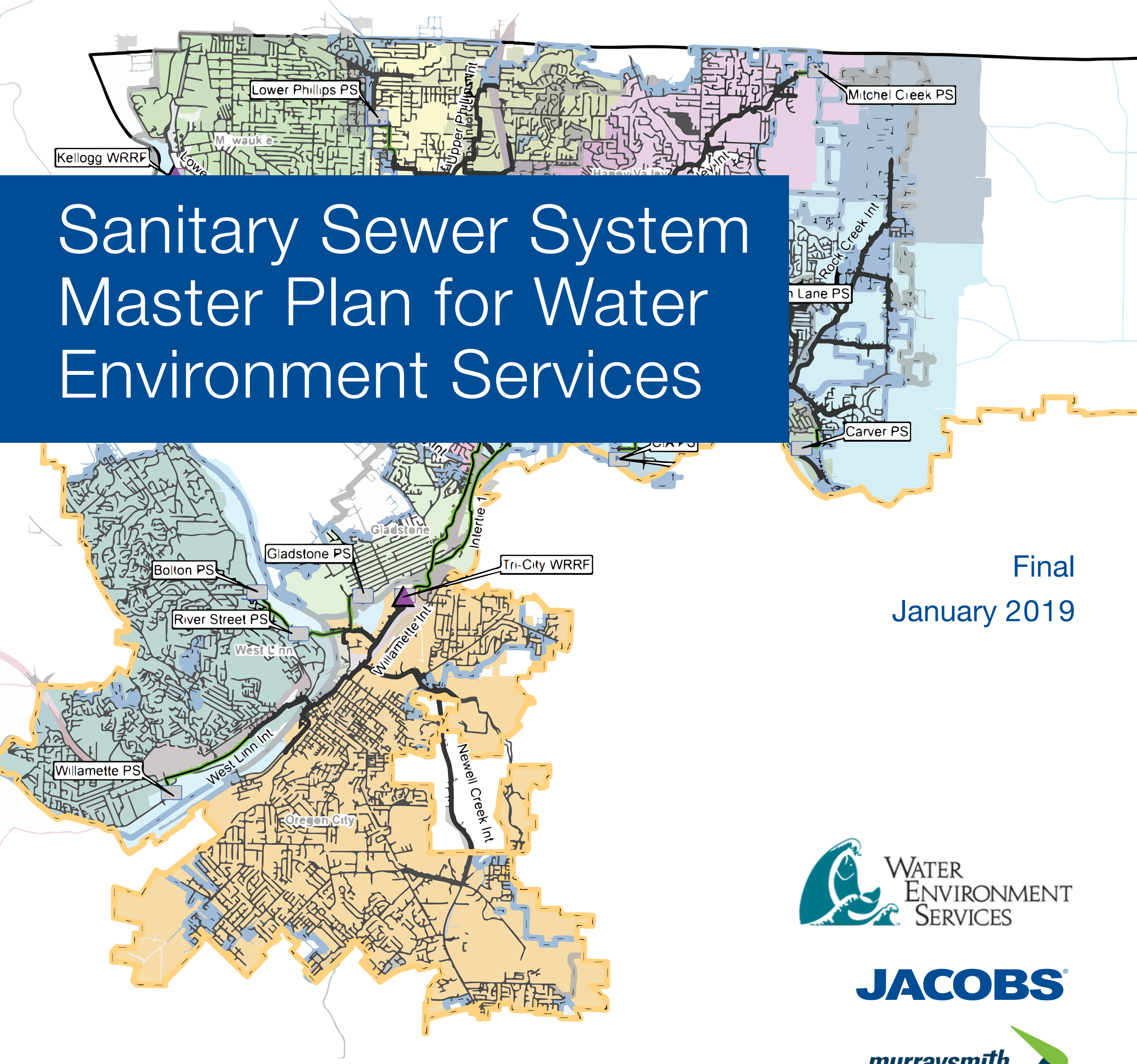


Sanitary Sewer System Master Plan for Water Environment Services

Final

January 2019

Water Environment Services

JACOBS

murraysmith

CENTURY WEST ENGINEERING

JETT Number: AX0907181122PDX

JACOBS

murraysmith

CENTURY WEST
ENGINEERING

Sanitary Sewer System Master Plan for Water Environment Services

Final

January 2019

Water Environment Services

Project No:	672585.03.30.10.12.02
Document Title:	Sanitary Sewer System Master Plan for Water Environment Services
Document No.:	AX0907181122PDX
Revision:	Final
Date:	January 2019
Client Name:	Water Environment Services
Project Manager:	Mark R. Johnson

Jacobs Engineering Group Inc.
2020 SW 4th Avenue, Suite 300
Portland, Oregon 97201
United States
T +1.503.235.5000
www.jacobs.com

Executive Summary

Water Environment Services (WES) is approaching a critical threshold for peak wet weather wastewater treatment capacity within its 46-square-mile service area. To address this capacity challenge, WES plans to expand the existing wastewater conveyance and treatment infrastructure while maintaining a critical focus on protection of public health and the environment.

Purpose

The purpose of this *Sanitary Sewer System Master Plan* (Master Plan) is to identify immediate needs in the sanitary sewer system and develop a corresponding set of capital improvement opportunities that WES can implement through the year 2040. The Master Plan was developed to provide a least-cost combination of conveyance and treatment improvements that provide maximum value across the system, including local infrastructure rehabilitation (tributary collection and local laterals), trunk line gravity conveyance upsizing, regional and intertie pump station upsizing, and wastewater treatment expansion. The Master Plan builds on an existing asset management framework to create a prioritized list of sustainable, long-term service alternatives, and provides guidance to member cities on future flow rates and rainfall-derived infiltration and inflow reduction targets and locations.

> The purpose of this Master Plan is to identify immediate needs in the sanitary sewer system and develop a corresponding set of capital improvement opportunities that WES can implement through the year 2040.

This executive summary presents contextual background information on the WES sanitary sewer system, followed by an overview of each Master Plan major section and a list of the recommendations derived from the analyses performed.

Background

WES owns and operates the trunk wastewater collection system, pump stations, and treatment systems within major portions of Clackamas County, Oregon. Historically, the largest service areas were operated within two treatment basins: (1) the Kellogg Water Resource Recovery Facility (WRRF) Basin and (2) the Tri-City WRRF Basin. The Kellogg WRRF receives wastewater from the member cities of Milwaukie, Happy Valley, and unincorporated areas within Clackamas County, while the Tri-City WRRF receives wastewater from the member cities of Oregon City, West Linn, and Gladstone. In 2000 and 2013, two intertie pump stations were constructed to divert wastewater from the Kellogg Basin to the Tri-City Basin, allowing WES to focus major treatment expansion investment at a single treatment facility. This Master Plan identifies the capital projects required to operate the trunk conveyance and regional pumping systems within the combined Kellogg and Tri-City WRRF basins by the year 2040.

In 1997, Metro adopted the *2040 Regional Framework Plan*. The framework plan identifies regional policies for implementing the 2040 Growth Concept and delineates, among other topics, the regional urban growth boundary. Metro amended the framework plan in 2005 and 2010, and again in 2014 as part of the adoption of the Climate Smart Strategy. The study area for the analyses documented in this Master Plan follows the urban growth boundary established by Metro and includes the meter basins within the WES service area.

Figure ES-1 provides an overview of the Master Plan study area.

