execute approved solutions
- Evaluate and update
- Modify strategy as needed

Figure 2.1 – Six-Step Process to Planning for Community Resilience (NIST, 2015)

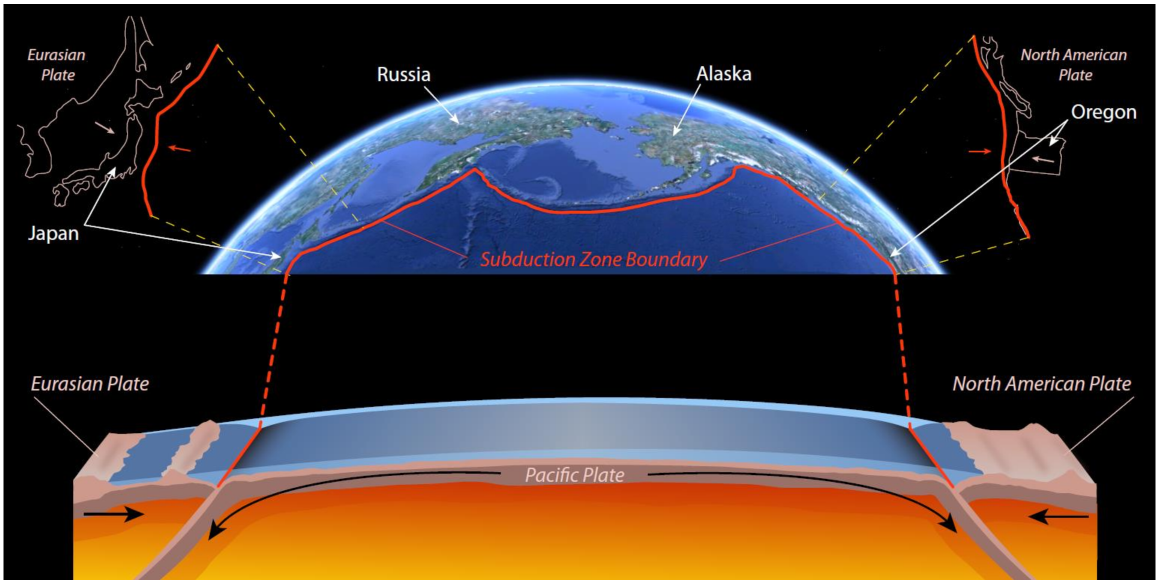
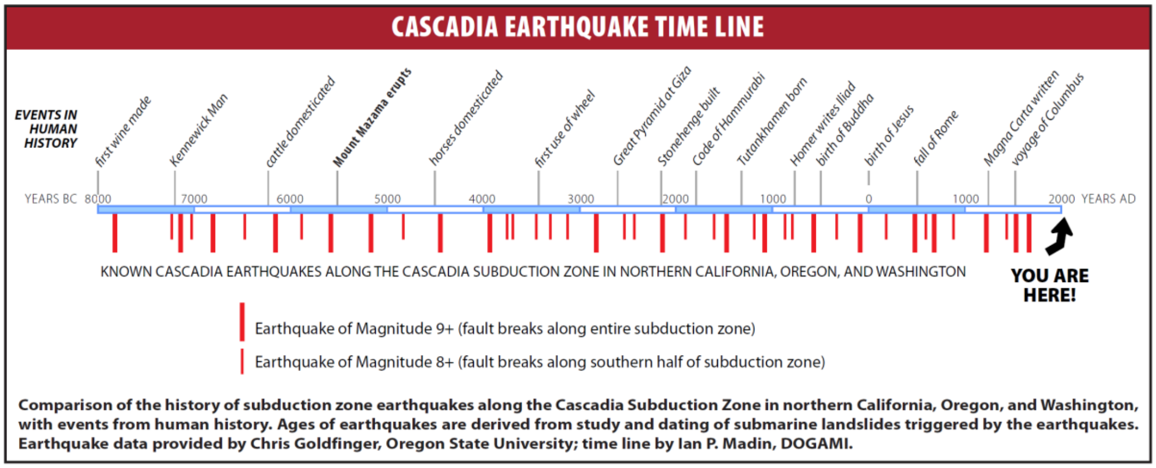


Figure 2.2 – Oregon and Northern Japan Mirror Image Subduction Zones (OSSPAC, 2013)



Comparison of the history of subduction zone earthquakes along the Cascadia Subduction Zone in northern California, Oregon, and Washington, with events from human history. Ages of earthquakes are derived from study and dating of submarine landslides triggered by the earthquakes. Earthquake data provided by Chris Goldfinger, Oregon State University; time line by Ian P. Madin, DOGAMI.

Figure 2.3 – Historic Cascadia Subduction Zone Earthquake Timeline (DOGAMI, 2010)

3.0 Level of Service Goals

Resilience planning involves establishing level of service (LOS) goals to define system performance expectations after being impacted by the hazard under consideration. These LOS goals could be simple, such as maintain service for 100 percent of customers during a routine winter storm that disrupts commercial electrical power for 24 hours, or they may be more complex for more damaging hazards like major earthquakes. This section presents examples of LOS goals included in other plans and then describes the LOS goals suggested for adoption by HWD.

3.1 SPUR Resilient City

In one of the first studies of its kind, the San Francisco Planning + Urban Research Association (SPUR) developed a series of policy papers aimed at raising awareness of how San Francisco's buildings and lifeline infrastructure are likely to perform in an expected earthquake and identifying actions that could be implemented before an earthquake to improve the City's resilience. The report outlined the importance of how the restoration timeline for water, wastewater, electrical power, and other lifeline systems impacts the speed with which a community can return to normal after a major disruption (SPUR, 2009). The report established the goals of restoring lifeline services to: 1) 90 percent of customers within 72 hours, 2) 95 percent of customers within one month, and 3) 100 percent of customers within four months after an expected level earthquake. It is assumed that critical facilities (e.g., hospitals, emergency operations centers, etc.) would be included in the 90 percent of customers restored within 72 hours. For buildings, the SPUR report defines the expected level earthquake as one having a 10 percent probability of occurring in a 50-year period and compares it to a magnitude 7.2 earthquake on the peninsula segment of the San Andreas Fault. The SPUR report also indicated that for lifeline systems, that typically have a longer design life than buildings, a larger expected level earthquake should be considered.

3.2 Oregon Resilience Plan

The threat of a Cascadia earthquake is a significant enough physical, economic, and social risk in the Pacific Northwest that in 2012 and 2013, at the request of the State of Oregon Legislative Assembly, the Oregon Seismic Safety Policy Advisory Commission (OSSPAC) and a team of volunteer professionals developed the *Oregon Resilience Plan: Reducing Risk and Improving Recovery for the Next Cascadia Earthquake and Tsunami* (OSSPAC, 2013). The *ORP* outlines steps that can be taken over a 50-year period to bring the state closer to resilient performance through a systematic program of vulnerability assessments, capital investments in buildings and infrastructure systems, new incentives to engage the private sector, and policy changes that reflect current understanding of the Cascadia threat to our community and economy.

OSSPAC assembled eight task groups, comprising over 160 volunteer subject-matter experts from government, universities, the private sector, and the general public. Task Groups included: (1) Cascadia earthquake scenario, (2) business and workforce continuity, (3) coastal communities, (4) critical and essential buildings, (5) transportation, (6) energy, (7) information and communications, and (8) water and wastewater. Task Group activities were overseen by OSSPAC and an Advisory Group. Each Task Group was charged to:

- Determine the likely impacts of a Magnitude 9.0 Cascadia earthquake and tsunami on its assigned sector, and estimate the time required to restore functions in that sector if the earthquake were to strike under present conditions;
- Define acceptable timeframes to restore functions after a future Cascadia earthquake to fulfill expected resilient performance; and
- Recommend changes in practice and policies that, if implemented during the next 50 years, will allow Oregon to reach the desired resilience targets.

The various task groups used estimates of the seismic hazard and expected ground motions developed by the Cascadia Earthquake Scenario Task Group in combination with knowledge of the construction era and condition of existing infrastructure to estimate the expected performance and service restoration times if the scenario event were to occur at the time the *ORP* was being developed.

The *ORP* used the SPUR model as a starting point for developing LOS goals (target timelines for restoration of services) after a Cascadia earthquake. These restoration targets were established assuming system resilience enhancements would be implemented over the following 50 years. These targets were set for three levels of service:

- Minimal level of service restored for the use of emergency response;
- Functional level of service up to 50 percent of capacity that is sufficient to get the economy moving again, and an
- Operational level of service where restoration is up to 90 percent of capacity (which may still rely on temporary fixes).

Table 3.1 summarizes the *ORP's* goals for the restoration of water service for the Willamette Valley (after 50 years of resilience improvements) and compares it to the expected performance if the earthquake were to have occurred at the time the *ORP* was written. The time differences between the *ORP* restoration target (LOS) goal and expected performance illustrates the resilience gaps that require investment in infrastructure improvements, and public policy enhancements over the coming years.

Table 3.1 – ORP Water System Recovery Goals: Valley Zone (adapted from OSSPAC 2013)

	0-24 hours	**1-3 days**	**3-7 days**	**1-2 weeks**	**2-4 weeks**	**1-3 months**	**3-6 months**	**6-12 months**	**1-3 years**	**3+ years**
Potable water available at supply source (WTP, wells, impoundment)	R	Y		G			X			
Main transmission facilities, pipes, pump stations, and reservoirs (backbone) operational	G					X				
Water supply to critical facilities available	Y	G				X				
Water for fire suppression – at key supply points	G		X							
Water for fire suppression – at fire hydrants			R	Y	G			X		
Water available at community distribution centers/points		Y	G	X						
Distribution system operational		R	Y	G				X		

Key to Table

Target Timeframe for Recovery:

Desired time to restore components to 20-30% operational	R
Desired time to restore components to 50-60% operational	Y
Desired time to restore components to 80-90% operational	G
Current state (90% operational)	X

3.3 NIST Community Resilience Planning Guide

The authors of the NIST *Guide* built upon the framework established by SPUR and the *ORP* in developing recommendations for community resilience planning. The categories, for which restoration timeline goals should be set, were further expanded to consider additional system components and to clarify that restoration timelines will likely vary based on the building cluster that is being supported (critical facilities, emergency housing, housing/neighborhoods, etc.). The *Guide* does not make recommendations for recovery timelines but provides a framework that communities can use to collectively establish these recovery timeline goals. The expanded *Guide* performance goal table along with the restoration timeline goals established by the *ORP* have been used in developing level of service goals for this project. Further description of the recommended HWD water system level of service goals developed as part of this project is provided in Section 3.6.

3.4 San Francisco Public Utilities Commission

The San Francisco Public Utilities Commission (SFPUC) outlines seismic design requirements in an agency specific engineering standard, *General Seismic Requirements for Design of New Facilities and Upgrade of Existing Facilities* (SFPUC, 2014). The purpose of the Standard is "to set forth consistent criteria for the seismic design and retrofit of San Francisco's water and wastewater infrastructures. These systems comprise buildings, aboveground and underground piping, retaining walls, underground structures, tanks and basins, dams and reservoirs, special structures, and equipment under the jurisdiction of the SFPUC."

The SFPUC Standard establishes that the water system basic level of service goal is to deliver winter day demand (WDD) within 24 hours after a major earthquake. For critical and non-redundant structures and components, this major earthquake is defined as having a 5% probability of exceedance in 50 years (975-year return period). The basic level of service goal also considers several supplemental criteria that include (SFPUC, 2014):

- Deliver WDD to at least 70% of SFPUC wholesale customers' turnouts within each of the three customer groups;
- Achieve a 90% confidence level of meeting the above goal, given the occurrence of a major earthquake;
- To achieve the basic level of service, the SFPUC shall rely on the wholesale customer's own water systems and supply or other regional water purveyor's systems. SFPUC will work with customers to assess their ability to contribute to their own system reliability;
- The SFPUC shall consider a facility to have failed if it cannot be brought back to its intended purpose within 24 hours without secondary damage resulting; and
- To achieve the basic level of service, the SFPUC shall assume that power supplies are available, whether from the grid or from standby sources.

The SFPUC shall assume that no significant repairs are performed in the first 24 hours following a major earthquake. Possible operations that might occur during the first 24 hours include valve operations, temporary bypasses, and restoration of minor planned outages, if regional infrastructure remains intact.

3.5 Community Needs Following a Major Earthquake

To support the region's economic and community recovery after a major disaster, infrastructure services are required to be restored as the building clusters that rely on these services come back online (i.e., a building that will take six months to reopen due to repair of structural damage doesn't need water service until the end of that six months). In some cases, like that for smaller businesses, an outage of critical services like water for more than a few weeks may mean a business cannot return to a location. The current expectation of many Oregonians is that water service will be restored within one month after a major earthquake (City Club, 2017). The water system recovery goals suggested in the *ORP* are generally consistent with this public expectation. The *ORP* also sets goals for partial recovery in the initial days and weeks after a major earthquake with the aim of supporting rapid economic and social recovery.

Given that it would be cost prohibitive to eliminate all earthquake damage, a fundamental short-term community need will be to provide water for fire suppression and for use by hospitals, emergency shelters, jails, and other similar facilities. Immediately after the event, it is anticipated that HWD will focus on repairing any damage to the distribution system supplying these critical customers and then quickly transition to restoring water service to other customers. This goal for rapid restoration of the water service will help support the Hillsboro Community's desire that residents will be able to shelter-in-place in their homes immediately after a major earthquake and that they will be able to resume a semi-normal daily routine after two to four weeks by returning to school/work, shopping at their local grocery store, receiving medical care at their local clinic, etc. All these normal activities involve the use of water. At first it is expected that temporary measures will be required to distribute water, but as the weeks progress more permanent fixes will be implemented and the temporary measures will slowly disappear.

Table 3.2 provides a breakdown of restoration priorities for City System customers that was jointly developed in a collaborative workshop conducted with the HDR team and HWD staff. The table links social/economic needs to restoration timeline goals [short-term (no disruption), short-term (1-3 days), intermediate-term (within 4 weeks), and long-term (months)]. Several of these social/economic needs are related to continuity of county government, since Hillsboro is the county seat for Washington County. Table 3.3 provides a similar breakdown of restoration priorities for Upper System customers.

Table 3.2 – City of Hillsboro Social/Economic Recovery Goals: City System

Response/Recovery Phase	Social/Economic Needs
Short-Term (no disruption)	• Water for fire suppression at key supply points • Tuality Community Hospital • Wholesale customers
Short-Term (1-3 days)	• City of Hillsboro/Washington County EOC • Police/Sherriff stations • Fire stations • Emergency shelters • Hillsboro Stadium • Shute Park • Hillsboro Libraries • Community water distribution points • Hillsboro Airport • Clean Water Services (pump seal water) • State of Oregon DEQ Environmental Quality Lab and Public Health Lab • Washington County Jail
Intermediate-Term (within 4 weeks)	• City of Hillsboro/Washington County facilities • Hillsboro School District • Medical office buildings • 90% of customer connections • 90% of fire hydrants
Long-Term (months)	• Remaining 10% of customer connections • Remaining 10% of fire hydrants

Table 3.3 – City of Hillsboro Social/Economic Recovery Goals: Upper System

Response/Recovery Phase	Social/Economic Needs
Short-Term (no disruption)	• Water for fire suppression at key supply points • Wholesale customers
Short-Term (1-3 days)	• EOCs • Police stations • Fire stations • Emergency shelters • Community water distribution points
Intermediate-Term (within 4 weeks)	• Municipal service facilities • School facilities • Medical office buildings • 90% of customer connections • 90% of fire hydrants
Long-Term (months)	• Remaining 10% of customer connections • Remaining 10% of fire hydrants

3.6 HWD Level of Service Goals

The *ORP* was developed assuming a three-tiered LOS goal approach to implement a phased restoration of services and help define the speed of recovery for a community's infrastructure systems. The *ORP* recommended a timeline for these three-tiered LOS goals but provided the flexibility for an individual utility to define how the levels of functional restoration are to be achieved for their specific system. The LOS (i.e., restoration timeline) goals proposed for adoption by HWD align with those presented in the *ORP* and are augmented by additional considerations suggested by the NIST *Guide*. Table 3.4 summarizes these goals for the HWD water system and the desired LOS goals for Joint Water Commission (JWC) treatment and transmission infrastructure. (Note that coordination of these LOS goals with JWC member agencies was outside the scope of this project.) The table provides additional information about the definition of what 30%, 60%, and 90% operational has been assumed to translate to for HWD water system infrastructure. For example, the 90% operational goal for hospital facilities has been defined to mean that the HWD distribution system is capable of delivering 90% of the winter day demand to hospital facilities within the HWD service area.

Table 3.4 – City of Hillsboro Water System Recovery Goals (adapted from OSSPAC 2013 and NIST 2015)

Water Systems	Target Timeframe for Recovery							
	Phase 1: Short-Term			Phase 2: Intermediate			Phase 3: Long-Term	
	Days			Weeks			Months	
	0-1	1-3	3-7	1-2	2-4	4-12	3-6	6-12
Source (HWD goal for JWC system, not necessarily adopted by JWC)								
Raw or source water and terminal reservoirs	30% WDD[a]	60% WDD		90% WDD				
Raw water conveyance (pump stations and piping to WTP)	30% WDD	60% WDD		90% WDD				
Water Production	30% WDD	60% WDD		90% WDD				
Well and/or Treatment operations functional	30% WDD	60% WDD		90% WDD				
Transmission (HWD goal for JWC system, not necessarily adopted by JWC)								
Backbone transmission facilities (pipelines, pump station, and tanks)	90% WDD							
Water for fire suppression at key supply points (to promote redundancy)	90% of required fire flow and duration available							
Control Systems								
SCADA and other control systems	90% of components required for normal operation are functional							
Distribution								
Critical Facilities								
Wholesale Users (other communities, rural water districts)	90% of WDD							
Hospitals	90% of WDD							
EOC, Police Stations, Fire Stations	60% of WDD	90% WDD						
Emergency Housing								
Emergency Shelters	60% of emergency water for drinking/sanitation	90% of emergency water for drinking/sanitation						
Housing/Neighborhoods								
Potable water available at community distribution centers		60% of emergency water for drinking/sanitation	90% of emergency water for drinking/sanitation					
Water for fire suppression at fire hydrants			30% of hydrants restored	60% of hydrants restored	90% of hydrants restored			
Community Recovery Infrastructure								
All other clusters			30% of customer connections restored	60% of customer connections restored	90% of customer connections restored			

[a] WDD = Winter Day Demand

Key to Table

Desired time to restore components to 30% operational	R
Desired time to restore components to 60% operational	Y
Desired time to restore components to 90% operational	G

4.0 HWD Backbone System Supporting Short-Term Community Needs

Satisfying short-term LOS restoration timeline goals requires critical components of the water treatment, transmission, and distribution system to remain operational or experience only minor damage after a major earthquake. These critical system components usually include: small diameter distribution pipelines and associated reservoirs/pump stations that connect to critical and essential facilities (hospitals, emergency shelters, etc.), large diameter transmission pipelines and associated pump stations, treatment plant structures, and certain support facilities (laboratories, maintenance shops, etc.). If an assessment of these critical system components reveals any gaps between the expected performance and that required to achieve the LOS goals, then these deficient components should be seismically retrofit or replaced, as appropriate.