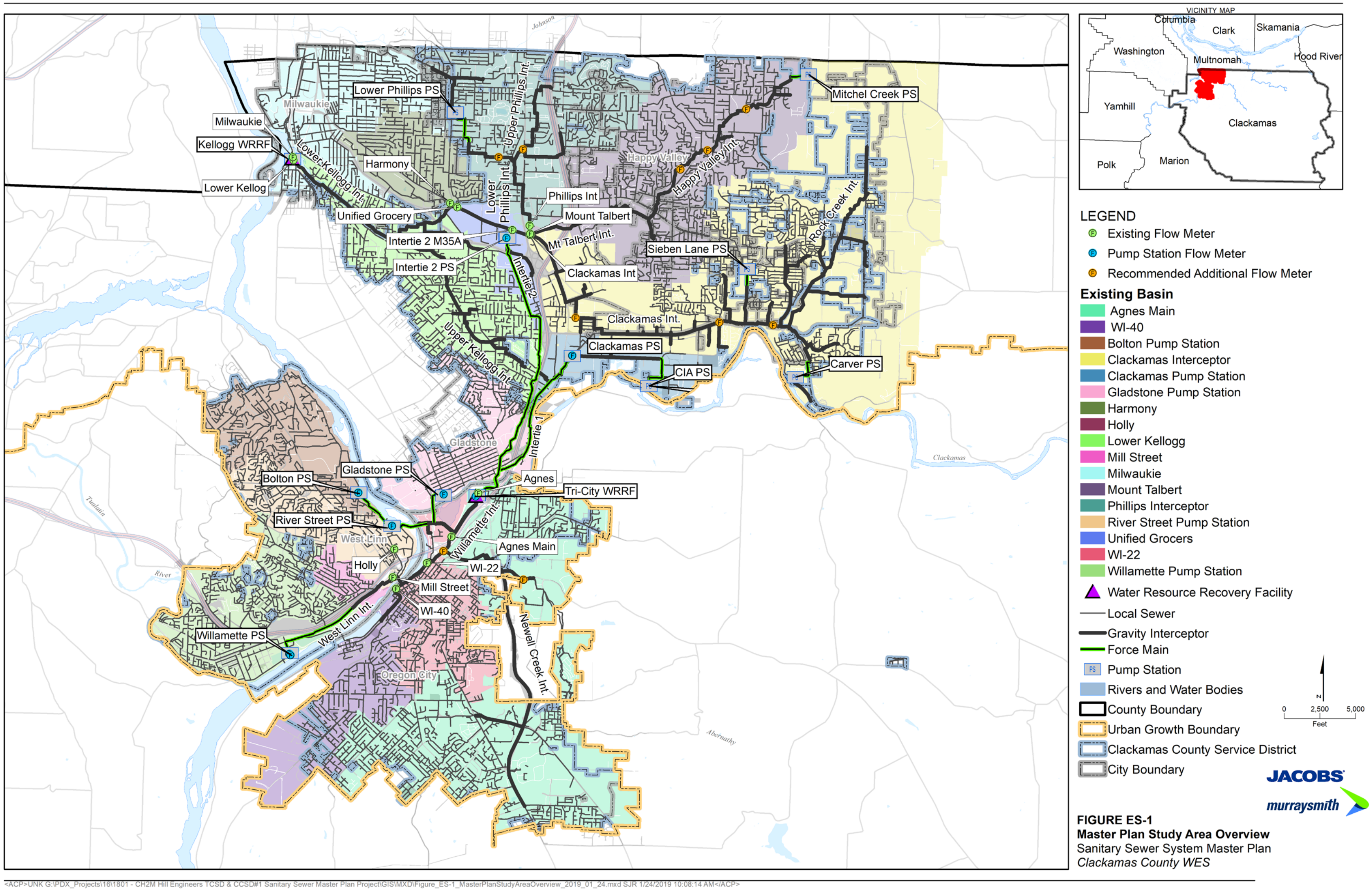


Figure ES-1. Master Plan Study Area Overview

Basis of Analysis

The primary objective of the Basis of Analysis was to develop an inventory of project data available from WES and request the data required for Master Plan development and completion. Data pertained to the condition assessment, geographic information systems, flowmeter, precipitation, and supervisory control and data acquisition, operation and maintenance, and other data consisting of future growth and existing assumptions summarized by transportation analysis zone, existing population, employee, and wet industrial data, a buildable lands inventory, and proposed capital sewer projects included in the 5-year capital improvement plan. The collected data were considered sufficient to complete the analyses described in this Master Plan.

Existing System Flow Development and Capacity Evaluation

Within the study area, WES owns and operates a large wastewater collection system with extensive infrastructure that consists of 13 trunk sewers (30 miles, 10-inch to 72-inch), 11 regional or intertie pump stations (including force mains), and two WRRF influent pump stations. Additionally, WES owns and maintains the smaller-diameter service piping in large portions of Happy Valley and unincorporated Clackamas County (about 300 miles of piping). Smaller-diameter tributary and service piping in Milwaukie, Oregon City, West Linn, and Gladstone are owned and operated by the respective cities.

WES owns and maintains flow monitoring equipment, permanent SCADA monitoring at pump stations, and precipitation gages, and relies on precipitation data from the City of Portland HYDRA rainfall network. The meter, gage, and SCADA data are used to evaluate existing system flow impacts and develop a calibrated hydrologic and hydraulic model.

To evaluate system capacity and associated capital improvements, the project team developed an InfoSWMM (Innovyze) hydraulic model that uses the industry-standard U.S. Environmental Protection Agency EPASWMM5 engine to evaluate system hydrologic response and system hydraulics. The model was developed to represent existing gravity piping greater than or equal to 10 inches in diameter, regional and intertie pump stations, and WRRF influent pump stations.

The historical storm event on November 22, 2011, was selected as the design storm to identify system deficiencies. The event exceeds 4.3 inches of precipitation over 60 hours. Because of the long storm duration and susceptibility of the system to RDI/I, the historic event produces an impact equal to or greater than the 5-year, 24-hour wintertime storm event.

The historical storm event on January 19, 2012, was selected as the design storm to size system improvements. The event exceeds 5.4-inches of precipitation over 60 hours. The design storm maximum 24-hour precipitation equals a one in 10-year precipitation frequency. The event was selected because of the trend showing increased frequency of large storms over the last decade.

The existing system has capacity to convey both dry weather flow (DWF) and groundwater infiltration (GWI) associated with winter season antecedent moisture conditions. During the design storm event, the resulting flow exceeds the treatment capacity and the existing gravity and pumping capacity at some locations. The capacity deficiencies result in predicted overflows at multiple locations. Peak flow rates are caused by high RDI/I, which in turn indicates the potential need for rehabilitation and reduction.

During the design storm event, the resulting flow exceeds the treatment capacity and the existing gravity and pumping capacity at some locations. The capacity deficiencies result in predicted overflows at multiple locations. Peak flow rates are caused by high RDI/I, which in turn indicates the potential need for rehabilitation and reduction.

Future System Flow Projections and Capacity Evaluation

The existing collection system capacity was evaluated for deficiencies with future flows in 5-year increments up to 2040 and for the buildout timeframe. The capacity evaluation used the November 22, 2011, design storm assuming system degradation (5-year design storm). The system was evaluated for flow depth, freeboard, velocity, and firm capacity deficiencies based on design criteria from WES.

Future DWF, GWI, and RDI/I peak flow estimates including degraded RDI/I cause system hydraulic deficiencies. The most substantial deficiencies occur during the design storm event and result from high RDI/I.

Future DWF, GWI, and RDI/I peak flow estimates including degraded RDI/I cause system hydraulic deficiencies. The most substantial deficiencies occur during the design storm event and result from high RDI/I.

Rainfall-derived Infiltration and Inflow Reduction Cost-Effectiveness Evaluation

Once the existing and future flow projections and capacity evaluations were completed, a system-wide cost effectiveness evaluation was performed to identify optimum levels of RDI/I reduction. The goal of the RDI/I reduction evaluation was to identify the least cost capital, operations, and maintenance investment across the system, including local infrastructure rehabilitation (tributary collection and local laterals), trunk line gravity conveyance upsizing, regional and intertie pump station upsizing, and wastewater treatment expansion.

The cost-effectiveness evaluation was performed by applying rehabilitation to subbasins sequentially from highest to lowest RDI/I impact, for three rehabilitation alternatives (20-, 30-, and 65-percent reduction), and for each timeframe. Costs encompass present value life-cycle estimates over 60 years including capital, operations, and maintenance.

The 65-percent reduction level was recommended by 2040 as the most cost-effective RDI/I reduction target. The recommendation assumes investment by cities and local jurisdictions to implement repair and replacement (R&R) programs and extend the useful life of aging pipelines, which also has the beneficial impact of reducing RDI/I. The R&R program must be supplemented by a RDI/I rehabilitation program to achieve the cost-effective solution.

Flow estimates for the future conditions at each WRRF for 2040 and buildout with targeted 65-percent RDI/I reduction are presented in Table ES-1 including a summary of Intertie 2 Pump Station diversion upgrades assuming a maximum capacity at the Kellogg WRRF of 25 million gallons per day (mgd). These flow rates are carried forward as the design flow rates for the alternatives evaluation.

The 65-percent reduction level was recommended by 2040 as the most cost-effective RDI/I reduction target. The recommendation assumes investment by cities and local jurisdictions to implement R&R programs. The R&R program must be supplemented by a RDI/I rehabilitation program to achieve the cost-effective solution.

Post-rehabilitation monitoring and hydraulic modeling are recommended to determine the impact and effectiveness of RDI/I reduction projects. This information may be used for ongoing refinement of both local RDI/I rehabilitation programs and downstream capacity improvements. To track the effectiveness of the RDI/I reduction target and update project priorities, WES should also continue the large-scale basin flow monitoring program at key locations. These flowmeter locations will serve as flow triggers for both capacity improvements and tracking of the 65-percent reduction level.

Table ES-1. Future Flow Estimates with Targeted 65-Percent RDI/I Reduction

Time	Flow Rate (mgd)	Kellogg WRRF	Intertie 2 PS	Tri-City IPS	Tri-City WRRF[a]
Existing	Average DWF	5.5	3.2	5.2	8.8
	Peak DWF	6.6	5.1	6.4	12.0
	Peak DWF + GWI	9.9	5.9	11.0	17.8
	Peak DWF + GWI + WWF[b]	25.0	14.5	62.3	78.3
	Peak Degraded DWF + GWI + WWF[c]	25.0	14.5	62.3	78.3
2040	Average DWF	7.2	5.5	6.6	12.6
	Peak DWF	9.2	6.6	9.2	16.2
	Peak DWF + GWI	14.2	7.4	14.1	22.3
	Peak DWF + GWI + WWF[b]	25.0	22.0	66.0	90.8
	Peak DWF + GWI + degraded WWF[c]	25.0	70.3	99.5	175.7
	Peak DWF + GWI + degraded & reduced WWF[d]	25.0	31.8	70.6	104.4
Buildout	Average DWF	11.0	7.1	9.7	17.7
	Peak DWF	13.9	7.9	13.8	22.6
	Peak DWF + GWI	21.2	8.9	20.1	30.5
	Peak DWF + GWI + WWF[b]	25.0	29.1	74.4	108.0
	Peak DWF + GWI + degraded WWF[c]	25.0	230.7	187.8	433.7
	Peak DWF + GWI + degraded and reduced WWF[d]	25.0	82.8	75.5	162.8

[a] Includes diversion flow rates from the Clackamas Pump Station and Intertie 2 Pump Station.

[b] Peak WWF during 11/2011 design storm, nondegraded flow rate.

[c] Peak WWF during 11/2011 design storm, degraded flow rate, no RDI/I reduction. Degraded flow rates by buildout are theoretical assuming no investment in replacement and repair of the system.

[d] Peak WWF during 11/2011 design storm, degraded flow rate, targeted 65-percent RDI/I reduction.

Collection System Condition Assessment

The project team performed a collection system condition assessment on a selection of the WES pump stations, gravity interceptors, and force main assets.

Pump Stations. The purpose of the pump station assessment was to assess the current condition of seven pump stations and their components. The component scores were combined for a comprehensive pump station assessment score. WES selected the pump stations that received the condition assessment. The pump stations not included in this assessment were either relatively new pump stations or had previously had a condition assessment evaluation by WES. The objective of the assessment was to help determine which pump station components will require attention to reduce the overall risk of an asset failure. Measures to reduce risk were incorporated into recommendations for capital improvement projects or as operational changes.

> The project team performed a collection system condition assessment on a selection of the WES pump stations, gravity interceptors, and force main assets. Condition-based recommendations were incorporated into the identification and prioritization of overall capital improvement projects.

The data collected in the field condition assessment were summarized by asset. The pump station assets are in very good condition with 78 percent of the assets in asset condition rating 1. The high percentage of assets in good and very good condition indicates that the maintenance program has maintained the assets well.

Gravity Interceptors. The purpose of the gravity interceptor work was to assess the condition of a selection of large-diameter sewer interceptors following a tiered investigation approach. The objectives of the assessment were to characterize the likelihood of failure (LOF) and identify recommended improvements and preventive maintenance alternatives.

The defect observations coded within the CCTV database were organized into three categories: structural, O&M, and corrosion. Performance issues were identified through hydraulic modeling and a review of external and internal factors. Performance defects and external/internal factors are not represented in the CCTV data, but are quantified in the overall LOF ratings.

By observation, the key findings are as follows:

- Performance deficiencies are the most significant contributor to LOF in the system.
- Relatively few inspected pipe segment assets (approximately 3 percent) have a “poor” physical condition rating of 4 or higher.
- O&M issues do not appear to be deleterious.
- None of the inspected gravity interceptors have an overall rating more severe than “Fair” (rating 3).

By observation, the key finding is that Willamette Interceptor has the highest total footage of pipes with a “Fair” rating of 3, followed by Clackamas Interceptor.

Force Mains. The purpose of the force main work was to provide a condition assessment of four preselected force mains, characterize the LOF, and identify recommended improvements and preventative maintenance alternatives. A tiered approach was used to inspect the force mains and their associated appurtenances. The tiered approach is based on an assessment of the known common modes of failure, and on the available data at the time. This approach balances risk with inspection costs and cannot completely guarantee that any and all potential failures are accounted for. Continued forecasting and maintenance plans and budgets should still include provisions for responding to intangible events and for implementing needed repairs.

The LOF ratings were compiled separately for the individual force main pipe reaches and appurtenances, and then all asset components were rolled-up into a LOF rating for each force main. The LOF ratings are a combination of the total category ratings and the associated weighting of each category in the overall LOF. By observation, the key finding here is that Willamette Force Main is the only force main with asset component LOF ratings greater than 2, resulting in the highest overall LOF rating of the force mains inspected.

Condition-based recommendations were incorporated into the identification and prioritization of overall capital improvement projects.

Risk-based Asset Evaluation

The risk evaluation of assets was based on consequence of failure and likelihood of failure. The asset hierarchy from previous master plans was expanded and revised based on condition assessment and hydraulic modeling results to provide overall risk scores for all assets. To conduct the risk assessment, the project team reviewed the framework and risk-measurement factors with WES, expanded the hierarchy with additional assets, reviewed initial scoring with WES staff, using

> The risk evaluation of assets was based on consequence of failure and likelihood of failure. The asset hierarchy from previous master plans was expanded and revised based on condition assessment and hydraulic modeling results to provide overall risk scores for all assets.

preliminary results to select assets for condition assessments, revising condition and capacity scoring, and calculated final risk scores for all assets.

The risk scores calculated were not used explicitly in the prioritization of projects because the capacity and condition deficiencies became a significant driver in project identification and prioritization. The risk scores can be considered in decisions regarding priority as more detailed capital improvement implementation plans are developed. Table ES-2 provides the overall risk scores for the existing assets that the projects and alternatives address.

Table ES-2. Risk Scores for Assets Addressed by Project Alternatives

Asset	Risk Score
Willamette Interceptor	68.5
West Linn Interceptor	66.3
Newell Creek Interceptor	42.8
Happy Valley Interceptor	41.6
Clackamas Interceptor	40.3
Mount Talbert Interceptor	36.6
Mount Scott Interceptor	31.7
Lower Phillips Interceptor	31.1
Country Village Interceptor	27.9
Intertie 2 Diversion Force Main	25.3
Oregon City Interceptor	21.4
Willamette Pump Station	21.2
Upper Phillips Interceptor	17.2
Willamette Force Main	16.5
Clackamas Force Main	16.5
Sieben Lane Pump Station	16.4
Lower Phillips Pump Station	12.0
Intertie 2 Pump Station	10.2
Intertie 1 Force Main	10.0
Clackamas Pump Station	8.7

WES may consider revising the existing likelihood of failure criteria weighting to better reflect actual drivers. Refining the risk score with higher weights on performance and physical condition is suggested for consideration to enhance the risk scoring process.

Alternatives Development and Evaluation

The alternatives development and evaluation process contributed to the selection of Master Plan improvement opportunities (also referred to as projects). Projects were developed based on the results of the capacity analysis, condition assessment, and cost-effective I/I reduction analyses. For some deficiency locations, more than one alternative was initially developed and evaluated using a set of screening criteria and presented to WES, where some alternatives were eliminated. The remaining alternatives were refined to incorporate feedback from WES and include sizing and cost estimates. The advantages and disadvantages of the alternatives were compared to support the selection of a preferred alternative(s).

Alternatives and associated design flow rates were developed for the 2040 timeframe with targeted 65% RDI/I reduction. Sizing of gravity infrastructure was identified for buildout capacity requirements as the gravity pipelines can have a life cycle of 80 to 100 years. The alternatives evaluation resulted in projects to mitigate risks associated with capacity and condition deficiencies and growth.

Alternatives and associated design flow rates were developed for the 2040 timeframe with targeted RDI/I reduction. Sizing of gravity infrastructure was identified for buildout capacity requirements as the gravity pipelines can have a life cycle of 80 to 100 years.

Project Recommendations and Prioritization

Following discussion of the alternatives developed and evaluated, WES decided to carry forward multiple alternatives for the systems served by the Clackamas Interceptor and Intertie 1 and 2 pump stations, and for the West Linn/Willamette interceptors. The complexity of the systems and the possible combinations available to fix them warranted the advancement of more than one alternative. In other locations, a single solution is recommended. Where multiple alternatives are carried forward, those alternatives will represent the starting point for subsequent predesign activities and selection of the preferred alternative.

WES decided to carry forward multiple alternatives for the systems served by the Clackamas Interceptor and Intertie 1 and 2 pump stations, and for the West Linn/Willamette interceptors. In other locations, a single solution is recommended.

Capital Improvement Projects

All of the recommendations assume the implementation of I/I reduction in the selected basins listed in Table ES-3 (Basin Details Identified for I/I Reduction by 2040).

Table ES-4 summarizes recommended projects and their respective priorities. Figure ES-2 shows the recommended projects. Projects were prioritized for implementation on the basis of: (1) the timing of the project need (based on deficiency timing) and (2) the requirements dictated by the interaction of an improvement relative to others in the system.

Table ES-3. Basin Details Identified for I/I Reduction by 2040

Priority	Subbasin	Basin	Jurisdiction	RDI/I Rate at Timeframe of Reduction Target	Estimated CIPP Rehab Length (miles)	Estimated Lateral Services	Category 1, Percentage (R&R Program)[a]	Category 2, Percentage (RDI/I Rehab Program)[b]
1	OC_M08	WI-40	Oregon City	54,600	9.7	300	100%	0%
2	OC_M10	WI-40	Oregon City	47,600	4.2	210	100%	0%
3	WL_2	Mill_Street	West Linn	31,500	8.0	1,410	87%	13%
4	Hwy_43	Holly	West Linn	28,000	20.2	1,570	79%	21%

Table ES-3. Basin Details Identified for I/I Reduction by 2040

Priority	Subbasin	Basin	Jurisdiction	RDI/I Rate at Timeframe of Reduction Target	Estimated CIPP Rehab Length (miles)	Estimated Lateral Services	Category 1, Percentage (R&R Program)[a]	Category 2, Percentage (RDI/I Rehab Program)[b]
5	US_1_10100 &DS_2_20400	Gladstone_PS	Gladstone	28,000	0.3	10	79%	21%
6	Buck_Street _2A-19	Holly	West Linn	27,600	3.6	290	78%	22%
7	1_10100	Gladstone_PS	Gladstone	25,400	7.3	1,320	73%	27%
8	Holly	Holly	West Linn	24,500	3.4	540	71%	29%
9	OC_M12	WI-40	Oregon City	24,500	30.9	1,920	71%	29%
10	2_20400	Gladstone_PS	Gladstone	23,700	9.5	1,020	69%	31%
11	River_Street	River_Str_PS	West Linn	23,200	2.1	490	68%	32%
12	WL_1_2B-1-0	Bolton_PS	West Linn	21,500	3.2	260	64%	36%
13	Willamette_9C-3	Willamette_PS	West Linn	20,600	10.2	670	62%	38%
14	Mill_Street	Willamette_PS	West Linn	19,700	19.7	990	60%	40%
15	OC_M05	Agnes_ Main	Oregon City	19,300	42.7	2,180	59%	41%
16	Mount_ Talbert	Mount_ Talbert	Clackamas Co	18,900	93.7	6,800	58%	42%
17	Bolton_3A-8	Bolton_PS	West Linn	18,000	21.1	1,450	56%	44%
18	Milwaukie	Milwaukie	Milwaukie	17,100	41.9	5,850	54%	46%
19	Clackamas_ PS	Clackamas_PS	Clackamas Co	15,000	12.9	2,130	53%	47%

[a] Category 1, R&R Program: Percentage of piping/laterals within the subbasin excluded from the cost-effectiveness analysis and attributed to local pipe repair and replacement.

[b] Category 2, RDI/I Program: Percentage of piping/laterals within the subbasin included in the cost-effectiveness analysis and attributed to RDI/I reduction.