The HDR team has collaborated with HWD to identify the proposed backbone for the City System shown in Figure 4.1. The backbone system provides water distribution system connections between the JWC transmission lines, HWD reservoirs and pump stations, and HWD distribution system pipelines that serve the facilities that are required to meet short-term community needs (see Table 3.2). The seismic resilience of the City System is greatly enhanced by redundancy in the distribution pipeline network and the fact that the majority of City customers can be supplied by either the JWC North Transmission Line (NTL) or South Transmission Line (STL).

The JWC treatment plant and transmission lines are also part of the backbone system that is required to enable HWD to deliver water to meet short-term community needs after a major earthquake but have not been included in the scope of this resilience study. When it comes online in 2026, the Willamette Water Supply Program (WWSP) raw water intake pump station, raw water transmission line, treatment plant, and finished water transmission line should also be considered as part of the backbone system for delivering water to HWD customers after a major earthquake. WWSP infrastructure is being designed to achieve 50% capacity within 48 hours after the 2,475-year return period event (WWSP, 2018), so the WWSP infrastructure will be able to reliably deliver water to interconnection points on the east side of the HWD City System (see Figure 4.1) after the M9.0 CSZ earthquake considered in this resilience assessment.

The backbone for the Upper System consists of the following components:

- Headworks Intake and Diversion Structures;
- Sedimentation Basin;
- Raw water transmission line between Diversion Structure, Sedimentation Basin, and Cherry Grove Slow Sand Water Treatment Plant;
- Cherry Grove Slow Sand Water Treatment Plant (SSWTP);
- 18” diameter transmission main between the SSWTP and Forest Grove; and
- Dilley Reservoir.

The backbone systems proposed for the HWD City System and Upper System are consistent with those envisioned during the development of the *ORP*. The backbone includes elements of the water system that are required to meet short-term LOS restoration timeframe goals in the initial days after a major earthquake. Since it would be challenging to implement any significant repairs to the backbone system in the initial days after an earthquake, the elements of the backbone system should be designed or retrofit such that they experience only minor or no geotechnical, structural, and nonstructural related damage during a major earthquake.

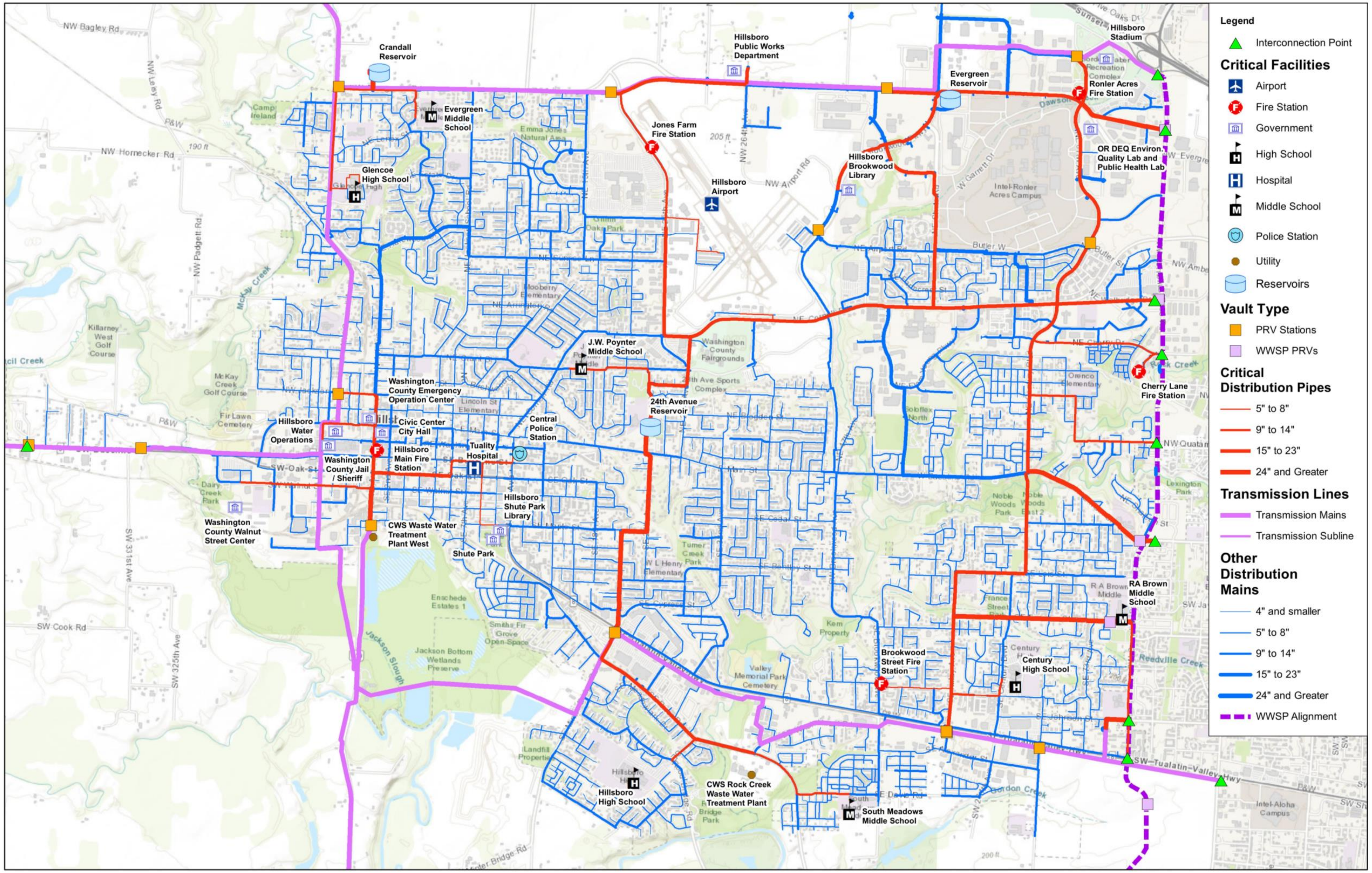


Figure 4.1 – City System Backbone

5.0 Translation of Level of Service Goals into System Performance Requirements

Several factors need to be taken into consideration when translating HWD LOS goals into performance requirements for the seismic design or retrofit of water system components. Section 5.1 describes several of the factors that have been considered in developing the recommended general performance requirements detailed in Section 5.2.

5.1 Considerations

The following subsections describe factors considered in developing performance requirements for the various components of the HWD water system. These factors should also be evaluated on a project-specific basis to determine if there are any unique features of the project that require modification of the general performance requirements.

5.1.1 Geotechnical Hazards

Observations from past earthquakes have indicated that geotechnical hazards are a major contributing factor to the expected post-earthquake performance of water systems. Infrastructure that is exposed to liquefaction, lateral spreading, or landslide geotechnical hazards requires special design considerations that include either mitigation measures to address the geotechnical hazard or predetermined work-arounds to bypass components that may fail during an earthquake. Water treatment plants can be particularly vulnerable to damage from earthquake-induced liquefaction and lateral spreading because these facilities are often constructed in low-lying areas near water sources. These areas correspond with those at high risk for liquefaction and lateral spreading. Transmission and distribution piping that crosses creeks our other low-lying areas are also particularly vulnerable to damage from earthquake-induced liquefaction and lateral spreading.

5.1.2 Effects of Aftershocks

Major earthquakes are often accompanied by numerous aftershocks. In the 2011 Tohoku Japan earthquake two major aftershocks caused additional damage to infrastructure systems, resulting in relapses in the number of customer outages (Nojima, 2012). It may be necessary to reevaluate system components or perform additional repairs after major aftershocks.

5.1.3 Repair Difficulty

Certain water system components (like large diameter transmission mains) may be very difficult to repair after an earthquake. If a component is anticipated to be difficult to repair and it is also important to system performance, then it should be designed to minimize any potential earthquake damage that would impact the functionality of the component. Other assets of this type could include pipes under railroad tracks or highways.

5.1.4 Availability of City of Hillsboro Water Department Staff

The first priority for many HWD staff in the initial hours and days following a major earthquake will be to ensure the health and safety of their families. Once those critical needs are addressed, HWD staff will, ideally, be available to report to work. However, even after they return to work, it is possible that the City Emergency Manager may assign HWD staff to work on non-water system related tasks that are deemed more critical to the City's disaster response activities. This scenario suggests that HWD staff may have limited ability to perform repairs or implement predetermined work-arounds in the initial hours and days after an earthquake. Critical components of the water system that are required to be operational within the first 3-7 days after an earthquake should be designed or seismically retrofitted to remain operational during and immediately after a major earthquake.

5.1.5 Availability of Design Professionals and Contractors

The restoration timeline goals and required repairs must be in line with the anticipated availability of qualified design professionals and contractors to design and implement the repairs. It is anticipated that the design and construction of major repairs to a pump station or treatment plant structure would take between 6-12 months. It is anticipated that the design and construction that replaces a pump station or treatment plant structure would take a minimum of 18 months. These timeframes may increase if the City decides to rebuild the pump stations to a higher standard of performance, i.e., a resilient design, which may require more planning and design time.

5.1.6 Availability of Repair Materials or Replacement Equipment

The HWD maintains limited supplies of emergency repair materials, but these supplies are not anticipated to be adequate for the number of repairs that may be necessary after a major earthquake. For disasters that impact a relatively small geographic region, it is possible that other nearby utilities could lend repair supplies. However, a CSZ earthquake will impact the entire Pacific Northwest (from Northern California to British Columbia) and relying on neighboring utilities as a potential source for repair materials is likely impractical.

Additionally, some equipment used in pump stations and treatment plants is not available from manufacturer's stock and has a long lead time for production. Special consideration must be given to this difficult-to-source equipment to ensure that it is either not damaged during an earthquake, a predetermined work-around has been established, or the equipment manufacturing lead time aligns with restoration timeline goals.

5.1.7 Infrastructure Dependencies

The restoration of water system infrastructure is highly dependent on other infrastructure systems. Examples of these dependencies include:

- Co-location with and damage to other lifeline systems (roads, bridges, wastewater pipes, etc.);

- Liquid fuel availability for trucks, generators, and equipment;
- Commercial electrical power;
- Transportation system for delivery of repair materials and mutual aid assistance crews; and
- Cellular communications system for coordination of HWD staff and contractors.

The level of service goals and performance requirements suggested in this report assume that all lifeline service providers will be making significant investments in the earthquake resilience of their systems in the next 45 years. If one or more lifeline sectors do not make these system improvements, then the speed of community recovery could be greatly impacted because of the dependencies between all infrastructure systems. Figure 5.1 shows an example of the complicated dependency relationships among lifelines in the San Francisco Bay Area (City and County of San Francisco Lifelines Council, 2014). Heavy and light lines widths depict the relative level of dependencies anticipated to occur between the various lifelines systems following a scenario M7.9 earthquake on the San Andreas fault.

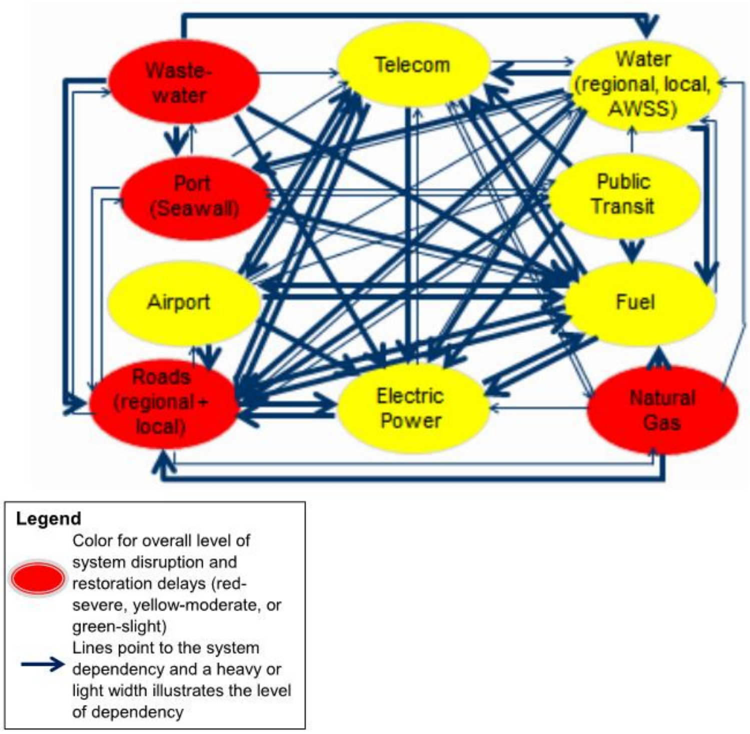


Figure 5.1 – Lifeline Interdependencies in the San Francisco Bay Area (City and County of San Francisco Lifelines Council, 2014)

5.2 Reservoirs, Pump Stations, and Valve Vaults

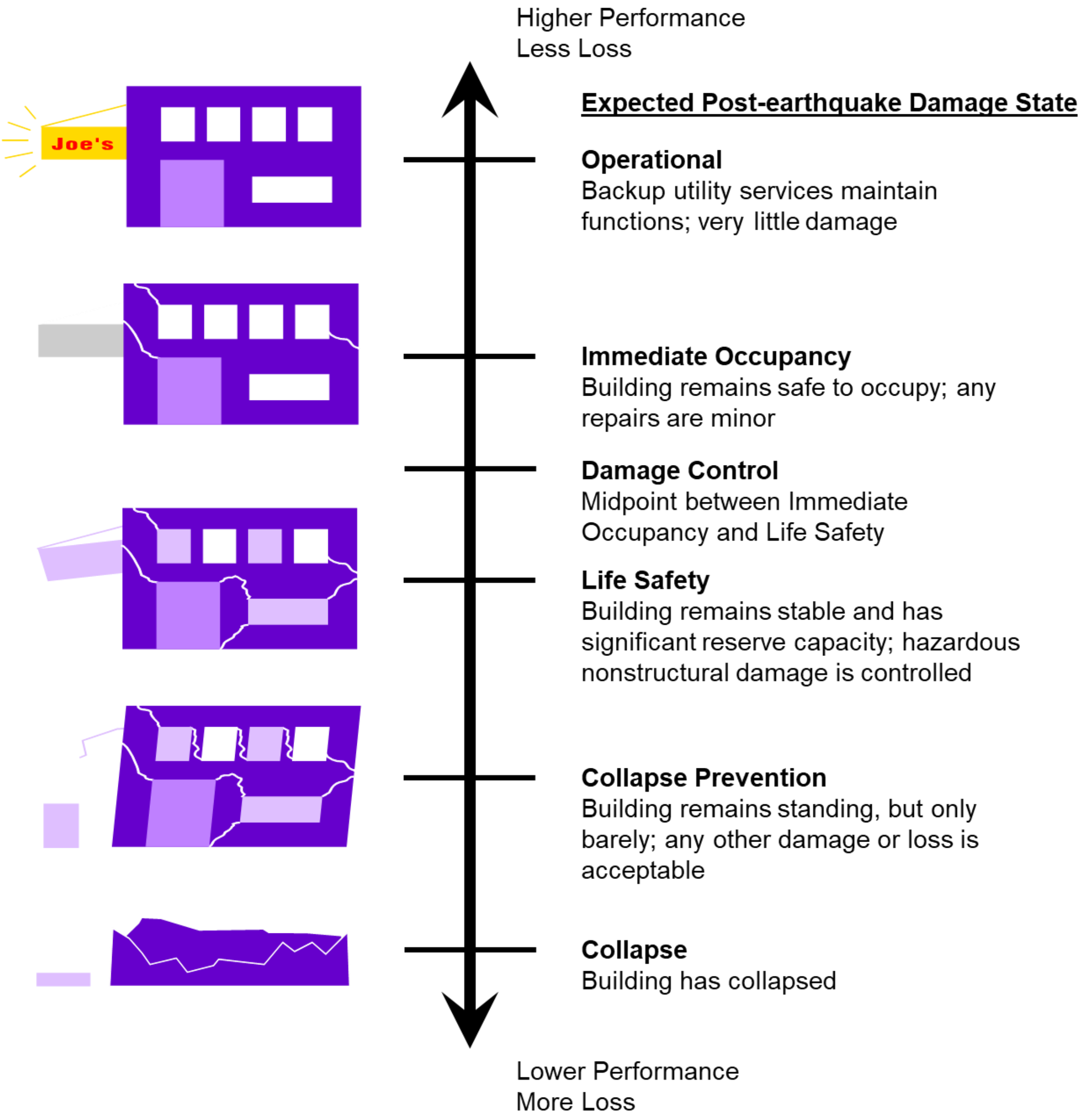
Water storage facilities and pump stations required to maintain water pressure for fire suppression are designated as Risk Category IV structures and water system structures not required to maintain water pressure for fire suppression are designated as Risk Category III structures according to the requirements of the latest edition of the *Oregon Structural Specialty Code* (OSSC, 2014). For new structures, the construction cost increase associated with elevating the design standard from Risk Category III to Risk Category IV is typically relatively minor. Therefore, it is recommended that all new water system structures should be designed per the more stringent *Oregon Structural Specialty Code* seismic design requirements for Risk Category IV structures. Also, since geotechnical hazards (e.g., liquefaction and lateral spreading, etc.) can significantly impact the performance of water system structures following a major earthquake, it is recommended that site-specific geotechnical investigations and analysis be conducted to characterize these potential hazards. Water system structure designs should include appropriate measures to mitigate these potential site-specific geotechnical hazards. Equipment associated with water system structures should be adequately braced and seismically certified, per the requirements of the latest edition of ASCE 7*, Minimum Design Loads for Buildings and Other Structures* (ASCE, 2011), so that it could remain operational after a design level earthquake, as long as dependent systems are also functional [e.g., electrical power (emergency generator or commercial), etc.]. Piping entering or exiting water system structures should be designed to accommodate the anticipated earthquake-induced relative movement between the structure and surrounding soil.