Table ES-4. Summary of Recommended Capital Improvement Projects

Area	Project Components	Capital Cost ($M)	Required Timeframe for Project to be in Service
West Linn/ Willamette	**Alternative 2 – West Linn/Willamette Storage Project** Retrofit existing lagoon for storage of 4 million gallons of untreated wastewater (eliminates 11 mgd peak flow) (Storage can be reduced for Build Out flows) – Includes sludge removal and rehabilitation of existing open lagoon Upsize Upper Willamette Interceptor to 18-36” Upsize Middle Willamette Interceptor to 36-54”	$37.3	Current

Table ES-4. Summary of Recommended Capital Improvement Projects

Area	Project Components	Capital Cost ($M)	Required Timeframe for Project to be in Service
	Alternative 3 – West Linn/Willamette Blue Heron Alignment Project Construct new Willamette PS at 10 mgd at 80 feet TDH Use existing 28” HDPE and 24” CCP Blue Heron piping Rehabilitate existing 24” FRP river crossing Install new 20” gravity pipe from Blue Heron piping to Willamette Interceptor Upsize Upper Willamette Interceptor to 18-42” Upsize Middle Willamette Interceptor to 54-60”	$21.5	
	Alternative 4 – West Linn/Willamette New Force Main Alignment Project Construct new Willamette PS at 10 mgd at 185 feet TDH Install new 24” parallel Willamette FM (using I-205 crossing alignment) Upsize Upper Willamette Interceptor to 18-36” Upsize Middle Willamette Interceptor to 42-54”	$23.3	
Mount Talbert/ Happy Valley	**Mount Talbert Interceptor Project** I/I source investigation	--	Current
Sieben Lane	**Sieben Lane Pump Station Project** Wet well and pump rehabilitation	$0.4	Current
WES Service Area	**I/I Reduction Program** Develop 65% I/I reduction program for 19 basins	--	Current
Clackamas/ Intertie 1/ Intertie 2	**Alternative 3 – Clackamas Diversion to Jennifer/Intertie 1 Project** Upsize Upper Clackamas Interceptor to 30-54” Increase Intertie 2 PS to 19 mgd at 150 feet TDH Complete and use 30” Intertie 2 FM segments Install new 48” gravity main from Clackamas Interceptor to Jennifer Main Upsize Jennifer Main to 42-48” Construct new Clackamas (Intertie 1) PS at 15 mgd at 120 feet TDH (Replaces existing PS) New 24” Intertie 1 FM Implement three Creeks hydraulic modifications	$52.6	Current (Intertie 2 PS and FM); 2020 (Clackamas Interceptor, Clackamas PS, Intertie 1 FM, Jennifer Main)
	Alternative 4 – Clackamas Diversion to Jennifer/Intertie 2 Project Upsize Upper Clackamas Interceptor to 30-54” Increase Intertie 2 PS to 19 mgd at 185 feet TDH Complete Intertie 2 30” FM segments Install new 48” gravity main from Clackamas Interceptor to Jennifer Main Upsize Jennifer Main to 42-48” Construct new second Clackamas (Intertie 1) PS at 12 mgd at 145 feet TDH Install new 30” FM from Clackamas PS to the 20” Intertie 2 FM (using Manfield Ct) and connect to lower segment of 20” existing Intertie 2 FM Implement three Creeks hydraulic modifications	$50.8	
Lower Clackamas	**Lower Clackamas Interceptor Rehabilitation Project** Rehabilitate existing Lower Clackamas Interceptor	$5.9	2025
Upper and Lower Phillips	**Lower Phillips Project** New Linwood PS at 2 mgd at 105 feet TDH New 12” Linwood FM Decommission existing Lower Phillips PS Reconfigure Lower Phillips FM to flow to new Linwood PS (no gravity improvements required) Upsize Lower Phillips Interceptor to 18-24”	$7.7	2025

Table ES-4. Summary of Recommended Capital Improvement Projects

Area	Project Components	Capital Cost ($M)	Required Timeframe for Project to be in Service
Rock Creek	**Rock Creek Interceptor Extension Project** 12”-18” extension to existing interceptor	$6.2	2025
Lower Willamette	**Lower Willamette Interceptor Rehabilitation Project** Line existing lower Willamette Interceptor	$11.8	2030
Oregon City	**Oregon City Interceptor Rehabilitation Project** Line existing upper Oregon City Interceptor	$1.5	2030
Newell Creek and Country Village	**Newell Creek Interceptor and Country Village Interceptor Project** Upsize upper Newell Creek Interceptor to 21” Use existing middle Newell Creek Int. Upsize lower Newell Creek Interceptor. to 24-27” Upsize Country Village Interceptor to 12-21”	$4.4	2040
Tri-City WRRF	**Treatment Plant Improvements with Storage** If West Linn/Willamette Alternative 2 (Storage) is implemented, increase treatment capacity to 93 mgd	$90	2020-2040[a]
	Treatment Plant Improvements Without Storage If any other alternatives are implemented, increase treatment capacity to 104 mgd	$112	

[a] The 93 mgd or 104 mgd capacity is not required until 2040; however, it is WES’s intention to perform the full capacity increase in the 2020 to 2030 timeframe. The existing peak flow of 78.3 mgd exceeds current treatment capacity of 68 mgd.

Minor Condition-based Improvement Projects

Table ES-5 summarizes recommended minor projects associated with condition-based findings.

Table ES-5. Summary of Recommended Minor Condition-Based Improvement Projects

Area	Project Components	Capital Cost	Timeframe
Bolton and River Street Force Mains	**Bolton and River Street Force Main Rehabilitation Project** Coating, rehabilitation, and/or replacement of pipe spools and appurtenances exposed in vaults	$20,000	Existing
Gladstone Force Main	**Gladstone Force Main Painting Project** Inspection of the bridge superstructure and assessment of needed painting touchups	$100,000	Existing
Willamette Force Main	**Willamette Force Main Rehabilitation Project** Demolition of existing unused air-vacuum relief valve and vault	$7,000	Existing
Lower Kellogg	**Lower Kellogg Interceptor Project** Monitoring with isolated spot repairs to remove active infiltration	$200,000	2025

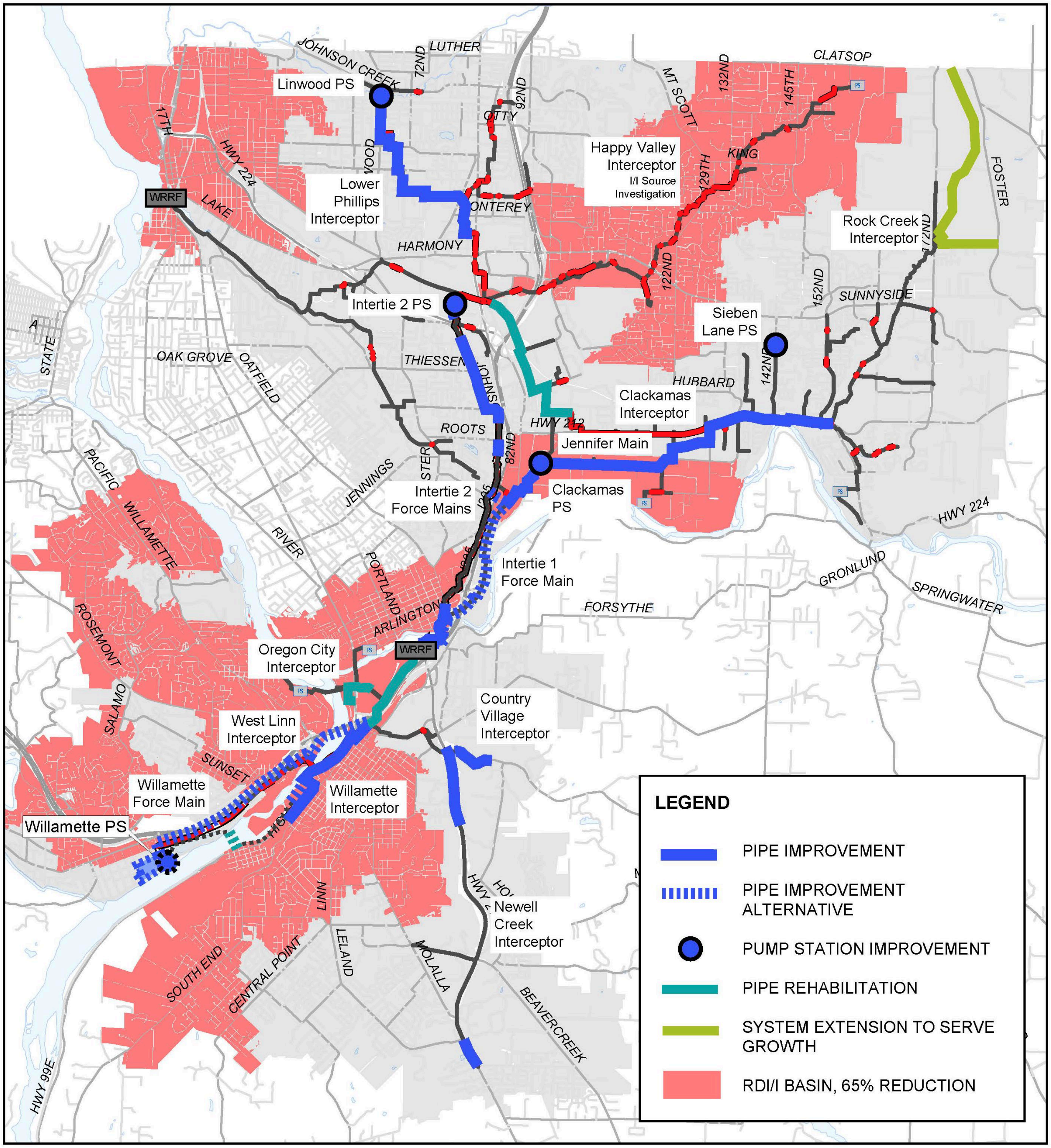


Figure ES-2. Recommended 2040 Capital Improvement Projects Map

Early Action Projects to Delay Capital Costs

Limited locations represent flow restrictions that are not common to an entire reach or area. Therefore, key locations in the system and associated conveyance system components have been identified for early implementation so that other elements of the recommended capital improvements can be deferred. The following projects are recommended for early implementation to provide flexibility for CIP implementation.