In order to meet the target LOS goals, water system structures need to meet or exceed defined levels of structural and nonstructural seismic performance. ASCE 41-13, *Seismic Evaluation and Retrofit of Existing Buildings* (ASCE, 2014), presents several structural and nonstructural seismic performance objectives and describes the expected level of earthquake damage associated with each performance objective. Also included are expectations about the operability and reparability of earthquake damage for these various performance objectives. The ASCE 41-13 descriptions of these performance objectives are provided below and summarized in Figure 5.2. Table 5.1 provides a comparison between these performance objectives and the intended performance associated with *Oregon Structural Specialty Code* Risk Categories.

Table 5.1 – Comparison of Seismic Performance Objectives with OSSC Risk Categories

Risk Category	**Performance Objective**[a]	
	Structural	**Nonstructural**
IV	Immediate Occupancy	Operational
III	Damage Control	Position Retention
I & II	Life Safety	Position Retention

[a] For the BSE-1N seismic hazard level as defined by ASCE 41-13



Higher Performance
Less Loss

Expected Post-earthquake Damage State

Operational
Backup utility services maintain functions; very little damage

Immediate Occupancy
Building remains safe to occupy; any repairs are minor

Damage Control
Midpoint between Immediate Occupancy and Life Safety

Life Safety
Building remains stable and has significant reserve capacity; hazardous nonstructural damage is controlled

Collapse Prevention
Building remains standing, but only barely; any other damage or loss is acceptable

Collapse
Building has collapsed

Lower Performance
More Loss

Figure 5.2 – Building Performance Objectives
(adapted from ASCE, 2014)

Structural Performance Objectives

Immediate Occupancy: “Immediate Occupancy” refers to the post-earthquake damage state in which only very limited structural damage has occurred. The basic vertical- and lateral-force-resisting systems of the building retain almost all their pre-earthquake strength and stiffness. The risk of life-threatening injury from structural damage is very low, and although some minor structural repairs might be appropriate, these repairs would generally not be required before re-occupancy. Continued use of the building is not limited by its structural condition but might be limited by damage or disruption to nonstructural elements of the building, furnishings, or equipment and availability of external utility services.

Damage Control: “Damage Control” refers to a midway point between Life Safety (see next description) and Immediate Occupancy (see previous description). This performance objective is intended to provide a structure with a greater reliability of resisting collapse and being less damaged than a typical structure, but not to the extent required of a structure designed to meet the Immediate Occupancy Performance Level. Although this level is a numerically intermediate level between Life Safety and Immediate Occupancy, the two performance objectives are essentially different from each other. The primary consideration for Immediate Occupancy is that the damage is limited in such a manner as to permit reoccupation of the building, with limited repair work occurring while the building is occupied. The primary consideration for Life Safety is that a margin of safety against collapse be maintained and that consideration for occupants to return to the building is a secondary impact to the Life Safety objective being achieved. The Damage Control Performance Level provides for a greater margin of safety against collapse than the Life Safety Performance Level would. The level might control damage in such a manner as to permit return to function more quickly than the Life Safety Performance Level, but not as quickly as the Immediate Occupancy Performance Level does.

Life Safety: “Life Safety” refers to the post-earthquake damage state in which significant damage to the structure has occurred but some margin against either partial or total structural collapse remains. Some structural elements and components are severely damaged, but this damage has not resulted in large falling debris hazards, either inside or outside the building. Injuries might occur during the earthquake; however, the overall risk of life-threatening injury from structural damage is expected to be low. It should be possible to repair the structure; however, for economic reasons, this repair might not be practical. Although the damaged structure is not an imminent collapse risk, it would be prudent to implement structural repairs or install temporary bracing before re-occupancy.

Nonstructural Performance Objectives

Operational: “Operational” refers to the performance level where most nonstructural systems required for normal use of the building are functional, although minor cleanup and repair of some items might be required. Achieving the Operational nonstructural performance level requires considerations of many elements beyond those that are normally within the sole province of the structural engineer’s responsibilities. For Operational nonstructural performance, in addition to ensuring that nonstructural components are properly mounted and braced within the structure, it is often necessary to provide emergency standby equipment to provide utility services from external sources that might be disrupted. It might also be necessary to perform qualification testing to ensure that all necessary equipment will function during or after strong shaking.

Position Retention: “Position Retention” refers to the nonstructural condition of a building after an event where, presuming that the building is structurally safe, occupants can occupy the building safely, with some limitations: normal use might be impaired, some cleanup might be needed, and some inspection might be warranted. In general, building equipment is secured in place and might be able to function if the necessary utility service is available. However, some components might experience misalignments or internal damage and be inoperable. Power, water, natural gas, communications lines, and other utilities required for normal building use might not be available. Cladding, glazing, ceilings, and partitions might be damaged but would not present safety hazards or un-occupiable conditions. For this performance level, the risk of life-threatening injury caused by nonstructural damage is very low.

Detailed geotechnical and structural seismic evaluations should be conducted for existing water system structures to determine if their anticipated seismic performance will enable LOS goals to be achieved. To satisfy the target water system restoration timeline, structures that must be operational soon after a major earthquake should be evaluated and if required, seismically retrofit to a more stringent structural and nonstructural performance level than those that are not required until later in the recovery phase. Table 5.2 provides the seismic retrofit criteria proposed for adoption by the HWD for water system infrastructure in terms of the structural and nonstructural performance objectives presented in ASCE 41. These performance objectives are for the Basic Safety Earthquake-1 for use with the Basic Performance Objective Equivalent to New Building Standards (BSE-1N). This BSE-1N seismic hazard level is consistent with that used to design new structures per the *Oregon Structural Specialty Code*. Note that the proposed LOS goals require that the water system has essentially been restored to a 90% operational level within 2-4 weeks after a M9.0 CSZ earthquake. This would suggest that the majority of system components are capable of achieving Immediate Occupancy structural performance and Operational nonstructural performance. Table 5.2 also includes alternative (less stringent) retrofit performance objectives for system components that might not be required to be returned to service until 1-6 months or 6-12 months after the earthquake. For example, if HWD decides to back feed the Upper

System from JWC transmission lines, it may be possible relax the restoration timeline goal for the SSWTP and to reduce the required level of seismic retrofit. Similarly, HWD may decide that the 24th Avenue Reservoir and Pump Station are not required to achieve short- and intermediate-term LOS goals and may elect to relax the restoration timeline goals for those water system structures.

Table 5.2 – Water System Seismic Retrofit Performance Objectives

Restoration Timeline	**Retrofit Performance Objective**[a]	
	Structural	**Nonstructural**
0-1 months	Immediate Occupancy	Operational
1-6 months	Immediate Occupancy	Position Retention[b]
6-12 months	Damage Control[c]	Position Retention[b]

[a] For the BSE-1N seismic hazard level as defined by ASCE 41-13.

[b] Assumes lead time for delivery and installation of damaged equipment falls within restoration timeline goals, otherwise equipment should be seismically certified per the requirements of the latest edition of ASCE 7.

[c] Assumes that the structural damage can be repaired within restoration timeline goals. For earthquake damage that may be especially difficult to repair within the target timeline, structure should be retrofit to satisfy the Immediate Occupancy performance objective.

6.0 Reservoir Structural Vulnerability Assessment

The expected structural and nonstructural performance of the City's four reservoirs has been evaluated for a M9.0 CSZ scenario earthquake. Sections 6.2.1 through 6.2.4 provide a short narrative description for each reservoir, followed by a table that summarizes the potential seismic structural and nonstructural deficiencies identified through desktop review of the available construction documents.

6.1 Approach

As part of this project, Shannon and Wilson, Inc. conducted a geotechnical seismic hazard assessment (Shannon & Wilson, 2018). In their report, Shannon & Wilson provided estimates of the spectral acceleration and permeant ground deformation (PGD) for liquefaction-induced settlement, liquefaction-induced lateral spreading, and earthquake-induced landslide associated with the M9.0 CSZ scenario earthquake. The seismic structural and nonstructural evaluations of the reservoirs were completed using a desktop evaluation of the available construction documents for the reservoirs. This evaluation has been based on: 1) the geotechnical seismic hazard assessment data provided by Shannon & Wilson, 2) a comparison of the seismic design parameters specified for original construction to the seismic acceleration parameters associated with the M9.0 CSZ scenario earthquake, 3) review of available construction documents to identified potential load path deficiencies, and 4) common deficiencies that have been observed for this type of construction.

The structural evaluation of these reservoirs is based only on review of available design drawings, calculations, and reports. Site visits to these reservoirs were not included as part of the scope of work for this project. We assume that the original design drawings and retrofit design drawings (if applicable) are an accurate representation of the as-built construction details. Additionally, we assume that anchorage and bracing of nonstructural components (including valves, piping, electrical cabinets, etc.) was installed per the requirements of the design standard (building code) indicated on the relevant design drawings.

The desktop evaluations conducted as part of this project have identified several potential seismic deficiencies with the reservoirs. These deficiencies are not unexpected, given the difference in the seismic hazard level prescribed by the building code at the time these structures were originally constructed/retrofit compared to the currently prescribed seismic hazard level and improvements in seismic detailing standards that have occurred since these structures were originally constructed/retrofit. Additionally, the structural and nonstructural performance required to achieve seismic resilience goals necessitates higher standards than have typically been considered for water system infrastructure.

6.2 Summary of Potential Seismic Deficiencies

6.2.1 Crandall Reservoir

The Crandall Reservoir is a wire-wound, circular, prestressed concrete water reservoir, designed in 2011 by CH2M Hill with a storage capacity of 10-million gallons. This reservoir has an inside diameter of 236 feet, a wall height of 36 feet 3 inches, and a reinforced concrete roof slab with a thickness of 10 inches. This reservoir is located north of NW Evergreen Road and east of NW Glencoe Road, at approximately 45° 33’ 3.87” north latitude and 122° 59’ 25.61” west longitude.

Table 6.1 presents observations from a desktop seismic assessment of the reservoir based on review of the original construction drawings provided by the City of Hillsboro. No site observation was conducted for this reservoir.

Table 6.1 – Crandall Reservoir - Seismic Evaluation Summary

Potential Deficiencies	Description
Seismic Structural	• Per Shannon & Wilson Report: 0.5-2 inches liquefaction induced settlement, 0.1-2 inches liquefaction-induced lateral spreading, 0-0.1 feet earthquake-induced landslide PGD. • The 16-inch thick core walls only include minimal horizontal reinforcement, at a reinforcement ratio of 0.0010 (three #4 bars at 36 inches on center).
Seismic Nonstructural	• Inlet and outlet pipes inside the reservoir are strapped down to a concrete saddle support, but the strap is ineffective to restrain movement along the axis of the pipe.

6.2.2 Evergreen Reservoir

The Evergreen Reservoir is a wire-wound, circular, prestressed concrete water reservoir, designed in 2002 by CH2M Hill per the 1997 Unifrom Building Code (UBC), with a storage capacity of 15 million gallons. This reservoir has an inside diameter of 292 feet, a wall height of 33 feet 6 inches, and a reinforced concrete roof slab with a thickness of 10 inches. This reservoir is south of NW Evergreen Parkway and east of NE Brookwood Parkway, at approximately 45° 33’ 0.32” north latitude and 122° 55’ 30.49” west longitude.

Table 6.2 presents observations from a desktop seismic assessment of the reservoir based on review of the original construction documents provided by the City of Hillsboro. No site observation was conducted for this reservoir.

Table 6.2 – Evergreen Reservoir - Seismic Evaluation Summary

Potential Deficiencies	Description
Seismic Structural	• Per Shannon & Wilson Report: 0.5-2 inches liquefaction induced settlement, 0-0.1 inches liquefaction-induced lateral spreading, 0-0.1 feet earthquake-induced landslide PGD. • The 18-inch-thick core walls only include minimal horizontal reinforcement, at a reinforcement ratio of 0.0009 (three #4 bars at 36 inches on center).
Seismic Nonstructural	• Original construction drawings indicate the use of flexible expansion joints for piping entering and exiting the reservoir. Diagrammatically these flexible expansion joints are shown as single ball assemblies. However, project specifications indicate that double ball assemblies were required for the project. SEFT assumes that double ball assemblies were installed. This should be verified, since single ball assemblies may not provide adequate movement capacity to accommodate the expected PGD. • Inlet and outlet pipes inside the reservoir are strapped down to a concrete saddle support, but the strap is ineffective to restrain movement along the axis of the pipe.

6.2.3 24th Avenue Reservoir

The 24th Avenue Reservoir is a wire-wound, circular, prestressed concrete water reservoir with a storage capacity of 6 million gallons. Original construction of the concrete dome reservoir was in 1962 as a wire-wrapped concrete reservoir with a reinforced concrete dome roof structure. This reservoir was retrofit in 2002 with exterior shotcrete and wire-wound prestressed reinforcement and seismic cables by CH2M Hill, using the 1997 UBC. The reservoir has an inside diameter of 150 feet, an exterior wall height of 41 feet, 3 inches, and has a concrete dome roof structure (with an inside radius of 159 feet, 4.5 inches) peaking at a height of 60 feet above the base of the wall, which allows for a maximum stored height of liquid of 44 feet, 6 inches. This reservoir is south of NE Parkwood Street and west of NE 25th Avenue, at approximately 45° 31’ 23.57” north latitude and 122° 57’ 28.67” west longitude.

Table 6.3 presents observations from a desktop seismic assessment of the reservoir based on review of the original and retrofit construction documents provided by the City of Hillsboro. No site observation was conducted for this reservoir.

Table 6.3 – 24th Avenue Reservoir - Seismic Evaluation Summary

Potential Deficiencies	Description
Seismic Structural	• Per Shannon & Wilson Report: 1-4 inches liquefaction induced settlement, 6-12 inches liquefaction-induced lateral spreading, 0-0.1 feet earthquake-induced landslide PGD. • Based on the expected magnitude of PGD, significant cracking of the concrete walls and foundation may occur. • The interior retrofit ring beam load transfer to the existing footing and the existing wall is limited, with only five inches of dowel embedment on the #5 reinforcing bars.
Seismic Nonstructural	• The interior overflow pipe is only restrained by the original concrete wall at the top of the wall and the reservoir footing, with an unbraced height of the 10 3/4” outside diameter pipe of approximately 40 feet.

6.2.4 Dilley Reservoir

The Dilley Reservoir is a ground supported round welded carbon steel tank, located within the footprint of an abandoned rectangular concrete reservoir. The steel tank was constructed in 1982, designed in accordance with AWWA D100-79, and has a storage capacity of 0.9 million gallons. Drawings for the original construction were incomplete and did not include the design criteria for which the reservoir was designed. The reservoir has an inside diameter of 80 feet, a wall height of 24 feet, and has a steel dome roof structure, supported by the perimeter walls and a single interior steel column. A 2015 seismic study by Peterson Structural Engineers indicated that the as-built inside diameter of the reservoir is 79 feet and recommended lowering the overflow pipe elevation to 17 feet above the base of the reservoir. This reservoir is south of SW Saddleback Drive and west of SW Old Highway 47, at approximately 45° 28’ 35.92” north latitude and 123° 8’ 45.46” west longitude.

Table 6.4 presents observations from a desktop seismic assessment of the reservoir based on review of the original construction documents, 2015 seismic assessment report, and 2016 seismic retrofit construction documents provided by the City of Hillsboro. No site observation was conducted for this reservoir. The scope of this desktop seismic assessment has excluded the support buildings adjacent to the reservoir that was constructed as part of the 2016 project.

Table 6.4 – Dilley Reservoir - Seismic Evaluation Summary

Potential Deficiencies	Description
Seismic Structural	• Per Shannon & Wilson Report: 0 inches liquefaction induced settlement, 0-0.1 inches liquefaction-induced lateral spreading, 0-0.1 feet earthquake-induced landslide PGD. • Per 2015 seismic study by Peterson Structural Engineers and 2016 seismic retrofit by Murraysmith and Peterson Structural Engineers, overflow elevation was lowered from 22.5 feet to 17 feet to account for change in seismic design requirements from the original design (AWWA D100-79) to current standards (AWWA D100-11). SEFT assumes the suggested reduction in overflow elevation has been implemented.
Seismic Nonstructural	• The inlet and outlet piping connections to the steel tank occur through the side of the tank above grade and immediately turn 90 degrees and go below grade. Drawings show that double ball flexible expansion joints were provided a short distance away from the tank. Pea gravel bedding is used as pipe zone backfill from the reservoir through the flexible expansion joint to reduce the restraint that the backfill provides against pipe movement. The drain piping connection is shown to be similar but is indicated as a single ball flexible expansion joint. However, project specifications indicate that double ball assemblies were required for the project. SEFT assumes that double ball assemblies were installed. This should be verified, since single ball assemblies may not provide adequate movement capacity to accommodate PGD.

7.0 Pump Station Structural Vulnerability Assessment

The expected structural and nonstructural performance of the City's three pump stations has been evaluated for a M9.0 CSZ scenario earthquake. Sections 7.2.1 through 7.2.3 provide a short narrative description for each pump station, followed by a table that summarizes the potential seismic structural and nonstructural deficiencies identified through desktop review of the available construction documents.

7.1 Approach

As part of this project, Shannon and Wilson, Inc. conducted a geotechnical seismic hazard assessment (Shannon & Wilson, 2018). In their report, Shannon & Wilson provided estimates of the spectral acceleration and permeant ground deformation (liquefaction-induced settlement, liquefaction-induced lateral spreading, and earthquake-induced landslide) associated with the M9.0 CSZ scenario earthquake. The seismic structural and nonstructural evaluations of the pump stations were completed using a desktop evaluation of the available construction documents for the pump stations. This evaluation has been based on: 1) the geotechnical seismic hazard assessment data provided by Shannon & Wilson, 2) a comparison of the seismic design parameters specified for original construction to the seismic acceleration parameters associated with the M9.0 CSZ scenario earthquake, 3) review of available construction documents to identified potential load path deficiencies, and 4) common deficiencies that have been observed for this type of construction.

The structural evaluation of these pump stations is based only on review of available design drawings, calculations, and reports. Site visits to these pump stations was not included as part of the scope of work for this project. We assume that the original design drawings are an accurate representation of the as-built construction details. Additionally, we assume that anchorage and bracing of nonstructural components (including valves, piping, electrical cabinets, etc.) was installed per the requirements of the design standard (building code) indicated on the relevant design drawings.

The desktop evaluations conducted as part of this project have identified several potential seismic deficiencies with the pump stations. These deficiencies are not unexpected, given the difference in the seismic hazard level prescribed by the building code at the time these structures were originally constructed compared to the currently prescribed seismic hazard level and improvements in seismic detailing standards that have occurred since these structures were originally constructed. Additionally, the structural and nonstructural performance required to achieve seismic resilience goals necessitates higher standards than have typically been considered for water system infrastructure.

7.2 Summary of Potential Seismic Deficiencies

7.2.1 Crandall Pump Station

The Crandall Pump Station is an L-shaped one-story reinforced masonry shear wall structure, with a plan area of approximately 3,500 square feet. The building houses a generator room, a pump room, a hydro / PRV room, a treatment room, and a water quality sample room. Just north of the building is an exterior fuel tank storage pad on a foundation shared by the pump station building. This pump station is north of NW Evergreen Road and east of NW Glencoe Road, at approximately 45° 33’ 3.87” north latitude and 122° 59’ 25.61” west longitude. The pump station is due west of the adjacent Crandall Reservoir.

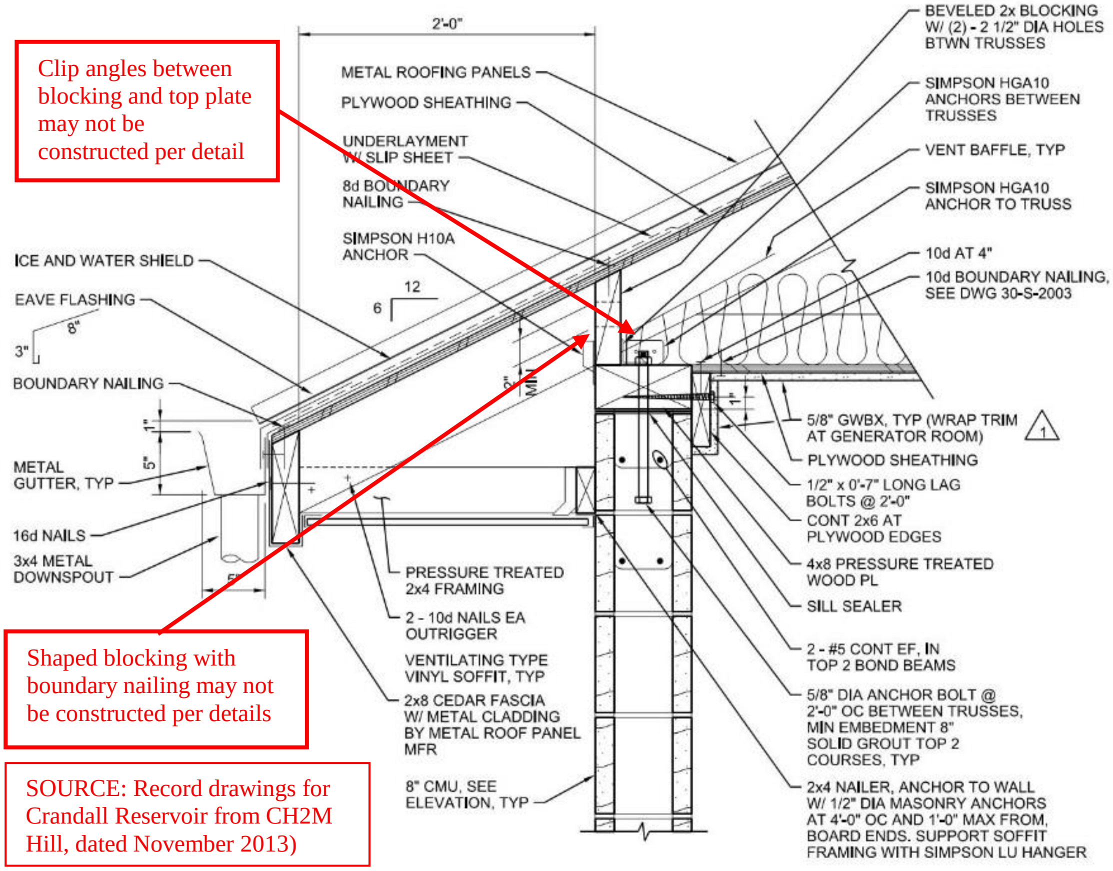
Table 7.1 presents observations from a desktop seismic assessment of the pump station based on review of the original construction drawings provided by the City of Hillsboro. No site observation was conducted for this pump station.

Table 7.1 – Crandall Pump Station - Seismic Evaluation Summary

Potential Deficiencies	Description
Seismic Structural	• Per Shannon & Wilson Report: 0.5-2 inches liquefaction induced settlement, 0.1-2 inches liquefaction-induced lateral spreading, 0-0.1 feet earthquake-induced landslide PGD. • The construction documents illustrate a complete load path for the roof diaphragm to the masonry shear walls. It is our experience (based on field observation of other similar construction in the region) that some of these details, though designed correctly, may not be constructed in accordance with the specified details. This includes the shaped blocking between the sloped plywood roof sheathing and the top plate of the masonry shear wall, shaped blocking at the building ridge, and the connection plates between blocking and top of wall construction. Refer to Figures 7.1 and 7.2 for additional information. It should be verified by a structural engineer or the City of Hillsboro Building Department that these details were constructed as shown in the original construction documents. • The interior non-load bearing masonry walls rely upon cross grain bending for out-of-plane wall resistance. • The total wall reinforcement ratio (0.0019) is slightly less than that required by ASCE 41-13 Tier 1 checklists (0.0020).

Table 7.1 – Crandall Pump Station - Seismic Evaluation Summary (cont.)

Potential Deficiencies	Description
Seismic Nonstructural	• The pump station is supported by soil that was improved using the cement deep soil mixing (CDSM) technique. The general notes provided in the original construction documents indicate an expected post-seismic settlement between areas with and without CDSM soil improvement of 7-10 inches. Piping between the pump station and reservoir is also supported by soil that was improved using the CDSM technique. Additionally, the joints for piping between the pump station and reservoir are specified to be restrained and allow 4 degrees minimum rotation for 12 inch diameter pipe and 3 degrees minimum rotation for 24 inch diameter pipe. Piping between the pump station and reservoir is anticipated to perform well during an earthquake. However, the JWC supply and low pressure zone piping that enters/exits the pump station is not supported by CDSM improved soil. It is anticipated that an abrupt 7-10 inches of differential permanent ground deformation will take place at the interface between CDSM improved soil and non-improved soil. It does not appear that JWC supply and low pressure zone piping adjacent to the pump station was specifically designed to accommodate this level of expected abrupt permanent ground deformation and damage to these pipes is likely to occur during a major seismic event. • It is our experience (based on field observation of other similar construction in the region) that some of the pipe bracing, equipment within the pump station, and ductwork within the attic space, provided by the contractor in a deferred submittal, may not comply with seismic bracing requirements in the code. The adequacy of nonstructural seismic bracing should be verified by a structural engineer or the City of Hillsboro Building Department. • The general notes provided in the original construction documents indicate that seismic certification was required for: low-voltage AC induction motors, low-voltage switchgear, low-voltage motor control, diesel engine generator set, and vertical turbine pumps. We assume that documentation of this seismic certification was reviewed and approved by the Structural Engineer of Record.

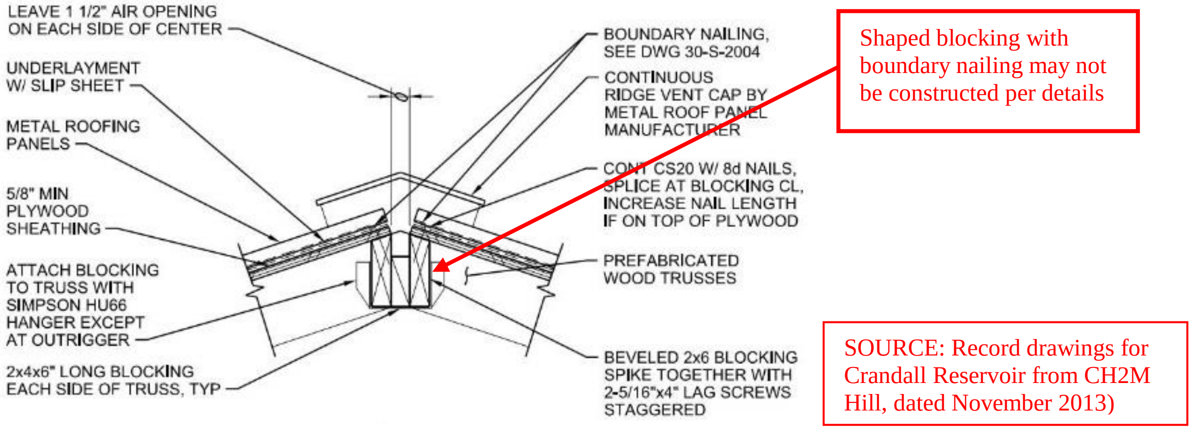


Clip angles between blocking and top plate may not be constructed per detail

Shaped blocking with boundary nailing may not be constructed per details

SOURCE: Record drawings for Crandall Reservoir from CH2M Hill, dated November 2013)

Figure 7.1 – Crandall Pump Station - Roof to Wall Connection



Shaped blocking with boundary nailing may not be constructed per details

SOURCE: Record drawings for Crandall Reservoir from CH2M Hill, dated November 2013)

Figure 7.2 – Crandall Pump Station - Ridge Connection

7.2.2 Evergreen Pump Station

The Evergreen Pump Station is a primarily rectangular one-story reinforced masonry shear wall structure, with a plan area of approximately 1,600 square feet. The building houses a generator room, a pump room, and a water quality monitoring room. This pump station is south of NW Evergreen Parkway and east of NE Brookwood Parkway, at approximately 45° 33’ 0.32” north latitude and 122° 55’ 30.49” west longitude. The pump station is due east of the adjacent Evergreen Reservoir. The Evergreen and 24th Avenue Pump Stations were designed and built at the same time, as similar buildings.

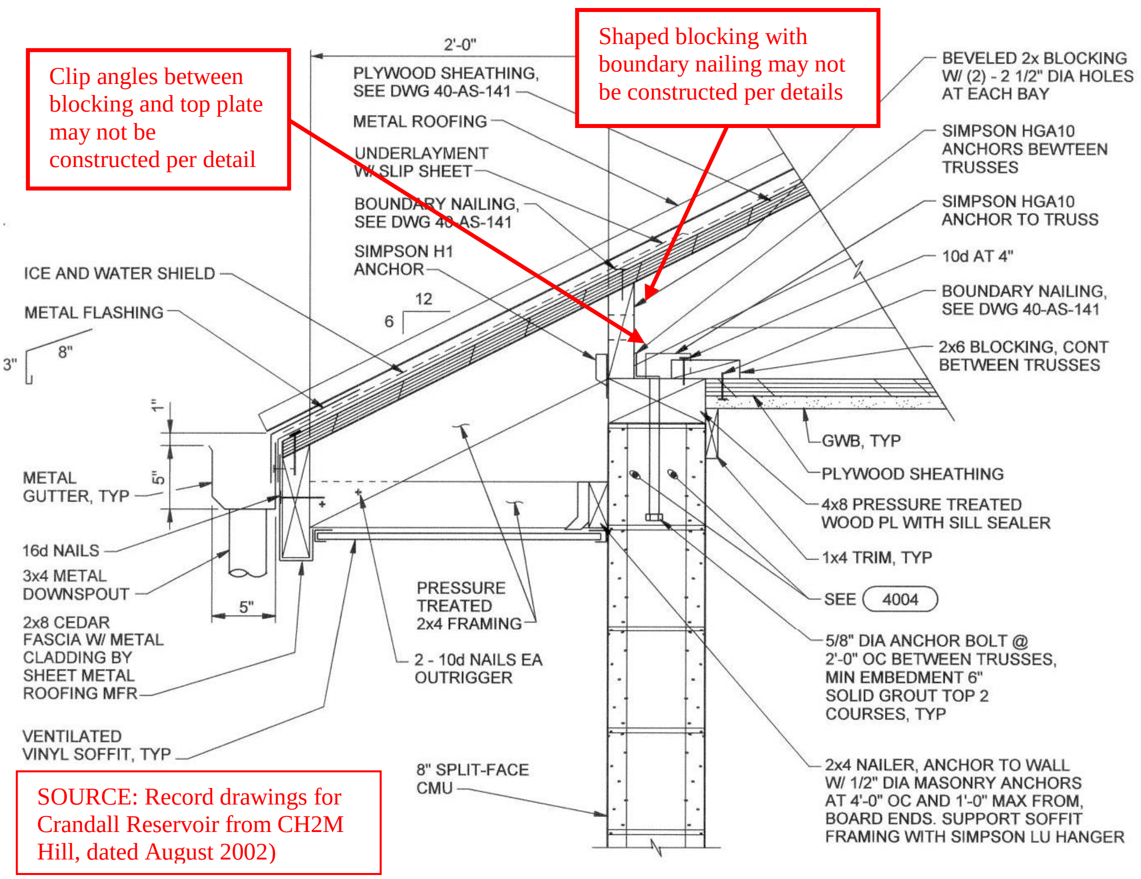
Table 7.2 presents observations from a desktop seismic assessment of the pump station based on review of the original construction documents provided by the City of Hillsboro. No site observation was conducted for this pump station.

Table 7.2 – Evergreen Pump Station - Seismic Evaluation Summary

Potential Deficiencies	Description
Seismic Structural	• Per Shannon & Wilson Report: 0.5-2 inches liquefaction induced settlement, 0-0.1 inches liquefaction-induced lateral spreading, 0-0.1 feet earthquake-induced landslide PGD. • The construction documents illustrate a complete load path for the roof diaphragm to the masonry shear walls. It is our experience (based on field observation of other similar construction in the region) that some of these details, though designed correctly, may not be constructed in accordance with the specified details. This includes the shaped blocking between the sloped plywood roof sheathing and the top plate of the masonry shear wall, shaped blocking at the building ridge, and the connection plates between blocking and top of wall construction. Refer to Figure 7.3 and 7.4 for additional information. It should be verified by a structural engineer or the City of Hillsboro Building Department that these details were constructed as shown in the original construction documents. • The total wall reinforcement ratio (0.0019) is slightly less than that required by ASCE 41-13 Tier 1 checklists (0.0020).

Table 7.2 – Evergreen Pump Station - Seismic Evaluation Summary (cont.)

Potential Deficiencies	Description
Seismic Nonstructural	• It is our experience (based on field observation of other similar construction in the region) that some of the pipe bracing, equipment within the pump station, and ductwork within the attic space, provided by the contractor in a deferred submittal, may not comply with seismic bracing requirements in the code. The adequacy of nonstructural seismic bracing should be verified by a structural engineer or the City of Hillsboro Building Department. • Typical generator installation does not include proper restraint of starter batteries. The adequacy of starter battery restraint should be verified by a structural engineer or the City of Hillsboro Building Department. • Equipment is likely not seismically certified to ensure functionality after a major earthquake. Seismic certification of equipment should be verified by a structural engineer or the City of Hillsboro Building Department.

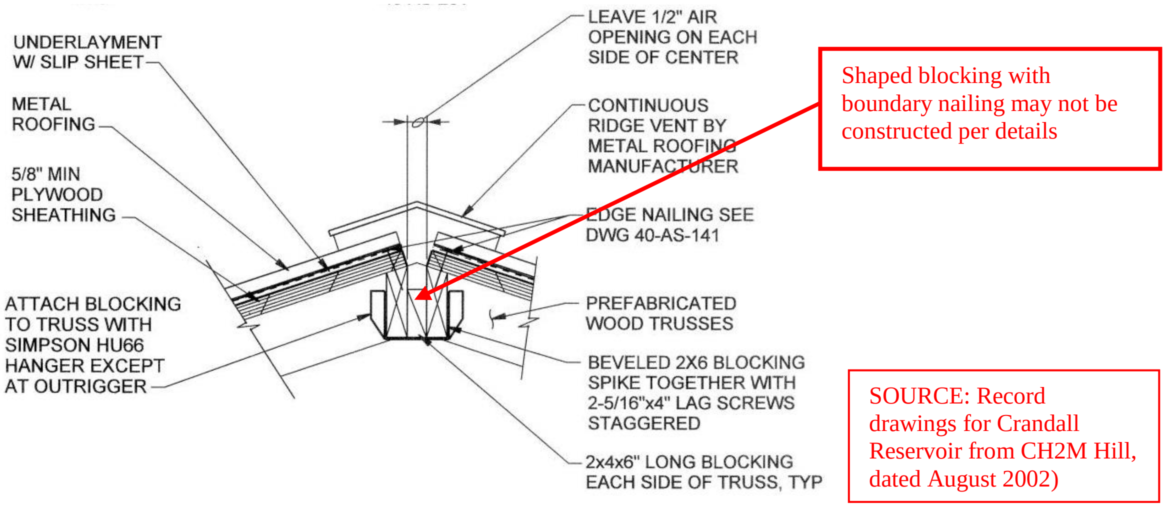


Clip angles between blocking and top plate may not be constructed per detail

Shaped blocking with boundary nailing may not be constructed per details

SOURCE: Record drawings for Crandall Reservoir from CH2M Hill, dated August 2002)

Figure 7.3 – Evergreen Pump Station – Roof to Wall Connection



Shaped blocking with boundary nailing may not be constructed per details

SOURCE: Record drawings for Crandall Reservoir from CH2M Hill, dated August 2002)

Figure 7.4 – Evergreen Pump Station - Ridge Connection

7.2.3 24th Avenue Pump Station

The 24th Avenue Pump Station is a primarily rectangular one-story reinforced masonry shear wall structure, with a plan area of approximately 1,600 square feet. The building houses a generator room, a pump room, and a water quality monitoring room. This pump station is south of NE Parkwood Street and west of NE 25th Avenue, at approximately 45° 31' 23.57" north latitude and 122° 57' 28.67" west longitude. The pump station is due west of the adjacent 24th Avenue Reservoir. The 24th Avenue and Evergreen Pump Stations were designed and built at the same time, as similar buildings.