Key locations in the system and the associated conveyance system components have been identified for potential phased implementation to delay other elements of the recommended capital improvements.

1) Early RDI/I source identification and RDI/I rehabilitation within the Mount Talbert and Happy Valley Interceptor Basin.
2) Early RDI/I source identification and RDI/I rehabilitation within the Milwaukie Basin.
3) Early projects on the Clackamas Interceptor, Jennifer Main, Clackamas Pump Station, and Intertie 2 Pump Station are recommended to create flexibility for full implementation over a 5 to 7-year time frame. The following sequencing is recommended:
    a) Implement near-term improvements to the upper portion of the Clackamas Interceptor, a diversion from the Clackamas Interceptor to the Jennifer Main, and the Jennifer Main are required to accommodate growth in the Clackamas Basin.
    b) Implement pump capacity increases at the Intertie 2 Pump Station and complete approximately 3,000 feet of parallel 30-inch force main at the southern end of the force main alignment.
    c) Implement new pumps, electrical, mechanical, and wet well capacity at the Clackamas Pump Station.
    d) Utilize recommended flowmetering at CL51, CL63, CL11, the permanent Clackamas Interceptor meter, and the permanent meter at the Clackamas Pump Station to evaluate optimal diversion flow split.
4) Early RDI/I source identification and RDI/I rehabilitation within the Willamette Pump Station Basin.
5) Early projects on the Willamette Interceptor and Willamette Pump Station are recommended to create flexibility for full implementation over a 5-year timeframe. The following sequencing is recommended:
    a) Implement near-term improvements to the upper portion of the Willamette Interceptor (between WI-54 and WI-22).
    b) If Alternative 3 is selected for the West Linn/Willamette deficiencies, perform inspection, preparation, and rehabilitation of existing Blue Heron river crossing and pipeline for use as new force main to the Willamette Pump Station. Extend gravity sewer between the Blue Heron pipeline and the Willamette Interceptor.
    c) Also associated with West Linn/Willamette deficiencies, implement new pumps, electrical, mechanical, and wet well capacity at the Willamette Pump Station including split wet well option for use of new Blue Heron Force Main and the existing Willamette Pump Station force main.

    For items (b) and (c), use permanent Willamette Pump Station, Mill Street, Holly, WI-40, and WI-22 meters to track capacity and to evaluate optimal diversion flow split. Coordinate project timing with RDI/I reduction in the Willamette Pump Station Basin.

Noncapital Master Plan Recommendations

Monitoring of RDI/I Trends, Degradation, and Success of RDI/I Reduction. The cost-effective solution identified in this Master Plan depends on the combined benefits of RDI/I reduction and improvements in the collection system to increase capacity. Because the rate and amount of both I/I increase over time and the effectiveness of RDI/I removal is estimated, it is critical to monitor flows in the system relative to these estimates. Monitoring locations similar to those used in the Master Plan will allow for the most direct comparisons of future actual flows and those estimated in this plan. Improvement timing can then be assessed for acceleration or delay based on the analysis of these data. Permanent monitoring that allows for the capture of multiple wet weather events is recommended in order to best compare the wet weather peak flows in the Master Plan to future system flows as the system ages, and RDI/I reduction and capacity improvements are implemented. Flow monitoring data can also identify key locations as indicators or flow triggers for both capacity improvements and tracking of the 65-percent reduction level.

General Preventive Maintenance. It is recommended that the interceptors be placed on a regular maintenance cycle that includes the following activities:

Noncapital Master Plan recommendations are organized into the following categories:

- Monitoring of RDI/I Trends, Degradation, and Success of RDI/I Reduction
- General Preventive Maintenance
- Tier 3 Inspections for Gravity Pipelines and Force Mains
- Pump Station Asset Obsolescence

- Pipe and manhole assets should be inspected on a frequency based on their overall risk rating. The methods of inspection should mirror those used in the tiered approach followed during this study.
- For the interceptors that were not inspected as part of this study, inspection should proceed on a schedule prioritized by their current risk rating until more detailed condition assessment data can be collected to supplant the institutional knowledge ratings (similar to the process followed in this study).

For the force mains, it is also recommended to perform a regular maintenance cycle which includes the following activities:

- Air relief valves should be flushed at least every year. In addition, they should be disassembled, cleaned, and rebuilt every 2 to 3 years.
- Control valves should be exercised every 1 to 2 years.

Pipe and vault assets should be inspected on a frequency based on their overall risk rating. The methods of inspection should mirror those used in the tiered approach followed during this study.

Tier 3 Inspections for Gravity Pipelines and Force Mains. Large-diameter rehabilitation projects can be more effectively designed and constructed if Tier 3, high resolution, multisensor information data are available. Multisensor inspection may include laser profiling, sonar, and/or pipe-penetrating radar. For the rehabilitation projects identified in this report, it is recommended that Tier 3 inspection be performed prior to detailed design or construction.

Based on the findings of the prior tiers, additional Tier 3 methods including acoustic surveying, in-line inspection tools, and dewatered CCTV were evaluated for some of the force mains. As of the time of this writing, no additional Tier 3 investigation were conducted as part of the Sanitary Sewer System Master Plan, but recommendations are made to conduct additional future Tier 3 investigation for select force mains.

Pump Station Asset Obsolescence. Pump station assets were placed into three categories relative to their obsolescence. The categories are Current—Supported, Not Current – Supported (asset is out of date, but parts/repairs are available), and Obsolete – Not supported (asset is out of date and parts/repairs are not available). Seven electrical components in the WES pump stations were found to be Not current--Supported, and four others were found to be Obsolete--Not supported. Replacement of not current or obsolete assets should be considered when developing planned capital improvements.

Contents

Appendixes

Tables

Figures

Acronyms and Abbreviations

BOD	biochemical oxygen demand
CCTV	closed-circuit television
CIP	capital improvement plan
CMZ	channel migration zone
DEQ	Oregon Department of Environmental Quality
DOGAMI	Oregon Department of Geology and Mineral Industries
DWF	dry weather flow
EDU	equivalent dwelling unit
FC	future condition
fps	foot or feet per second
ft/ft	feet per foot
GIS	geographic information system
gpad	gallons per acre per day
GWI	groundwater infiltration
IPS	influent pump station
Jacobs	Jacobs Engineering Group Inc.
Master Plan	Sanitary Sewer System Master Plan
MCC	motor control center
mgd	million gallons per day
NPDES	National Pollutant Discharge Elimination System
PS	pump station
RDI/I	rainfall-derived infiltration and inflow
R&R	Repair and Replacement (Program)
service area	area identified at specified time period
SSO	sanitary sewer overflow
study area	total area including future growth
TSS	total suspended solid
VFD	variable frequency drive
WES	Clackamas County Water Environment Services
WinCan	Specialized application for the inspection and administration of wastewater network systems
WRRF	Water Resource Recovery Facility
WWF	wet weather flow

1. Introduction

Water Environment Services (WES) provides wastewater management services to approximately 76,200 households and 84,700 workers (employees) in the 46-square-mile service area. Figure 1-1 shows the study area for this Master Plan. WES has retained CH2M HILL Engineers Inc. (now Jacobs Engineering Group Inc. [Jacobs]), in association with Murraysmith, Inc., and Century West Engineering, Inc., to prepare this *Sanitary Sewer System Master Plan* (Master Plan).

1.1 Purpose

The primary purpose of the Master Plan is to establish a roadmap for identifying immediate needs in the current sanitary sewer system and, in conjunction with identified needs, develop an outline of capital improvement needs that WES can implement through 2040. The roadmap builds on an existing asset management framework to create a prioritized list of sustainable, long-term service alternatives that address both capacity and condition deficiencies. A secondary purpose of this Master Plan is to provide guidance to member cities on future flow rates and rainfall-derived infiltration and inflow (RDI/I) reduction target and locations.

This Master Plan has been developed in accordance with Oregon Administrative Rule (OAR) 660-011 which requires that "a city or county shall develop and adopt a public facility plan for areas within an urban growth boundary containing a population greater than 2,500 persons. The purpose of the plan is to help assure that urban development in such urban growth boundaries is guided and supported by types and levels of urban facilities and services appropriate for the needs and requirements of the urban areas to be serviced, and that those facilities and services are provided in a timely, orderly and efficient arrangement…" The organization of this plan generally follows the recommended organization in *Preparing Wastewater Planning Documents and Environmental Reports for Public Utilities* (DEQ et al., 2018).

1.2 Background

WES owns and operates the trunk wastewater collection system, pump stations, and treatment systems within major portions of Clackamas County, Oregon. Historically, the largest service areas were operated in two treatment basins: (1) the Kellogg Water Resource Recovery Facility (WRRF) Basin and (2) the Tri-City WRRF Basin. The Kellogg WRRF receives wastewater from the cities of Happy Valley, Johnson City, a portion of the city of Milwaukie and unincorporated areas within Clackamas County; while the Tri-City WRRF receives wastewater from the cities of Oregon City, West Linn, and a portion of the city of Gladstone. In 2000 and 2013, two intertie pump stations were constructed to divert wastewater from the Kellogg Basin to the Tri-City Basin, allowing WES to focus major treatment expansion investment at a single treatment facility and avoiding expansion of the Kellogg WRRF. This Master Plan identifies the capital projects required to operate the trunk conveyance and regional pumping systems within the combined Kellogg and Tri-City WRRF basins by the year 2040.