Table 7.3 presents observations from a desktop seismic assessment of the pump station based on review of the original construction documents provided by the City of Hillsboro. No site observation was conducted for this pump station.

Table 7.3 – 24th Avenue Pump Station - Seismic Evaluation Summary

Potential Deficiencies	Description
Seismic Structural	• Per Shannon & Wilson Report: 1-4 inches liquefaction induced settlement, 6-12 inches liquefaction-induced lateral spreading, 0-0.1 feet earthquake-induced landslide PGD. • Based on the expected magnitude of PGD, significant cracking of the masonry shear walls and concrete foundation may occur. • The construction documents illustrate a complete load path for the roof diaphragm to the masonry shear walls. It is our experience (based on field observation of other similar construction in the region) that some of these details, though designed correctly, may not be constructed in accordance with the specified details. This includes the shaped blocking between the sloped plywood roof sheathing and the top plate of the masonry shear wall, shaped blocking at the building ridge, and the connection plates between blocking and top of wall construction. Refer to Figure 7.3 and 7.4 for additional information. It should be verified by a structural engineer or the City of Hillsboro Building Department that these details were constructed as shown in the original construction documents. • The total wall reinforcement ratio (0.0019) is slightly less than that required by ASCE 41-13 Tier 1 checklists (0.0020).

Table 7.3 – 24th Avenue Pump Station - Seismic Evaluation Summary (cont.)

Potential Deficiencies	Description
Seismic Nonstructural	• Original construction drawings indicate the use of flexible expansion joints for piping entering and exiting the reservoir. Diagrammatically these flexible expansion joints are shown as single ball assemblies. However, project specifications indicate that double ball assemblies were required for the project. SEFT assumes that double ball assemblies were installed. This should be verified, since single ball assemblies may not provide adequate movement capacity to accommodate the expected PGD. • It is our experience (based on field observation of other similar construction in the region) that some of the pipe bracing, equipment within the pump station, and ductwork within the attic space, provided by the contractor in a deferred submittal, may not comply with seismic bracing requirements in the code. The adequacy of nonstructural seismic bracing should be verified by a structural engineer or the City of Hillsboro Building Department. • Typical generator installation does not include proper restraint of starter batteries. The adequacy of starter battery restraint should be verified by a structural engineer or the City of Hillsboro Building Department. • Equipment is likely not seismically certified to ensure functionality after a major earthquake. Seismic certification of equipment should be verified by a structural engineer or the City of Hillsboro Building Department.

8.0 PRV Vault Structural Vulnerability Assessment

The expected structural and nonstructural performance of two of the City's representative PRV Vaults has been evaluated for a M9.0 CSZ scenario earthquake. Sections 8.2.1 and 8.2.2 provide a short narrative description for each PRV Vault, followed by a table that summarize the potential seismic structural and nonstructural deficiencies identified by the ASCE 41-13 Tier 1 and TCLEE Monograph No. 22 checklist-based evaluations. These two Sections also include selected photos of each PRV Vault taken during a site visit conducted on May 3rd, 2018.

8.1 Approach

As part of this project, Shannon and Wilson, Inc. conducted a geotechnical seismic hazard assessment (Shannon & Wilson, 2018). In their report, Shannon & Wilson provided estimates of the spectral acceleration and permeant ground deformation (liquefaction-induced settlement, liquefaction-induced lateral spreading, and earthquake-induced landslide) associated with the M9.0 CSZ scenario earthquake. This structural and nonstructural evaluation has been based on the geotechnical seismic hazard assessment data provided by Shannon & Wilson.

The seismic structural evaluation of these representative PRV Vaults was completed using the Tier 1 procedure of ASCE 41-13. This Tier 1 procedure uses a checklist-based approach to identify potential seismic structural deficiencies that have been commonly observed in past earthquakes. The Tier 1 procedure also uses quick-check calculations to evaluate potential deficiencies in the primary components of the seismic load resisting system.

The seismic nonstructural evaluation of these representative PRV Vaults was completed using the nonstructural seismic evaluation checklists presented in ASCE 41-13 supplemented by TCLEE Monograph No. 22 *Seismic Screening Checklists for Water and Wastewater Facilities* (TCLEE, 2002). Similar to the ASCE 41 Tier 1 structural evaluation procedure, this checklist-based evaluation approach is used to identify potential seismic nonstructural deficiencies that have been commonly observed in past earthquakes.

The ASCE 41 Tier 1 and TCLEE Monograph No. 22 evaluations conducted as part of this project have identified several potential seismic deficiencies with the PRV Vaults. These deficiencies are not unexpected, given the difference in the seismic hazard level prescribed by the building code at the time these structures were originally constructed compared to the currently prescribed seismic hazard level and improvements in seismic detailing standards that have occurred since these structures were originally constructed. Additionally, the structural and nonstructural performance required to achieve seismic resilience goals necessitates higher standards than have typically been considered for water system infrastructure.

8.2 Summary of Potential Seismic Deficiencies

8.2.1 Representative NTL PRV Vault

The City of Hillsboro ties into the Joint Water Commission (JWC) owned North Transmission Line (NTL), at multiple locations as the water supply for users within its jurisdiction. At each of these tie-in locations, there is a pressure-reducing valve (PRV) to reduce the water pressure from the pressurized transmission line to pressures suitable for distribution to water system users. Each of these pressure-reducing valves are housed within a pressure-reducing valve vault (PRV Vault). Based on our understanding, through coordination with the HWD, each of the five PRV Vaults associated with tie-in points to the JWC's NTL are of similar construction style and vintage, and the equipment within and supporting the vault is of similar as-built conditions. Therefore, for this project, SEFT, HDR and HWD have selected the PRV Vault at NE 25th Street as the representative PRV Vault for the HWD connections to the NTL. This PRV Vault is located west of NE 25th Street, south of NW Evergreen Road and west of the Hillsboro Airport, at approximately 45° 33' 0.49" north latitude and 122° 57' 49.55" west longitude.

The PRV Vault is a precast concrete utility vault, buried below grade, with a lid flush with exterior grade. These utility vaults have a plan area of 120 square feet, with inside wall dimensions of 20-feet by 6-feet, and a vault clear height of 6 feet, 7 inches. Vault orientation is such that the 20-foot dimension is parallel to the axis of the HWD water main.

The construction of the vault is comprised of two precast components, a vault base and a vault lid. The vault base includes walls cast integrally with the base slab of the vault, and these walls extend to a height of approximately 5 feet above the vault base elevation. The vault lid has thickened edges along the perimeter of the lid slab, transitioning to a short wall segment that sits atop the vault base wall. At this seated vault lid to vault base interface, the vault lid wall stands proud of the vault base wall by approximately 1-inch. This joint was originally grouted, but without a positive connection from this grout to the vault base or the vault lid, some of the grout has fallen away, exposing the gasket seal provided between the vault lid and the vault base segments. Multiple openings in the vault lid provide accessibility to the PRV, including a manhole and four galvanized steel access hatches.

At this NE 25th Street PRV Vault, the water main is nominally 18 inches in diameter, and is oriented with water flowing from west to east. All pipe materials are ductile iron pipe. At the PRV, inside the vault, the pipe diameter decreases to 10 inches. Also, within the vault, there is a bypass line, using 6-inch diameter pipe to bypass the PRV. This bypass line also includes a pressure reducing valve (at the section of the bypass line where the diameter is reduced to 3 inches) and a surge relief valve. The surge relief valve discharges vertically out through the PRV Vault and through a daylighted section of pipe north of the vault. The vault also includes a sump, collecting infiltrating groundwater, and has a sump pump discharge pipe that drains to the east of the PRV Vault.

On the water main pipeline outside the PRV Vault, flexible couplings are provided within 3 feet of the PRV Vault wall at the inlet and outlet side of the PRV Vault. Additionally, a flexible coupling is provided inside the vault at the inlet side of the PRV. At the NE 25th Street PRV Vault, this flexible coupling shows evidence that the full rotational capacity of the flexible coupling has already been exhausted, given the as-built configuration of the flexible coupling. All pipes that pass through the PRV Vault walls (including the main line, pump discharge, and pressure relief line) include a Link-Seal modular wall sealant material surrounding the full perimeter of the pipes.

Piping within the PRV Vault is gravity supported by pipe stanchions at pipe joints, with a base plate bearing on the vault base. At one location on the main line, and one location on the bypass pipe line, the pipe line is supported by a stiffened plate, anchored to a concrete support block cast on top of the vault base. The construction documents indicate that this concrete support block is doweled into the vault base. The anchorage of the stiffened plate to the concrete pier is incomplete, with anchors either missing nuts or the base plate not being flush with the top of the concrete pier, making anchors less effective for resisting seismic shear loads (bending in anchor due to standoff).

SCADA equipment, providing monitoring services for the PRV, is housed in a cabinet just west of the PRV Vault. Electrical conduit exits the cabinet and enters the PRV Vault through the vault wall. Conduit distributes to monitor the pressure reducing valves and the pressure sensors. All conduit connections to the main line provide excess conduit lengths to provide flexibility in the cable connections. The SCADA cabinet is anchored to a concrete slab foundation that was poured in two segments. Inside the cabinet, a backup battery is provided and sitting on the base of the cabinet, without any anchorage.

Table 8.1 presents observations from SEFT’s ASCE 41-13 and TCLEE Monograph No. 22 checklist-based seismic assessment (including site visit) of the representative PRV Vault off the NTL. Refer to Figures 8.1 through 8.7 for site visit photos of this PRV Vault.

Table 8.1 – 25th Street PRV Vault - Seismic Evaluation Summary

Potential Deficiencies	Description
Seismic Structural	• Per Shannon & Wilson Report: 1-12 inches liquefaction induced settlement, 6-24 inches liquefaction-induced lateral spreading, 0-0.1 feet earthquake-induced landslide PGD. • Joints of stacked precast valve vault construction may separate due to sliding forces associated with seismic lateral earth pressures on the face of the PRV Vault. • Sand, silt, or groundwater may infiltrate and leak into the PRV Vault at the precast concrete construction joint.
Seismic Nonstructural	• Relative movement between the PRV Vault structure and the adjacent soil may damage pipes. • The pipes and valves inside the PRV Vault are unbraced, except at the PRV Vault walls. Pipes may experience damage or fracture. • The observed flexible coupling, inside the PRV Vault, appears to have exhausted all its available rotational capacity. • The PRV is unbraced. • Pipe supports at the concrete piers exhibit several potential deficiencies. The base plate includes a stand-off from the top of the concrete pier that is not grouted, not all anchors are provided with sufficient edge distance within the concrete pier, and not all anchors include properly installed nuts. • Some pipe stanchions do not include anchors through the base plate into the vault base. • Separation of the PRV Vault lid and the PRV Vault base may result in damage to pipes and conduits that are anchored to both the base and the lid (e.g., surge relief pipe). • The SCADA cabinet is anchored to two concrete foundation segments, with some anchors ineffective as they are anchored into the joint between two foundation elements. • The UPS battery inside the SCADA cabinet is unbraced. • Equipment is likely not seismically certified to ensure functionality after a major earthquake.