The Master Plan supports the *Metro 2040 Regional Framework Plan* (Metro, 1997), which identifies the regional urban growth boundary (UGB), coordinates land use designations, and establishes housing and employment densities. Study area boundaries and meter basins are within the UGB established by Metro (Figure 1-1).

1.3 Related Plans

This Master Plan derives information from the following related plans and documents:

- *Clackamas County Service District Master Plan* (Clackamas County, 2009)
- *Clackamas County Service District No. 1 Hoodland Master Plan for Wastewater Services* (Water Environment Services, 2017)
- *Metro 2040 Regional Framework Plan* (Metro, 1997)
- *Population Forecast for Clackamas County Service Districts Memorandum* (EcoNorthwest, 2016)

- *Rock Creek Interceptor Preliminary Routing Analysis, Task 2 North Extension, Task 3 East Extension Memorandum* (Century West Engineering, 2007)
- *Sanitary Sewer Master Plan* (Gladstone, April 2017)
- *Sanitary Sewer Master Plan* (Oregon City, June 2014)
- *Sanitary Sewer Master Plan Update* (West Linn, December 1999; Flow Monitoring in 2016)
- *Tri-City WPCP Site Master Plan* Update (Richwine Environmental, Inc., 2013)
- North Clackamas Revitalization Area Sanitary Sewer Improvements design plans (Clackamas County)

1.4 Target Audience

This Master Plan is targeted to the following audience:

- WES managers and staff responsible for guiding capital planning decisions, prioritizing expenditures, and providing reliable service to meet regulatory requirements, protect the public and the environment, and support the long-term goals of the community.
- to obtain guidance on future flow rates and RDI/I reduction target and locations.
- Oregon Department of Environmental Quality (DEQ) regulatory staff to review, derive permitting information, and meet potential funding requirements.
- Members of the public to provide a better understanding of WES services and responsibilities, ongoing operations and maintenance activities, facility conditions, and recommended concepts to meet current and future needs and requirements.
- Subsequent engineering design teams to support successful project implementation.

1.5 Organization of This Master Plan

This Master Plan is organized into the following sections:

- **Section 1**: **Introduction** orients the reader to the Master Plan purpose, background, related plans, target audience, and organization.
- **Section 2**: **Basis of Analysis** describes the process followed to acquire and review project data available from WES and apply that data to Master Plan development and completion.
- **Section 3**: **Existing System Flow Development and Capacity Evaluation** provides information to summarize contributing service basins and pipeline/pump station infrastructure inventory in the Master Plan study area. Documents WES design criteria, model development, design storm selection and existing system capacity deficiencies.
- **Section 4**: **Future System Flow Projections and Capacity Evaluation** provides information to summarize future system capacity including documentation of household and employment projections within the study area, description of future dry and wet weather flow methodologies, and presentation of future system deficiencies.
- **Section 5**: **Rainfall-derived Infiltration and Inflow Reduction Cost-Effectiveness Evaluation** summarizes system-wide cost effectiveness analysis and provides recommendations on target RDI/I reduction to minimize capital, operations, and maintenance investment.
- **Section 6**: **Collection System Condition Assessment** describes the efforts and outcomes of the collection system condition assessment performed on a selection of the WES pump stations, gravity interceptors, and force main assets.
- **Section 7**: **Risk-based Asset Evaluation** describes the risk evaluation of assets based on consequence of failure and likelihood of failure. The asset hierarchy from previous master plans was expanded and revised based on condition assessment and hydraulic modeling results to provide overall risk scores for all assets.

- **Section 8: Alternatives Development and Evaluation** describes the alternatives development and evaluation process to select Master Plan projects. Alternatives and projects were developed based on the results of the capacity, condition, and inflow/infiltration (I/I) reduction analyses and initially were evaluated against a set of screening criteria to eliminate and refine alternatives.
- **Section 9: Project Recommendations and Implementation** provides a summary of the selected alternatives described in Section 8. This section also provides a prioritization of projects based on (1) the timing of the need for the project based on deficiency timing and 2) the requirements dictated by the interaction of an improvement relative to others in the system
- **Section 10: References** lists the documents cited in text.

Supporting materials developed as the Master Plan evolved are provided in Appendixes A through H.

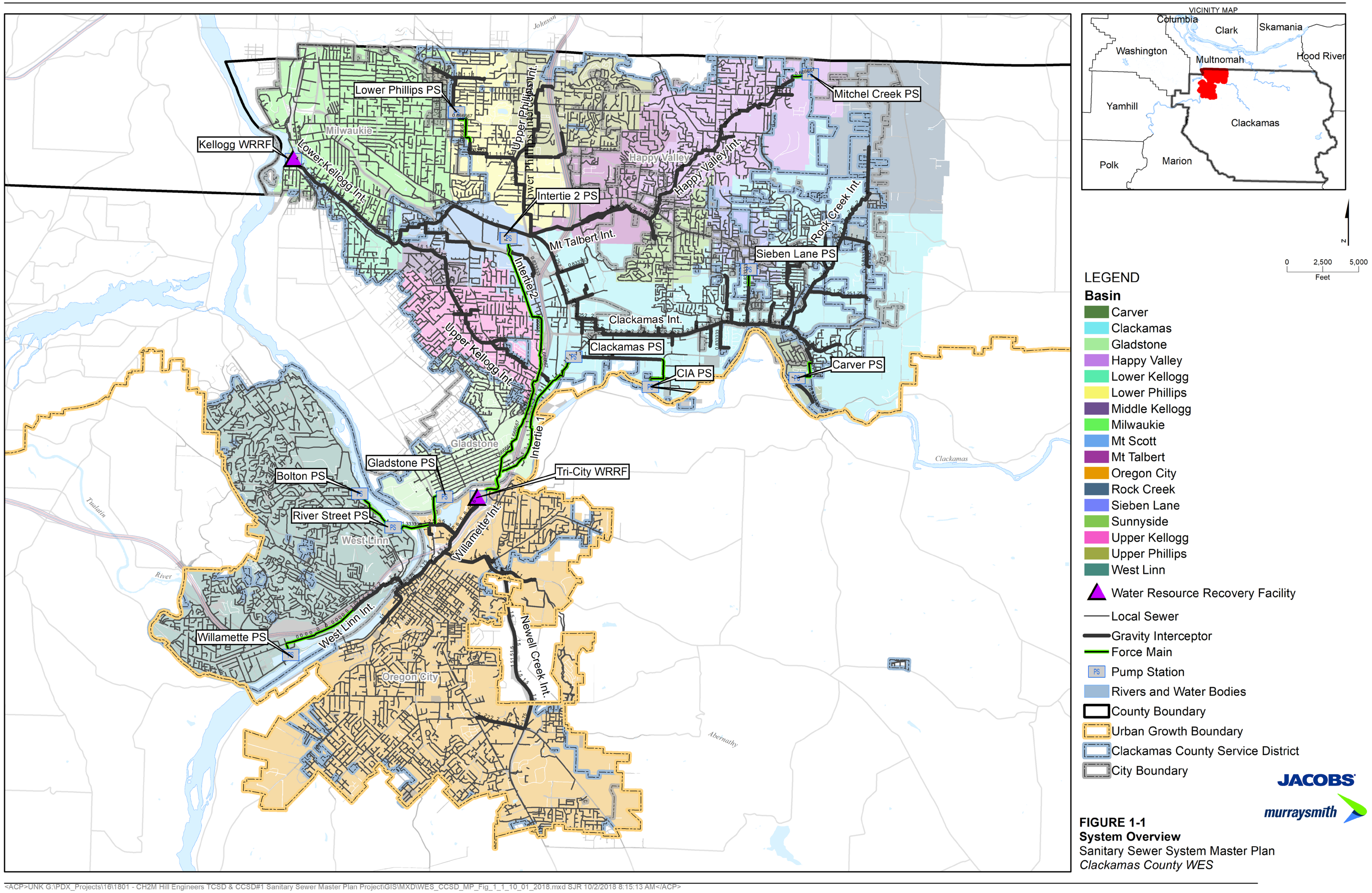


Figure 1-1. System Overview

2. Basis of Analysis

The basis of analysis consisted of a review of existing collection system data and the development of a flow monitoring plan and existing flow data assessment. This section focuses on the review of existing data.

2.1 Objectives

The primary objective of the Basis of Analysis was to develop an inventory of project data available from WES and request additional data required for Master Plan development and completion. Secondary objectives were to accomplish the following:

- Understand future growth and existing assumptions from ECONorthwest.
- Understand all the components within the collection system.
- Understand collection system as currently operated.
- Acquire all existing flow monitoring records.
- Understand diversion of flow between Kellogg WRRF and Tri-City WRRF.
- Understand the condition of the system's various assets.
- Understand the history of Sanitary Sewer Overflows (SSOs).
- Develop the information required to create a hydraulic capacity model of the existing system.
- Acquire all the GIS files necessary for mapping the system.

2.2 Methodology and Analysis

The core methodology of the Basis of Analysis was to obtain and review available data from Water Environment Services. Jacobs staff worked with the City and County planning departments covering jurisdictions within WES to collect and inventory data related to the condition assessment, GIS, flowmeter, precipitation, and SCADA, operation and maintenance, and other data needs. Preliminary data requests were made during the project kick-off meeting on February 17, 2016, followed by detailed subsequent requests through April 2016.

The following information was requested during the Hydraulic Model Update Meeting on April 28, 2016:

- Collection system – model network review and request for drawings
- Flow monitoring data
- Pump station data review and operational questions
- Intertie and diversion operations review and questions
- General operation goals and discuss specific control settings of Intertie 2 with operations staff
- Known capacity issues and reported sanitary sewer overflows (SSOs)
- Planning data update on the status of ECONorthwest planning work and deliverables

The following information was requested for the hydraulic analysis:

- GIS data and record drawings for updating hydraulic model of existing conditions
- Precipitation data for design storm evaluation
- Flow monitoring data, existing population and employment data, and operations data for model calibration
- Future population and employment data for future system loading

For the condition assessment segment of the Master Plan, the following information was required:

- Existing CCTV inspection electronic database
- CMMS work order history database
- Sewer and pump station record drawings
- Previous database of pump station assessments

2.3 Findings

The data received were considered sufficient to proceed and complete the Master Plan. Table 2-1 lists the data requested and received.

Table 2-1. Data Requested and Received

Data Category	Specific Data Requested	Data Received	Applicable Master Plan Sections
Condition Assessment Data			
CCTV	There is no current CCTV database with defect codes. However, requesting when a pipe segment had been televised.	Example CCTV databases were found by WES and delivered to Jacobs.	Not applicable
Record drawings for the force mains	6,200’ of 18” DI from Willamette Pump Station, installed in 1986	6,200’ of 18” DI from Willamette Pump Station, est. 1986	Sections 3 and 6
	6,300’ of 16” DI from Bolton Pump Station installed in 1985	6,300’ of 16” DI from Bolton Pump Station	Sections 3 and 6
	2,600’ of 12” DI from River Street Pump Station installed in 1985	2,600’ of 12” DI from River Street Pump Station	Sections 3 and 6
	2,800’ of 20” Concrete Cylinder Pipe from Gladstone Pump Station installed in 1985	2,800’ of 20” Concrete Cylinder Pipe from Gladstone Pump Station, est. 1985	Sections 3 and 6
CMMS work order history database	Cleaning, repairs, inspection	Received	Section 6
GIS Data			
Sanitary Sewer GIS	Pipe network (diameters, invert elevations, materials, date of installation; manhole rim and invert elevations); Pump/lift station location	Pipe network received Pump/lift station location received.	Sections 3, 6, and 7
County Background GIS	Tax lots Roadways Rail Zoning Contours Wetlands / Critical Areas Floodplain Archaeological boundaries	Received – roadways, contours, wetlands, flood plains Provided portal info to download tax lots and zoning Received – wetlands/critical areas, floodplain Restricted (unavailable) – cultural, archaeological.	Sections 3, 6, and 7
Utilities GIS	Storm Water Electric Gas Communication utilities	Storm GIS File received Because water, electric, gas, communication require coordination with other utility companies or Cities, they were not included in analysis.	Sections 3, 6, and 7
Services GIS	Fire Police Hospital School locations	Received – fire, school, hospitals	Sections 6 and 7
Flowmetering GIS	Flowmetering locations	Draft PDFs received from Matt House. GIS shapefiles not received	Sections 3, 5, and 6

Table 2-1. Data Requested and Received

Data Category	Specific Data Requested	Data Received	Applicable Master Plan Sections
Flowmeter, Precipitation, and Scada Data			
WES Flowmeters and SCADA (Flow, velocity, and depth data)	For the past 5-years to current, preferably in 5 to 15-min increments.	Received – data for the following locations (2011-present): • Agnes • Agnes Main • Bolton • Clackamas Interceptor • Gladstone • Mill Street • Milwaukie • Mount Talbert • Phillips • River Street • Unified Grocery • WI 22 • WI 40 • Harmony • Willamette • Intertie 2 Pump Station • Clackamas Pump Station • WL20-10 • Kellogg Plant Influent • Tri-City Plant Influent Received – annual summary of average flow by season, and max day flow at treatment plants from 2000-2015 Outstanding flow data: • M35A (Johnson Rd near railroad tracks, 15-min data) • Older influent flow data at Kellogg and Tri-City Plants for design storm analysis (pre-2011, 15-min to hourly data preferred).	Sections 3, 4, 5, and 6
Precipitation data for WES gage(s)	Historic and current data, 5- to 15-min increments preferred, hourly max	Received – Precipitation data for: Unified Grocery River Street Clackamas Interceptor Bolton Pump Station	Section 3
Records of SSOs and documented causes		Received– database of SSOs	Sections 3, 6, and 7
Operation and Maintenance			
Pump station data	Number of pumps Wet well dimensions Pump on/off set points VFD settings if applicable	Received – pump station data	Sections 3, 6, and 7
Pump station asset data for eight pump stations not in the data base. (Five pump stations that will be evaluated and three that are new and will not be evaluated.)	ACES Setup Template contains fields for requested information	Received – for 5 Pump Stations.	Sections 3, 6, and 7

Table 2-1. Data Requested and Received

Data Category	Specific Data Requested	Data Received	Applicable Master Plan Sections
Updated condition assessment on six pump stations evaluated by WES staff.	Information can be transmitted via spreadsheet or entered into ACES database – need to coordinate entry if latter approach is used.	Received	Sections 6 and 7
Operational data related to diversions	Weir or gate heights Control Strategy	Received Diversion Pump Station Control Strategy document.	Sections 3 and 6
Other Data			
Future growth and existing assumptions from ECONorthwest summarized by transportation analysis zone	Population estimates Forecast of employees, Known wet industrial development	Received June 6, 2016.	Section 4
Existing population, employee data and wet industrial data	Requested as soon as available from ECONorthwest to support model calibration.	Received June 6, 2016.	Section 3
Buildable Lands Inventory	If available – may not be necessary if ECONorthwest data are sufficient	Using ECONorthwest Data	Section 4
Proposed capital sewer projects included in 5-year CIP.		Received	Sections 7 and 8

3. Existing System Flow Development and Capacity Evaluation

Section 3 provides information to summarize the contributing service area and pipeline/pump station infrastructure inventory in the Master Plan study area. The section provides details on development and calibration of the trunk sewer model used to estimate system flow rates and analyze system capacity deficiencies. Design criteria for evaluating system capacity are outlined and include design storm selection. Finally, existing system capacity deficiencies are highlighted based on exceedance of the design criteria.

3.1 Objectives

The objectives of this section are as follows:

- Define the existing system service area, basin delineation, households, and employees.
- Provide an inventory of WES pipeline and pump station infrastructure.
- Document hydraulic model development and calibration.
- Summarize capacity design criteria and design storm selection.
- Describe existing system capacity deficiencies.

3.2 Methodology and Analysis

3.2.1 Service Area Definition

WES owns and operates the trunk wastewater collection system, pump stations, and treatment systems within major portions of Clackamas County, Oregon. Historically, the largest service areas were operated in two treatment basins: (1) the Kellogg WRRF Basin and the Tri-City WRRF Basin. The Kellogg WRRF receives wastewater from the cities of Happy Valley, Johnson City, a portion of the city of Milwaukie and unincorporated areas within Clackamas County; while the Tri-City WRRF receives wastewater from the cities of Oregon City, West Linn, and a portion of the city of Gladstone. In 2000 and 2013, two intertie pump stations were constructed to divert wastewater from the Kellogg basin to the Tri-City basin allowing WES to focus major treatment expansion investment at a single treatment facility and avoiding the expansion of the Kellogg Facility.

This Master Plan identifies the capital projects required to operate the trunk conveyance and regional pumping systems within the combined Kellogg and Tri-City WRRF basins. The Master Plan supports the *Metro 2040 Regional Framework Plan* (Metro, 1997), which identifies the regional UGB, coordinates land use designations, and establishes housing and employment densities. Study area boundaries and meter basins are within the UGB established by Metro and are shown on Figure 3-1.

3.2.2 Pipeline and Pump Station Inventory

Within the study area, WES owns and operates a large wastewater collection system with extensive infrastructure including thirteen trunk sewers (30 miles, 10-inch to 72-inch), eleven regional or intertie pump stations (including force mains), and two WRRF influent pump stations. Additionally, WES owns and maintains the smaller diameter service piping in large portions of Happy Valley and unincorporated Clackamas County (~300 miles of piping). Smaller diameter tributary and service piping in Milwaukie, Johnson City, Oregon City, West Linn, and Gladstone are owned and operated by the respective cities.

The pipeline and pump station inventories are summarized in Tables 3-1, 3-2, and 3-3 and presented in Figure 3-1.

Table 3-1. Interceptor Piping Inventory

Interceptors	Length (feet)							
	8-inch	10 to 12-inch	15 to 18-inch	21 to 27-inch	30 to 36-inch	42 to 48-inch	54-inch	72-inch
Lower Kellogg Interceptor	0	0	0	0	0	9,812	0	0
Mount Scott Interceptor	0	0	0	0	5,810	5,586	0	0
Lower Phillips Interceptor	0	8,553	0	0	0	0	0	0
Mount Talbert Interceptor	0	0	0	9,314	0	0	0	0
Happy Valley Interceptor	1,060	3,821	12,373	0	0	0	0	0
Clackamas Interceptor	0	66	4,328	19,964	0	0	0	0
Jennifer Main	0	6,442	22	0	0	0	0	0
Willamette Interceptor	0	687	2,054	788	641	1,672	3,206	3,201
Abernathy Interceptor	0	0	0	0	0	5,103	0	0
Newell Creek Interceptor	0	0	9,564	5,510	0	0	0	0
Rock Creek Interceptor	0	3,581	128	6,622	4,628	1,012	0	0
Upper Phillips Interceptor	0	2,290	5,322	154	0	0	0	0
Upper Kellogg Interceptor	0	6,232	3,464	0	0	0	0	0

Table 3-2. Total Pipe Inventory, WES and Non-WES Owned

Jurisdiction	Length (miles)							
	8-inch	10 to 12-inch	15 to 18-inch	21 to 27-inch	30 to 36-inch	42 to 48-inch	54-inch	72-inch
Happy Valley and Unincorporated Clackamas County[a]	297	25	13	8	2	3	0	0
Milwaukie[b]	37	8	2	1	0	0	0	0
Gladstone[b]	22	6	2	1	0	0	0	0
Oregon City[b]	131	15	11	5	1	4	2	4
West Linn[b]	87	13	12	6	0	0	0	0
Johnson City[b]	1							

[a] Trunk and small diameter piping owned and maintained by WES.