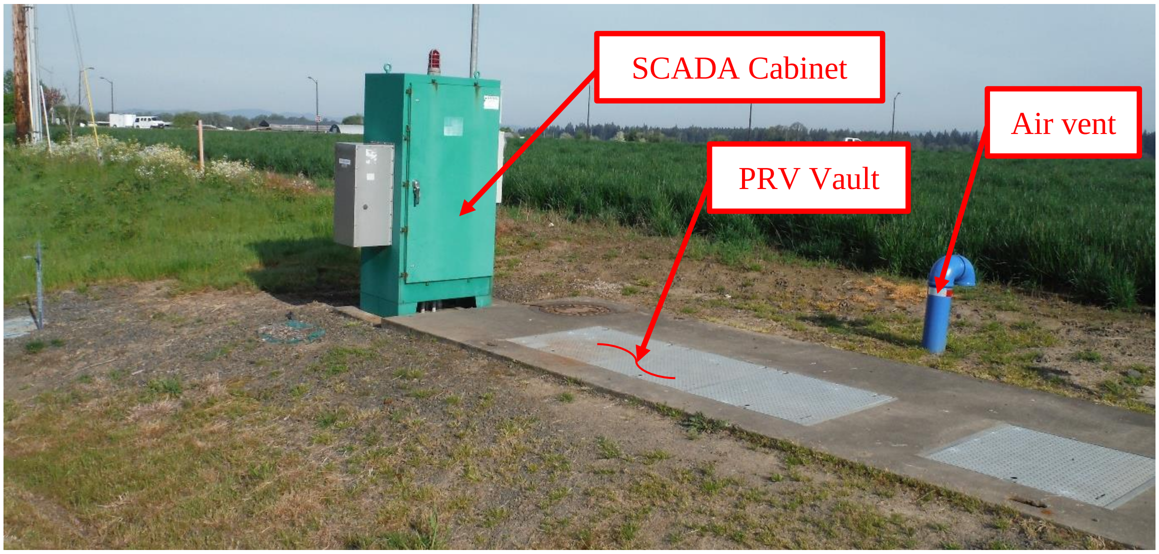


Figure 8.1 – 25th Street PRV Vault - Overall View

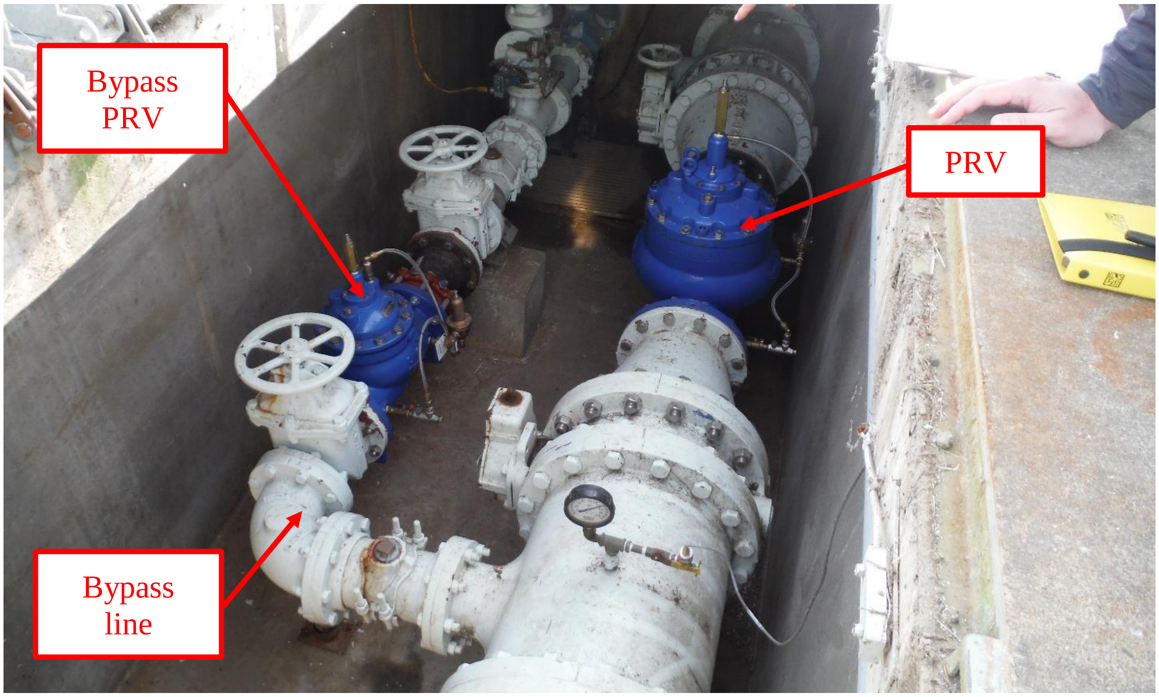


Figure 8.2 – 25th Street PRV Vault - Interior Components

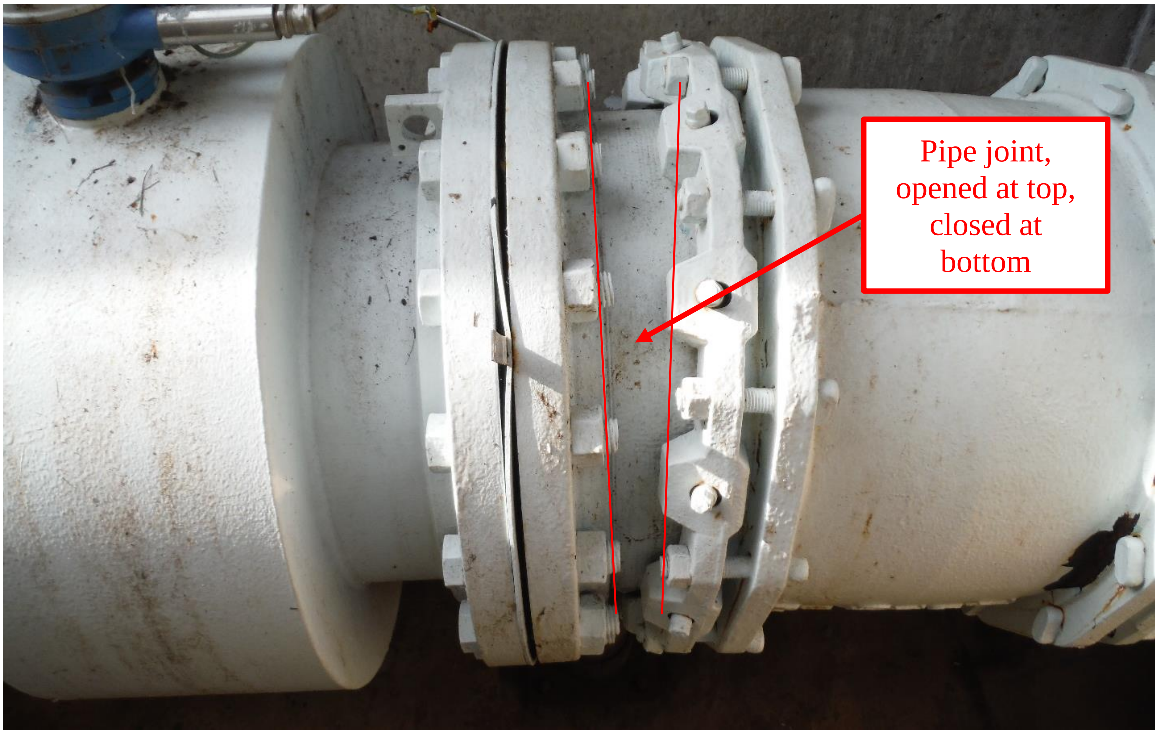


Figure 8.3 – 25th Street PRV Vault - Flexible Joint with Capacity Exhausted

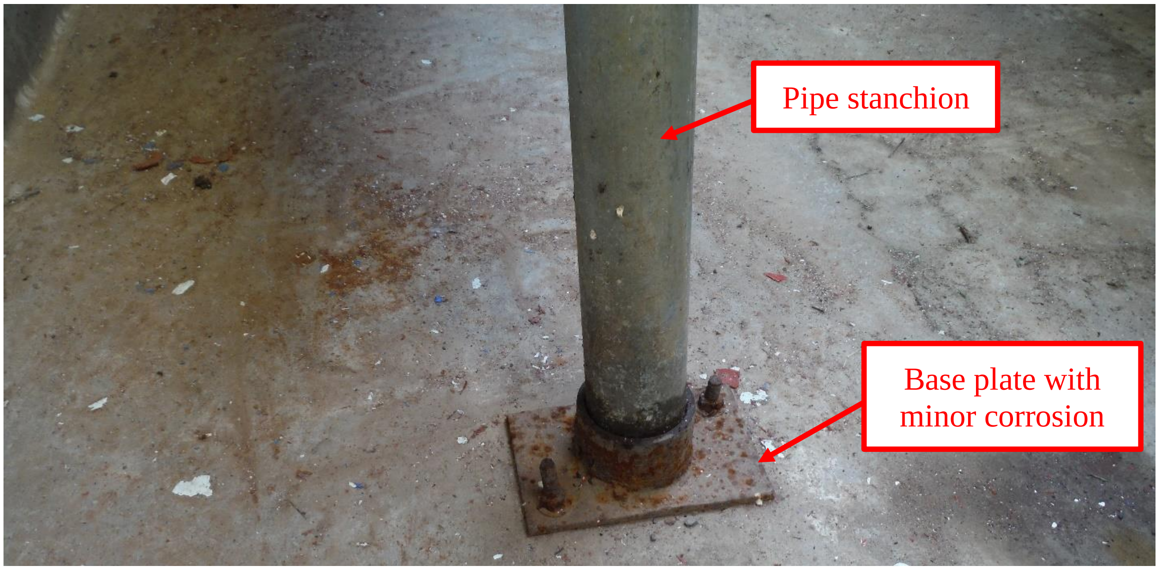


Figure 8.4 – 25th Street PRV Vault - Base Plate with Minor Corrosion

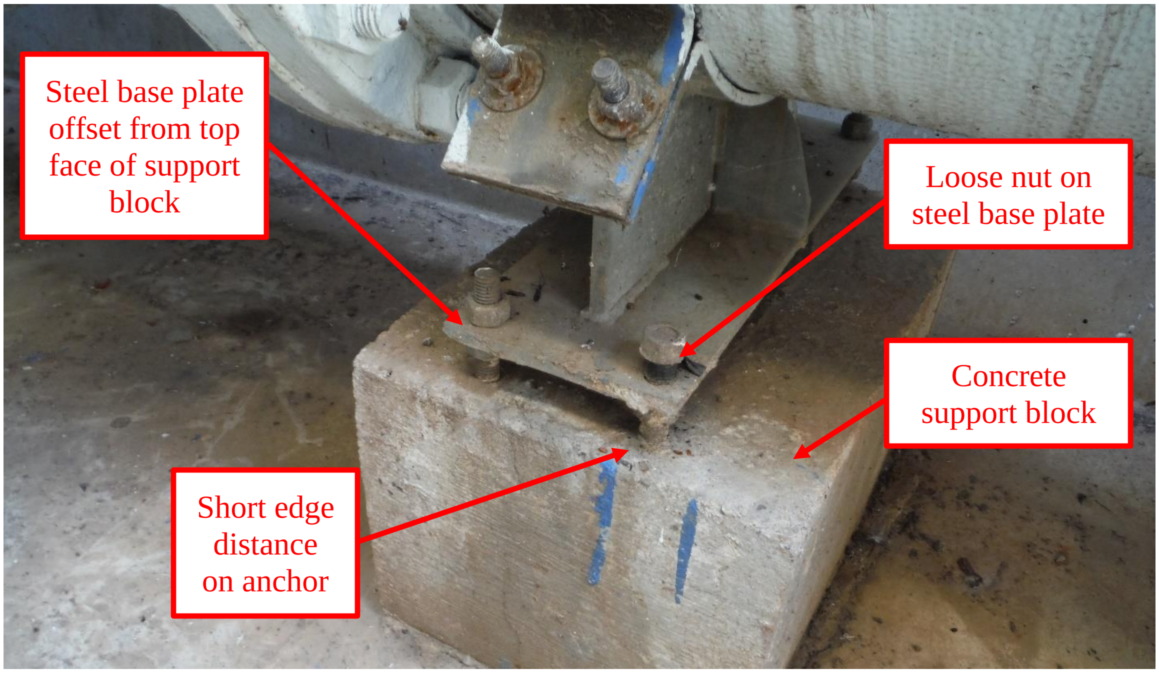


Figure 8.5 – 25th Street PRV Vault - Ineffective Anchorage at Support Block

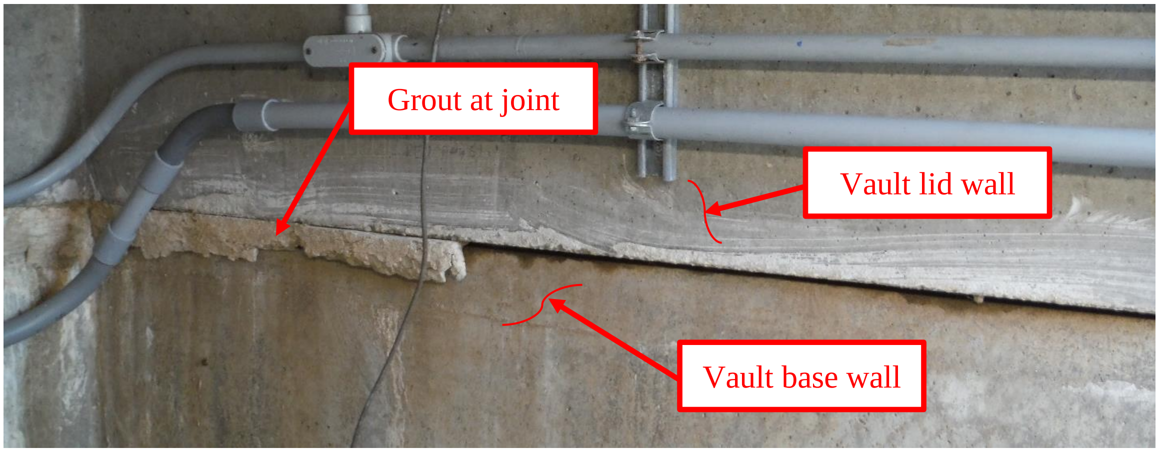


Figure 8.6 – 25th Street PRV Vault - Vault Wall Joint

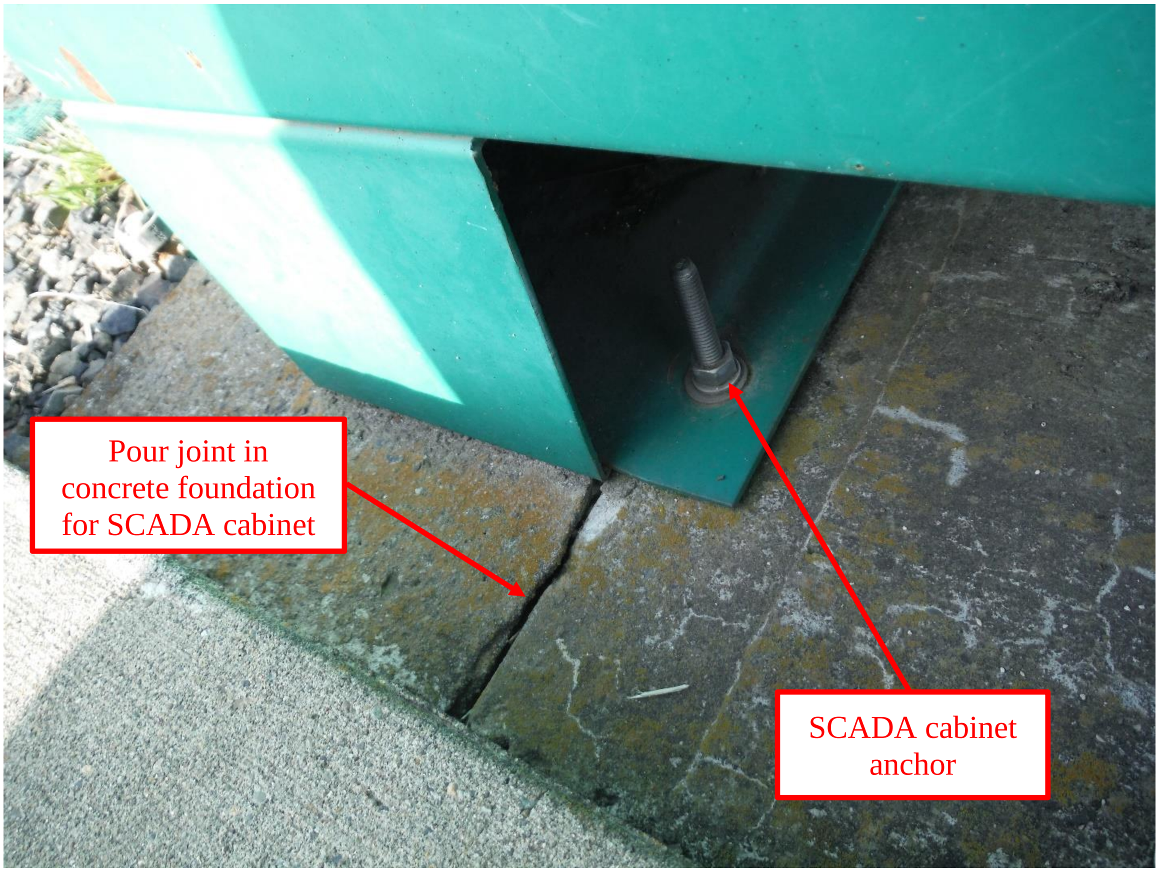


Figure 8.7 – 25th Street PRV Vault - Segmented Foundation at SCADA Cabinet

8.2.2 Representative STL PRV Vault

The City of Hillsboro ties into the Joint Water Commission (JWC) owned South Transmission Line (STL), at multiple locations as the water supply for users within its jurisdiction. At each of these tie-in locations, there is a pressure-reducing valve (PRV) to reduce the water pressure from the pressurized transmission line to pressures suitable for distribution to water system users. Each of these pressure-reducing valves are housed within a pressure-reducing valve vault (PRV Vault). Based on our coordination with HWD, we are considering the PRV Vault at South 1st Avenue as representative of all the PRV Vaults associated with tie-in points to the JWC's STL. Note though that this PRV Vault includes modifications to the bypass lines after the original construction that may not be consistent with the rest of the PRV Vaults associated with the STL. This PRV Vault is located east of South 1st Avenue, north of SW Spring Street, at approximately 45° 30' 52.32" north latitude and 122° 59' 23.30" west longitude.

This PRV Vault is a precast concrete utility vault, buried below grade, with a lid situated just above exterior grade at the west side, with the lid flush with grade around the rest of the perimeter. This PRV vault has a plan area of 136 square feet, with inside wall dimensions of 8 feet, 9 inches by 15 feet, 6 inches, and a vault clear height of 7 feet, 2 inches. Vault orientation is such that the long dimension is parallel to the axis of the HWD water main. The PRV Vault at South 1st Avenue appears to be larger than the typical vault detailed in the vault construction documents from 1980.

The construction of this vault is comprised of cast-in-place and precast concrete construction. The vault base and vault walls are of cast-in-place construction. Based on the construction documents, it appears that the vault base is a concrete mat foundation, with doweled, keyed joint connection to the 10-inch concrete walls around the perimeter of the PRV Vault. The vault lid appears to be of precast concrete construction, with three precast elements in a row along the long direction of the vault. Each precast concrete vault lid element is a concrete slab, with thickened edges along the perimeter. The vault lid edge does not align with the outside face of the vault walls – the vault lid edge stops a few inches short of the vault wall edge. Adjacent vault lid elements do not appear to be interconnected and a gasket seal is provided between adjacent vault lid elements. Multiple openings in the vault lid components provide accessibility to the pressure reducing valve, including a manhole and a steel access hatch.

At this South 1st Avenue PRV Vault, the main line off the STL is nominally 36 inches in diameter and is oriented with water flowing from north to south within the PRV Vault. All pipe sections are of ductile iron material. At the PRV, inside the PRV Vault, the pipe diameter decreases to 24 inches. Off the mainline, there is a bypass line that splits into two parallel bypass lines, just beyond a surge relief valve and outlet pipe. Both bypass lines include valves to control flow. One bypass lines include a pressure-reducing valve, and the other has the bypass tied to an outlet pipe with a surge relief valve. Both bypass lines route around the mainline with the PRV. The surge relief pipe daylights out through the top of the PRV Vault, and then goes back underground, just south of the PRV Vault.

On the water main pipeline, flexible couplings are specified within a few feet of the PRV Vault wall at the inlet and outlet side of the PRV Vault. This flexible coupling is harnessed, restrains coupling movement from separation and disconnection of the two pipe segments. Additionally, all joints within 200 feet of the PRV Vault are restrained. All pipes that penetrate the PRV Vault walls and lid pass through holes in the concrete PRV Vault that match the diameter of the pipe. There is no flexibility in the pipes at penetrations through the PRV Vault.

Piping within the PRV Vault is gravity supported by pipe stanchions at pipe joints, with a base plate bearing on the vault base. At the end of the inlet and outlet main line, inside the PRV Vault, the pipe is supported by a concrete support block cast on the vault base. The original construction documents illustrate a positive connection between the concrete support block and the vault base, and a strap over the top of the pipe anchored to the concrete support block. There is no observed evidence in the field of any strap restraining the pipe to the concrete support block, though strapping may be concealed by the concrete.

SCADA equipment, providing monitoring services for the PRV, is housed in a cabinet above the PRV Vault. Electrical conduit exits the base of the cabinet and down through the lid of the PRV Vault. Conduit distributes to monitor the pressure reducing valves and the pressure sensors. All cable connections to the main line provide excess cable lengths to provide flexibility in the line. The SCADA cabinet is anchored to the PRV Vault lid. Inside the cabinet, a backup battery is provided and anchored to the wall of the cabinet. Above the PRV Vault lid, there is an air vent pipe, approximately three feet tall, that was at one point anchored to the vault lid, though the anchorage has corroded.

Table 8.2 presents observations from SEFT's ASCE 41-13 and TCLEE Monograph No. 22 checklist-based seismic assessment (including site visit) of the representative PRV Vault off the STL. Refer to Figures 8.8 through 8.14 for site visit photos of this PRV Vault.

Table 8.2 – 1st Avenue PRV Vault - Seismic Evaluation Summary

Potential Deficiencies	Description
Seismic Structural	• Per Shannon & Wilson Report: 3-12 inches liquefaction induced settlement, 12-24 inches liquefaction-induced lateral spreading, 0-0.1 feet earthquake-induced landslide PGD. • The joint between the cast-in-place PRV Vault wall and the precast valve vault lid may separate due to sliding forces associated with seismic lateral earth pressures on the face of the PRV Vault. • The PRV Vault lid does not have any interconnectivity between precast segments, resulting in an incomplete vault lid diaphragm.
Seismic Nonstructural	• Relative movement between the PRV Vault and the adjacent soil may damage pipes. • The pipes inside the PRV Vault are unbraced, except at the valve vault walls. Pipes may experience damage or fracture. • Pipe supports appear to lack the pipe to pipe support flat steel strap restraint that was shown in the original construction drawings. • Pipe stanchions at the vault base do not include anchors through the base plate into the vault base. • The PRV is unbraced. • Relative sliding between the PRV Vault lid and the valve vault base will result in damage to pipes and conduits that are anchored to both the base and the lid (for example the surge relief pipe). • Anchors for the air vent pipe above the PRV Vault have corroded to the point that the air vent pipe is unrestrained. • The section of surge relief pipe above the PRV Vault is unbraced. • Relative movement between the wooden access platform and the inlet pipe may fracture the pressure sensor at the south end of the PRV Vault. • Equipment is likely not seismically certified to ensure functionality after a major earthquake.

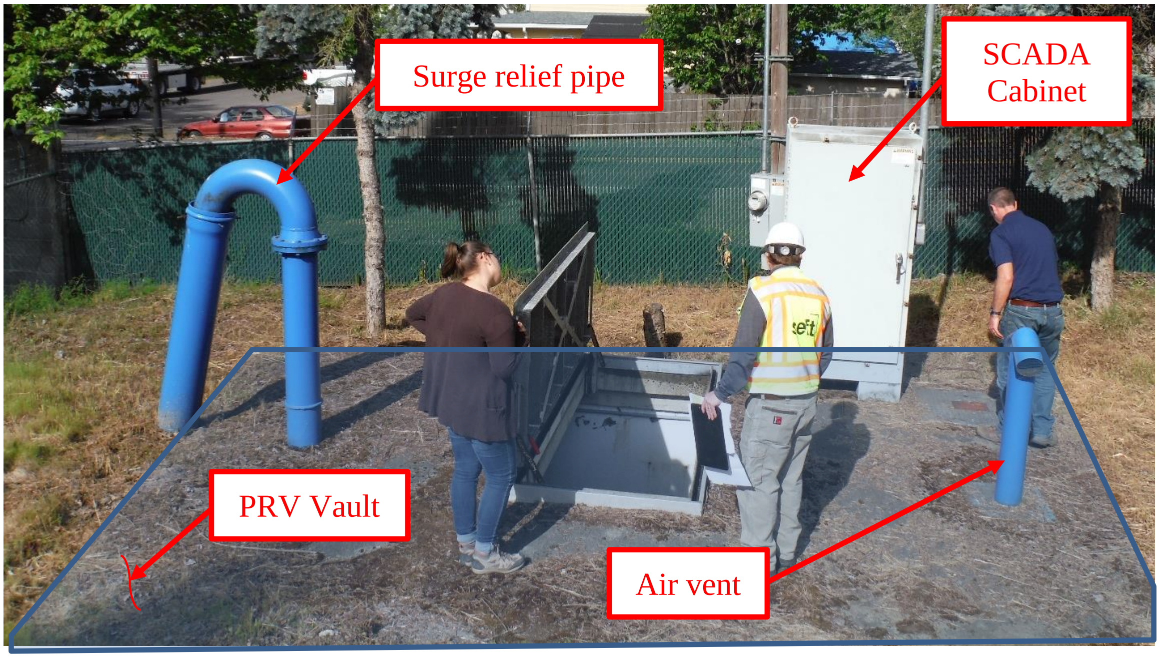


Figure 8.8 – 1st Avenue PRV Vault - Overall View

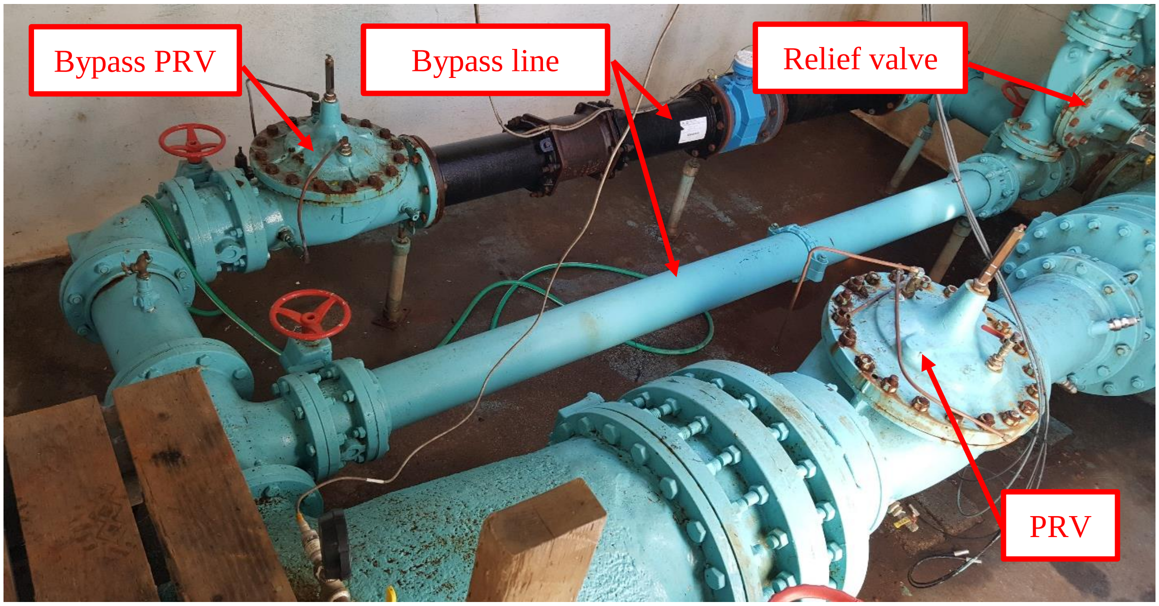


Figure 8.9 – 1st Avenue PRV Vault - Interior Components

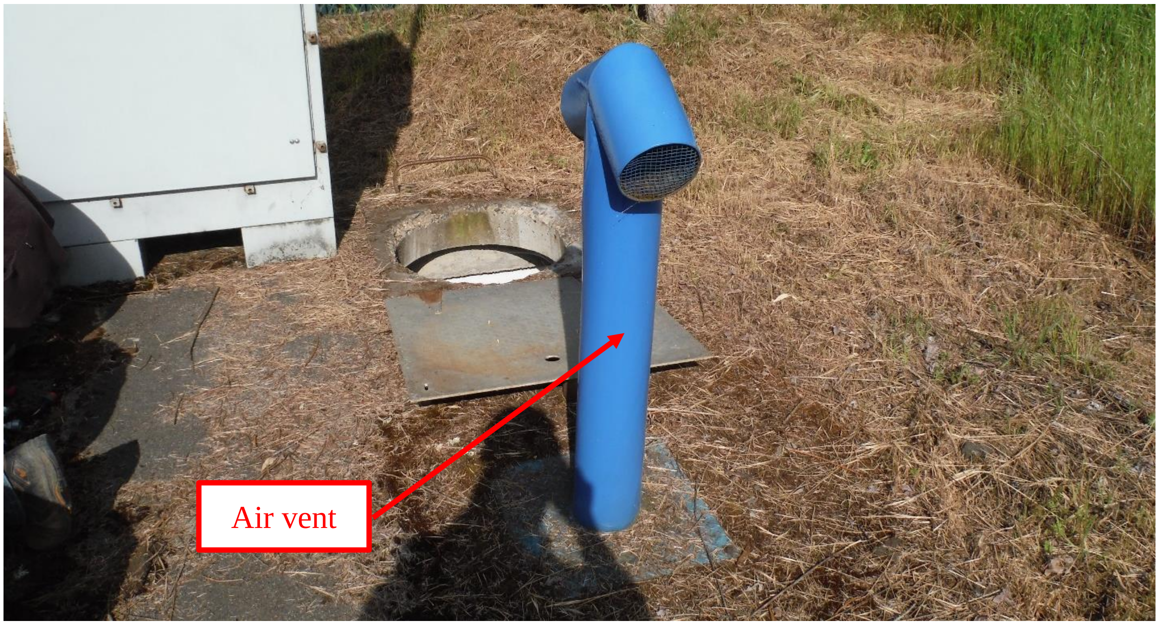


Figure 8.10 – 1st Avenue PRV Vault - Air Vent Pipe

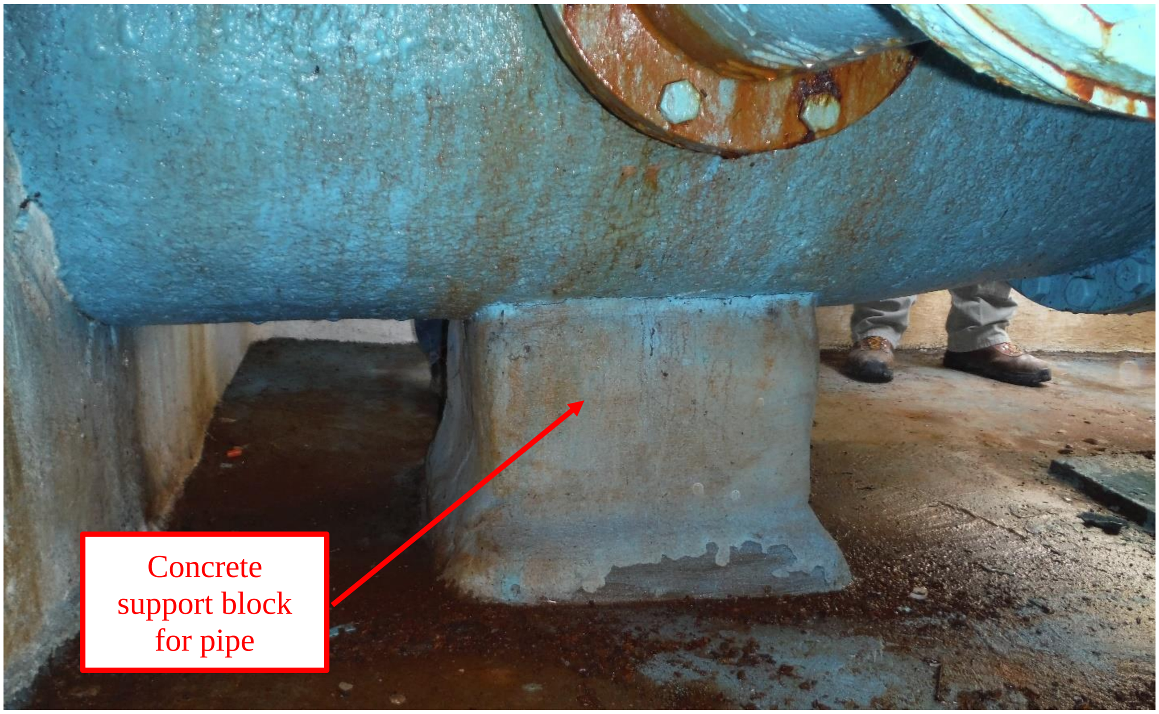


Figure 8.11 – 1st Avenue PRV Vault - Concrete Support Block for Pipe

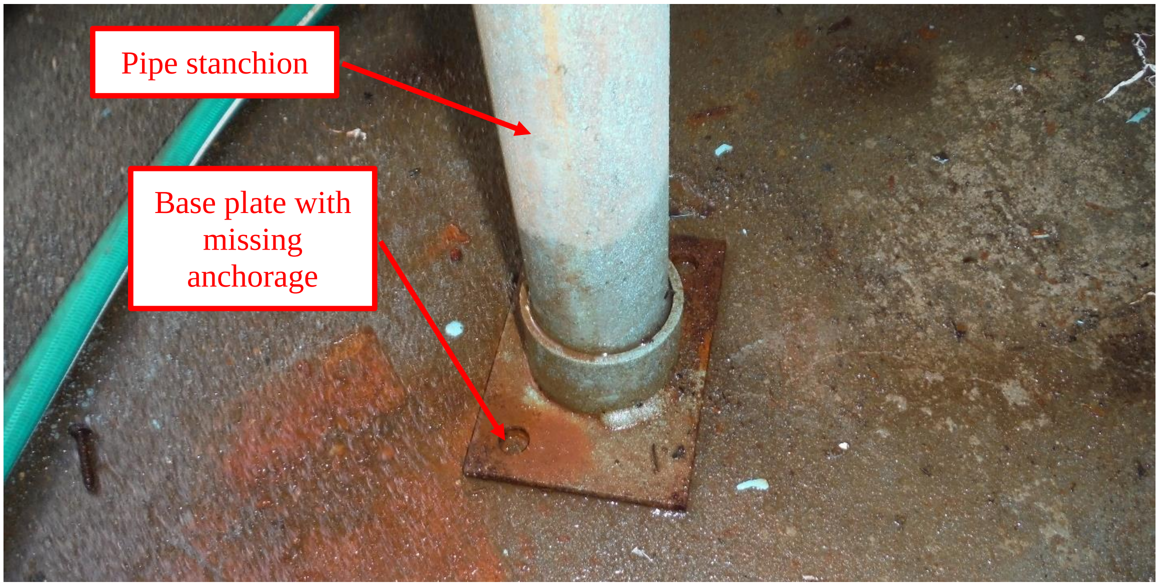


Figure 8.12 – 1st Avenue PRV Vault - Pipe Stanchion Support

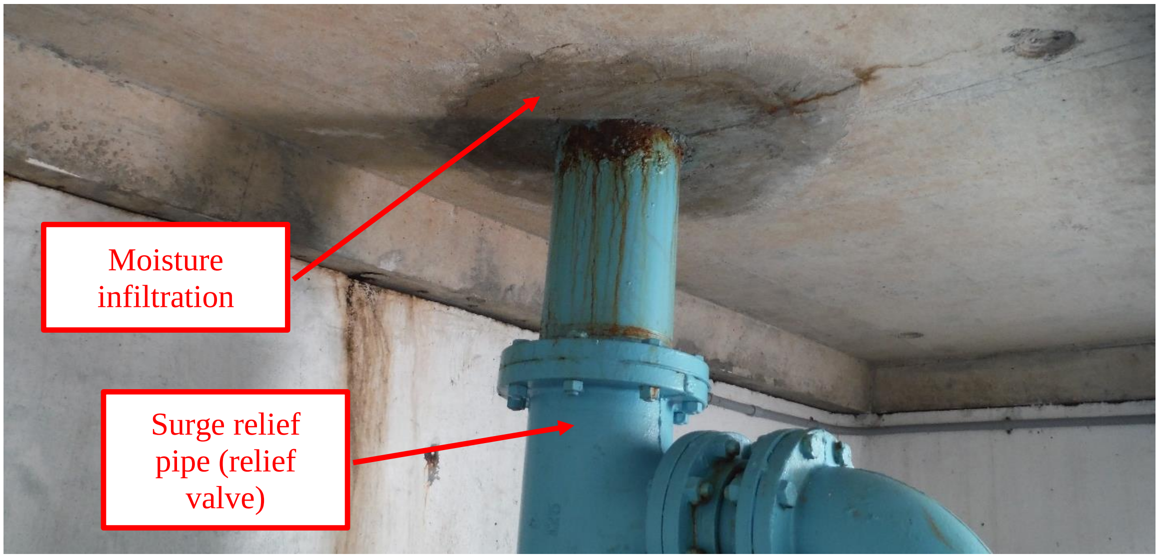


Figure 8.13 – 1st Avenue PRV Vault - Surge Relief Pipe Penetration Through Vault Lid

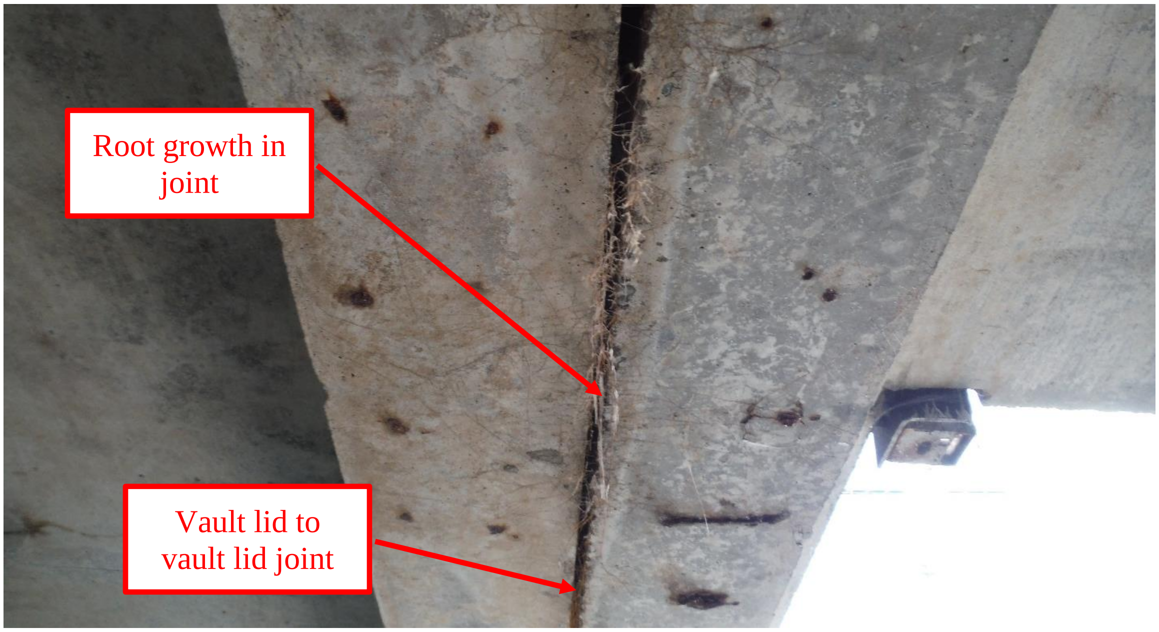


Figure 8.14 – 1st Avenue PRV Vault - Vault Lid Joint

9.0 Preliminary Recommendations for Resilience Improvements

Disaster resilience is a relatively new and emerging area of specialization for lifeline utilities. Recent examples from earthquakes in Japan, New Zealand, and Chile have illustrated that achieving disaster resilience often requires raising the bar above and beyond historical minimum standards and having pre-established plans for systematic response and recovers after a major disaster strikes. HWD has already proactively undertaken numerous important resilience measures including, but not limited to: JWC transmission line redundancy (NTL and STL), requiring use of restrained joint pipe, performing seismic retrofits of two reservoirs, and partnering with TVWD in the WWSP to establish a redundant and seismically resilient water supply for City customers.

This section presents preliminary recommendations for improvements that will enhance the seismic resilience of the HWD water system. These recommendations are based on the LOS goals established by this project for water system restoration after a M9.0 CSZ scenario earthquake, the structural/nonstructural seismic assessment conducted for HWD reservoirs, pump stations, and representative PRV vaults, and review of the Hillsboro Water Department Emergency Response Plan (Hillsboro Water Department, 2014).

9.1 Design Standards

9.1.1 Resilient Design Guidelines

This project has been guided by the recommendations of the *ORP* with a goal of making the HWD water system resilient over a 50-year timeframe from when the *ORP* was issued in 2013 (by approximately 2065). In order to achieve this seismic resilience goal, it is recommended that HWD develops their own Resilient Design Guidelines. These guidelines should include a process for implementing resilience considerations into project planning, life-cycle cost assessment, consideration of dependencies on other HWD assets and/or other infrastructure systems, design (including both new design and seismic retrofit), and construction that are appropriate for supporting system-wide LOS goals following a major earthquake. Specific recommendations should be included to address geotechnical hazards and for detailed design of water system facilities (including both structural and nonstructural design requirements). It is also suggested that the guideline contains a resilience checklist to aid HWD in transparently documenting project decisions related to seismic resilience. The Resilient Design Guidelines should be reviewed and potentially updated on a routine basis to reflect enhancements in industry standards, in-field experience, and recent technological innovations.

9.1.2 Consistency in Design and Construction

HWD engages numerous engineering consultants and contractors to design and construct projects for the City. Incorporating seismic resilience into design and construction is a relatively new concept that requires going above and beyond historical minimum standards. Therefore, it is recommended that HWD develop an internal process to ensure consistent application of resilience principles across the broad spectrum of HWD design and construction projects. This process will be beneficial for ensuring consistency not only for similar projects that occur at different times, but also for similar projects that are implemented at the same time by different design teams and construction teams. It is anticipated that this internal process will include, but not be limited to: educating HWD project managers on the fundamentals of earthquake resilience, enhancing HWD design and construction guidelines from a resilience perspective, clearly indicating resilience goals in a project's request for proposal, and implementing resilience checklists as part of HWD quality assurance reviews.

9.1.3 Structural and Nonstructural Performance Objectives

To support achievement of HWD LOS goals following a CSZ earthquake within the next 45 years, it is recommended that the system performance requirements described in Section 5.2 begin to be immediately implemented as design standards on HWD projects. Any projects that involve more than just minor equipment upgrades should be evaluated by HWD as a potential opportunity to implement a seismic retrofit. These recommendations include, but are not limited to:

- **Geotechnical Hazards:** Design of new and retrofit of existing structures should include appropriate measures to mitigate potential site-specific geotechnical hazards, including but not limited to: settlement, differential settlement, liquefaction-induced settlement, liquefaction-induced lateral spreading, liquefaction-induced buoyancy of below-grade structures, and landslide-induced permeant ground deformation;
- **New Construction:** New water system structures should be designed as Risk Category IV structures (essential facilities) according to the requirements of the latest edition of the *Oregon Structural Specialty Code*;
- **Retrofit of Existing Structures:** Existing water system structures should be seismically retrofit per the recommendations of Table 5.2;
- **Equipment:** New equipment within water system structures that is required to be operational after a major earthquake should be adequately braced and seismically certified, per the requirements of the latest edition of ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, so that it will remain operational after a design level earthquake; and
- **Pipe/Structure Interfaces:** Piping entering or exiting a water system structure should be designed to accommodate any anticipated earthquake-induced relative movement between the structure and surrounding soil.

9.2 Reservoirs

Based on a limited desktop structural and nonstructural review of original construction documents for Crandall and Evergreen Reservoirs, and original and retrofit construction documents for Dilley Reservoir, these reservoirs are expected to perform well structurally when subjected to the M9.0 CSZ scenario earthquake. However, potential damage may occur where unbraced piping within the reservoirs is subjected to sloshing loads. It is recommended that HWD further evaluate the adequacy of pipe bracing to resist sloshing loads and install additional bracing, as appropriate.

Based on a limited desktop structural and nonstructural review of original and retrofit construction documents for 24th Avenue Reservoir, the functionality of this reservoir may be impaired by damage resulting from significant permanent ground deformation when subjected to the M9.0 CSZ scenario earthquake. The Shannon & Wilson report (Shannon & Wilson, 2018) indicates that the reservoir site may experience 1-4 inches of liquefaction-induced vertical settlement and 6-12 inches of liquefaction-induced lateral spreading (horizontal ground deformation). This may result in cracking of the concrete walls and foundation of the reservoir and damage to associated piping. It is recommended that HWD consider performing a more detailed geotechnical and structural evaluation to assess the expected performance of the reservoir and to develop specific seismic improvement recommendations.

9.3 Pump Stations

Based on a limited desktop structural and nonstructural review of original construction documents for Crandall Pump Station, this pump station is expected to perform well structurally when subjected to the M9.0 CSZ scenario earthquake. The Crandall Pump Station is supported by soil that was improved using the cement deep soil mixing (CDSM) technique. The reservoir and piping between the pump station and reservoir is also supported by soil that was improved using the CDSM technique. The general notes provided in the original construction documents indicate an expected post-seismic settlement between areas with and without CDSM soil improvement of 7-10 inches. The JWC supply and low pressure zone piping that enters/exits the pump station is not supported by CDSM improved soil. It is anticipated that an abrupt 7-10 inches of differential permanent ground deformation will take place at the interface between CDSM improved soil and non-improved soil. It does not appear that JWC supply and low pressure zone piping adjacent to the pump station was specifically designed to accommodate this level of expected abrupt permanent ground deformation and damage to these pipes is likely to occur during a major seismic event. Further evaluation of this piping is recommended.

Based on a limited desktop structural and nonstructural review of original construction documents for Evergreen Pump Station, this pump station is expected to perform well structurally when subjected to the M9.0 CSZ scenario earthquake.

Based on a limited desktop structural and nonstructural review of original construction documents for 24th Avenue Pump Station, the functionality of this pump station may be impaired by damage resulting from significant permanent ground deformation when subjected to the M9.0 CSZ scenario earthquake. The Shannon & Wilson report (Shannon & Wilson, 2018) indicates that the pump station site may experience 1-4 inches of liquefaction-induced vertical settlement and 6-12 inches of liquefaction-induced lateral spreading (horizontal ground deformation). This may result in cracking of the masonry walls and concrete foundation of the pump station and damage to associated piping. It is recommended that HWD consider performing a more detailed geotechnical and structural evaluation to assess the expected performance of the pump station and to develop specific seismic improvement recommendations.

For all three pump stations, it is recommended that a field observation be conducted to ensure the as-built construction details are consistent with those shown on the original construction drawings. SEFT has observed inconsistent implementation of similar construction details for other similar structures that have resulted in an incomplete seismic load path between the roof diaphragm and masonry shear walls. It is also recommended that a field observation be conducted to evaluate that the installed nonstructural anchorage and/or bracing is acceptable to meet the Position Retention nonstructural performance objective of ASCE 41-13. SEFT has observed inadequate nonstructural bracing in other recently constructed similar structures. It is also recommended that the post-earthquake functionality of pump station equipment be verified by ensuring that critical equipment required for operation of the pump stations satisfies the seismic certification requirements of the current edition of ASCE 7. This may require replacing some older components with new seismically certified components if compliance can’t be verified by the methods permitted in ASCE 7 (analysis, testing, or experience data).

9.4 PRV Vaults

Based on a structural and nonstructural evaluation using the Tier 1 procedure of ASCE 41-13 supplemented by TCLEE Monograph No. 22, the functionality of the PRV Vaults may be impaired by damage resulting from significant permanent ground deformation when subjected to the M9.0 CSZ scenario earthquake. The Shannon & Wilson report (Shannon & Wilson, 2018) indicates that the 25th Street site may experience 1-12 inches of liquefaction-induced vertical settlement and 6-24 inches of liquefaction-induced lateral spreading (horizontal ground deformation) and the 1st Avenue site may experience 3-12 inches of liquefaction-induced vertical settlement and 12-24 inches of liquefaction-induced lateral spreading. This may result in cracking of the concrete walls and foundation of the valve vaults and damage to associated piping. It is recommended that HWD consider performing a more detailed geotechnical and structural evaluation to assess the expected performance of the valve vaults and to develop specific seismic improvement recommendations. It is also recommended that seismic bracing be enhanced and/or provided for critical components in the valve vault and associated

SCADA cabinet (heavy PRV valves, concrete anchor edge distance on SCADA cabinet, UPS battery in SCADA cabinet, etc.)

9.5 Emergency Response Planning

The driving force behind resilience is the ability for a community to recovery quickly from an event. In addition to mitigation measures that can be taken before a disaster occurs to minimize the damage to the system from an event, effort can also be taken to better prepare for responding to the event so that staff are more efficiently mobilized and have access to the best information and resources to rapidly restore system functionality.

Although the current Hillsboro Water Department Emergency Response Plan includes consideration of responding to an earthquake (one-page checklist), the plan appears to be mostly focused on relatively isolated incidents (power failure, severe weather, chemical release, etc.). A CSZ earthquake will be a major natural disaster that will challenge the HWD's emergency response capabilities in a far more significant manner than a winter storm or other more routine disruption. Since the earthquake will likely impact the entire Pacific Northwest, Hillsboro is not likely to receive mutual aid assistance in the short-term. Earthquake damage is expected to significantly impact operation of all lifeline systems, even after significant investments in infrastructure improvements over the next 45 years. It is recommended that HWD develop a Continuity of Operations Plan (COOP), or other appropriate plan, that specifically addresses the expected challenges in the days, weeks, and months following a CSZ earthquake. The COOP should initially address how HWD will respond to a CSZ earthquake given the current performance expectations for the region's infrastructure and should be routinely updated to reflect resilience enhancements as they are implemented. The following recommendations will help enable HWD to more rapidly and efficiently respond to and recover from a major earthquake.

Contractual Agreements

Responding to and recovering from a major earthquake will require engineering and construction activities that exceed the internal capacity of HWD staff and repair supplies that exceed available HWD stockpiles. Engineers and contractors (potentially with specialized equipment and stock inventory) will be needed to assist HWD in restoring the water system and potentially large quantities of pipe and other materials will be required for system repairs. Efficiently mobilizing engineers, contractors, and supply vendors will require pre-arranged agreements to be in place so that HWD doesn't have to wait for various City Departments to provide contract approval. The following recommendations should be considered in developing these agreements:

- **Engineering Consultants:** Consider modifying contract language to include requirements for engineering consultants to agree to provide emergency on-call services and that require engineering consultants to have their own internal continuity of operations plan. These engineering consultants would be pre-qualified and on a stand-by list to provide response and recovery assistance to aid HWD in rapidly restoring functionality of the water system.

- **Contractors**: Consider modifying contract language to include requirements for contractors to agree to provide emergency on-call services, that require contractors to have their own internal continuity of operations plan, and that require contractors to take certain emergency response and repair training that would address HWD needs after a major earthquake. These contractors would be pre-qualified and on a stand-by list to provide response and recovery assistance to aid HWD in rapidly restoring functionality of the water system.
- **Supply Vendors**: Consider developing agreements with regional and national vendors, as appropriate, who could provide repair materials to aid HWD in rapidly restoring functionality of the water system. Agreements should address considerations such as the scenario for which vendors will provide assistance, product type and quantities that will be held exclusively for use by HWD, payment arrangements, and pick-up/delivery arrangements. These agreements should be reviewed and potentially updated on a routine basis to reflect changes in the composition of critical asset inventories and construction techniques (e.g., pipe type, pipe bedding material, pump and motor type, etc.) and to reflect any changes in HWD strategies for post-earthquake response and recovery.

Assessment and Response Prioritization

Given the potential number of repairs to the HWD system that will be required after a major earthquake, it is recommended that HWD develop and document efficient and effective repair methods and an initial plan for how to prioritize limited resources during the initial response phase. The following recommendations should be considered in developing this plan for assessment and response prioritization:

- **Pre-Prioritization**: Based on the results of seismic assessments of the HWD system, it is recommended that HWD develop an initial prioritized listing for the order in which to conduct post-earthquake damage assessments of critical assets. Copies of this plan should be maintained in both electronic and hard-copy format at key HWD work locations.
- **Prioritization Guidelines**: Given the potential number of distribution pipeline repairs that may be required after a major earthquake, it is recommended that the HWD develop and document efficient and effective repair methods to address commonly expected damage. These guidelines may be particularly beneficial for mutual aid crews and contractors from outside the Pacific Northwest who might not be familiar with unique regional practices.
- **GIS-Based Damage Assessment Tool**: It is recommended that HWD consider developing a GIS-based damage assessment tool that utilizes existing information about the HWD system (soil susceptibility to earthquake-induced permeant ground deformation, pipe and joint type, pipe condition, etc.) and can interface with USGS ShakeMap data (near-real-time mapping of ground motion and shaking intensity following an earthquake) to predict locations of probable damage. This tool should

also be able to incorporate post-earthquake damage assessment observations from the field to refine recommended prioritized locations for inspection and/or repair. A similar tool was developed to assist in the wastewater system recovery process following the Christchurch, New Zealand earthquake sequence of 2010-2011 (SCIRT, 2015).

Response Collaboration

It may be possible for HWD to leverage equipment and field observations from other City Departments during the response and recovery phases after a major disaster. The HWD should coordinate with the City Emergency Manager and other City Departments regarding opportunities for response collaboration in terms of sharing field data, communication equipment, staff, etc., as appropriate. The following recommendations should be considered regarding response collaboration:

- **Field Observations:** It is recommended that HWD work with the City Emergency Manager to implement a framework for sharing post-earthquake damage observations between the various City Departments and potentially private lifeline utility providers. For example, while assessing transportation routes, The City of Hillsboro Public Works Department may observe a sink-hole resulting from a leaking water pipeline and be able to share the location with HWD through the City EOC or other established communication channels.
- **Equipment Storage**: HWD should assess the locations where equipment and vehicles are stored that will be required for post-earthquake response. If those storage locations are identified as being potentially vulnerable to a seismic event or if those locations will be inaccessible due to transportation system or other earthquake damage in the surrounding area, HWD should find alternative locations that are less prone to damage or access dependencies.
- **Public Works Department Coordination**: The City of Hillsboro Public Works Department provides fleet maintenance for City owned vehicles and equipment. The HWD should coordinate with the Public Works Department and City Emergency Manager to develop clear and documented expectations for allocation of fleet and fleet maintenance resources during the response and recovery phases after a major disaster.

Equipment Preparation

HWD should ensure that an accurate inventory is maintained of existing stockpiles and assess the needs for additional repair supplies and equipment. One drawback for any equipment that is purchased solely for the purpose of response (e.g. portable emergency generator) is that the equipment will need to be exercised, maintained, and stored (at a cost) for an indefinite period of time. It is possible that equipment could be purchased and never used in its lifetime because of the unknown timing of an earthquake or other disaster. However, if some equipment can be useful to supplement normal operational purposes or could possibly be shared with other City Departments for their routine operations, it may be economically viable to purchase, store, and maintain this equipment. HWD should also have an understanding of where ordering replacement parts for critical assets may not be an option, for example, older pump stations where replacement pumps and/or parts are no longer manufactured. For these cases, HWD should develop a plan for restoring services at those locations.

Sustained Operations

The Hillsboro Water Department Emergency Response Plan addresses sustained response and recovery operations by suggesting that at least two alternates should be identified and trained for each key position within the incident management team. This suggestion is likely practical for field level operations positions but may be more difficult for more senior management positions, as was noted by utilities after the 2010-2011 Christchurch, New Zealand earthquake sequence (Offer, et al., 2016). It is suggested that the HWD COOP include strategies for providing appropriate off-duty time for staff at all levels of the organization. This will be critical for sustaining response and recovery operations for a month or possibly longer.

Financial Resources

Immediately after a major earthquake occurs that damages the HWD water system, it is anticipated that significant financial expenditures will be required associated with purchasing repair supplies, compensating consultants and contractors for design and implementation of water system repairs, paying staff for significant overtime, etc. This is anticipated to be coupled with a significant decrease in revenue resulting from service outages or customer’s inability to pay after the disaster. The financial impact will likely exceed the HWD cash reserves. Federal disaster aid may be available after the event, but short-term emergency funds will likely be required prior to Federal reimbursement. It is recommended that HWD evaluate options for establishing the necessary financial resources for sustained response and recovery operations after a major earthquake (operating reserves, capital reserves, emergency reserves, line of credit, etc.) and implement an appropriate strategy for funding response and recovery.

9.6 Dependencies

In order to achieve HWD LOS goals following a major earthquake, the water system will be dependent on numerous internal dependencies (repair supply stockpiles, equipment, staff, etc.) and external dependencies (transportation routes, liquid fuel, electricity, cellular communications, etc.). It is recommended that HWD take a proactive role in coordinating with the City Emergency Manager and other City Departments to characterize these dependencies. As critical dependencies are identified, HWD is encouraged to implement HWD resilience improvement projects that benefit not only the seismic resilience of the HWD system but of other lifeline systems as well (e.g. replacement of a seismically-vulnerable but non-critical HWD distribution pipeline that might impact a major transportation route). The evaluation and coordination of dependencies is expected to be a long-term effort driven by the increasing understanding of the interrelated vulnerabilities across lifeline systems. Integrated community-level planning will be required to fully address these dependencies and achieve a seismically resilient community. It is recommended that HWD conduct a study to assess internal and external dependencies that will impact post-disaster response and recovery. This study should actively engage the City Emergency Manager and other partner agencies to holistically evaluate the complicated dependency relationships that will impact the speed at with the community is able to respond and recover from a CSZ earthquake or other disaster.

Additionally, it is recommended that consideration of these dependencies be incorporated into the Resilient Design Guidelines to be developed by HWD. For near-term projects to be designed and constructed prior to completion of the HWD Resilient Design Guidelines, it is recommended that a project-specific dependency assessment be conducted to identify opportunities for incorporating measures to mitigate potential dependencies (e.g. harden pipelines under emergency transportation routes, increase fuel storage capacity for emergency generator, etc.).

10.0 Limitations

The opinions and recommendations presented in this report were developed with the care commonly used as the state of practice of the profession. No other warranties are included, either expressed or implied, as to the professional advice included in this report. This report has been prepared for the City of Hillsboro to be used solely in its evaluation of the seismic safety of the pressure-reducing valve vaults, reservoirs, and pump stations referenced. This report has not been prepared for use by other parties and may not contain sufficient information for purposes of other parties or uses.

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