[b] Trunk piping owned and maintained by WES, small diameter piping owned and maintained by respective City.

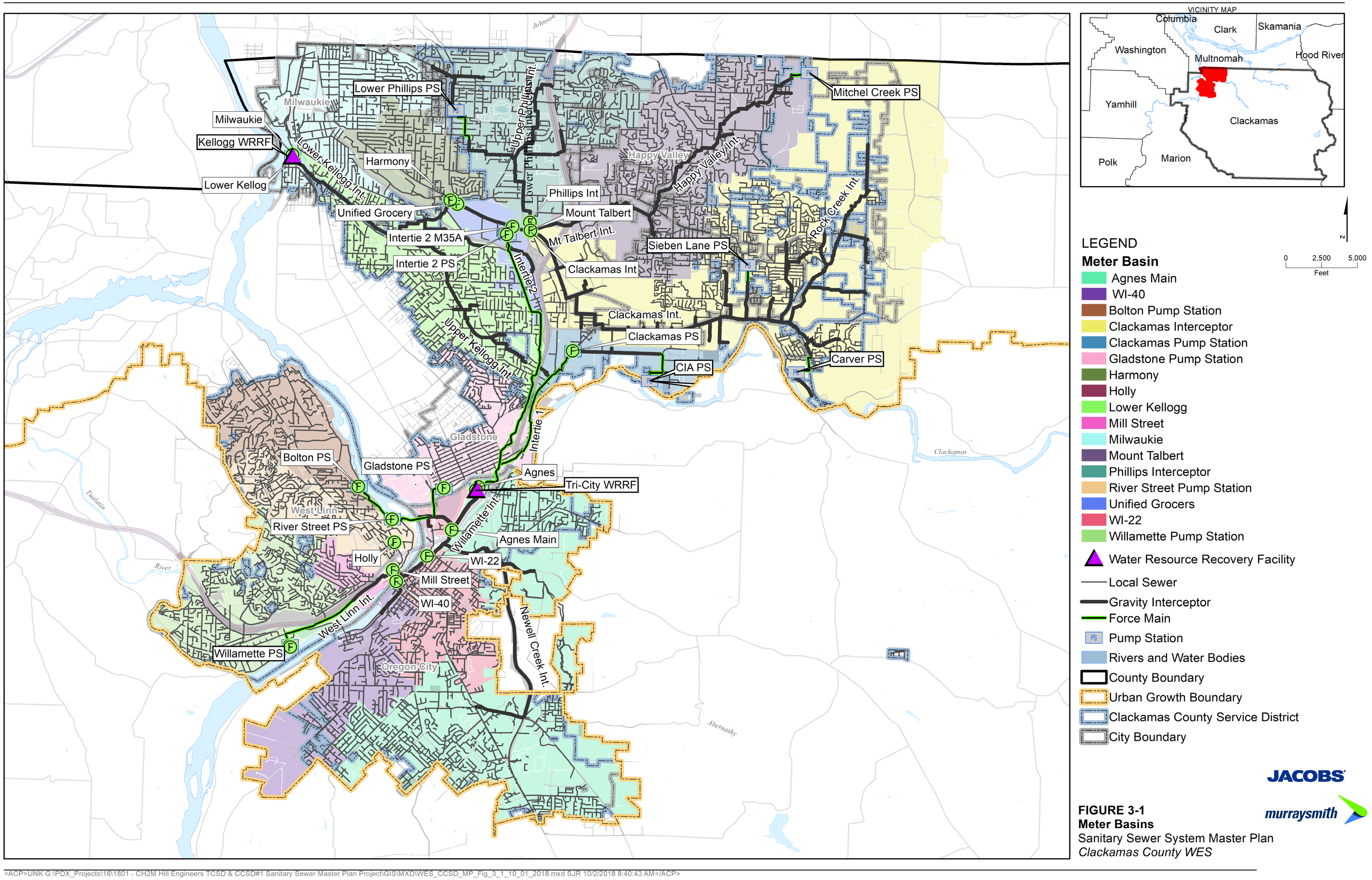


Figure 3-1. System Overview with Meter Basins

Table 3-3. Pump Station and Force Main Inventory

Pump Station	Firm Capacity (mgd)	Maximum Capacity (mgd)	Force Main Diameter (inches)	Force Main Length (miles)
Bolton	4.0	5.5	16	1.2
Carver	2.6	3.2	12	0.4
CIA	1.6	1.9	10	0.5
Clackamas	2.5	3.0	12	2.5
Gladstone	5.9	7.2	20	0.5
Intertie 2	10.4	16.7	20	4.0
Lower Phillips	1.0	1.7	8	0.6
Mitchell Creek	0.5	1.0	8	0.4
River Street	2.8	3.2	12	0.5
Sieben Lane	2.2	3.0	10	0.2
Willamette	4.4	5.8	18	1.2
Tri-City IPS	67.7	89.3	72	-
Kellogg IPS	37.6	50.4	60	-

[a] Firm capacity is defined as peak flow capacity with largest pump out of service. Maximum capacity includes all pumps operating.

Notes:

IPS = influent pump station

mgd = million gallons per day

3.2.3 Basin Delineation and Flow Monitoring

WES owns and maintains flow monitoring equipment, permanent Supervisory Control and Data Acquisition (SCADA) monitoring at pump stations, and precipitation gages. They also rely on precipitation data from the City of Portland HYDRA rainfall network at a gage located at 2033 Southeast Harney Street (near boundary of Milwaukie and Portland, 1.5 miles from Kellogg WRRF). An inventory of the meter locations is provided in Table 3-4 including reference to the available historic date ranges at each site and summary of data quality. Sewer basins were delineated at the meter scale. Flowmeters, pump stations, and precipitation gages are presented in Figure 3-1 including delineation of each meter basin.

The meter, gage, and SCADA data were used to evaluate existing system flow impacts and to develop a calibrated hydrologic and hydraulic model. The data were reviewed during key dry and wet weather periods utilizing the following methods:

- Time series of flow data were reviewed for consistency and quality. Potential inaccuracies may occur as instantaneous flow spikes (meter error), data gaps, or poor data quality after a large flow event.
- Time series of velocity and depth data were reviewed for consistency and quality. Potential inaccuracies may occur as instantaneous velocity or depth spikes (meter error), negative values, data gaps, variability of data, or poor data quality after a surcharged flow event.
- Scatter data of depth versus velocity were reviewed for correlation and potential outliers. Data should correlate linearly between velocity and depth. The correlation may diverge as a result of poor-quality data or surcharging.
- Overall data quality was identified as good to fair and adequate for calibrating the District model and extrapolating system flow rates. Precipitation during the December 2015 time period in particular

resulted in measured system response and surcharging during several larger storm events consistent with a 2 to 10-year precipitation frequency.

Table 3-4. Flowmeter Inventory and Data Quality

Meter and Basin	Location/Description	Data Availability	Data Quality
Agnes	West side of Agnes Avenue across from bank	01/2011 - 02/2016	Good to Fair
Agnes Main	Agnes Ave south of the Tri-City WRRF	01/2011 - 02/2016	Good to Fair
Bolton Pump Station	East of Bolton Pump Station	12/2011 - 02/2016	Good to Fair
CCSD 1 Diversion	Combined diversion flow from Clackamas Pump Station and Intertie 2 Pump Station to Tri-City WRRF	01/2011 - 02/2016	Good to Fair
Clackamas Interceptor	Clackamas Interceptor	01/2011 - 02/2016	Fair
Clackamas Pump Station	Discharge valve vault Clackamas Pump Station	05/2015 - 02/2016	Good
Gladstone Pump Station	Influent manhole to Gladstone Pump Station	01/2011 - 02/2016	Fair
Harmony	West side of Linwood before railroad	06/2012 - 05/2014, 02/2015 - 02/2016	Fair
Holly	In front of tax lot 22E30CA02000, West Linn manhole	03/2014 - 02/2016	Fair to Poor
Intertie 2 - M35A	End of Johnson Road near railroad	06/2013 - 02/2016	Good
Intertie 2 Pump Station	Discharge valve vault on Intertie 2 Pump Station 20-inch force main	07/2013 - 02/2016	Good
Kellogg IPS	IPS at Kellogg WRRF	10/2011 - 02/2016	Good
Mill Street	Near West Linn Paper Company	01/2011 - 02/2016	Good to Fair
Milwaukie	Near Kellogg WRRF	01/2011 - 02/2016	Good to Fair
Mount Talbert	Mount Talbert Interceptor	01/2011 - 02/2016	Good to Fair
Phillips Interceptor	Phillip Pump Station Interceptor	01/2011 - 02/2016	Fair
River Street Pump Station	River Street Pump Station manhole	01/2011 - 02/2016	Good to Fair
Tri-City IPS	IPS at Tri-City WRRF	01/2011 - 02/2016	Good
Unified Grocery	Near Unified Grocery, northwest corner near railroad	01/2011 - 02/2016	Good to Fair
WI-22	Willamette Interceptor, west side of Mcloughlin Blvd and 14th in Oregon City	11/2014 - 02/2016	Good
WI-40	Willamette Interceptor, McLoughlin Blvd across the street from tax lot 22E31AB07900	05/2014 - 02/2016	Good to Fair
Willamette Pump Station A	Across the street from Willamette Pump Station	01/2011 - 02/2016	Good to Fair
Willamette Pump Station B	South of Willamette Pump Station	01/2011 – 05/2014, 03/2015 – 10/2015	Good to Fair

3.2.4 Model Development

To evaluate system capacity and associated capital improvements, the team developed an InfoSWMM (Innovyze) hydraulic model from WES geographic information system (GIS). The model utilizes the industry standard EPASWMM5 engine (United States Environmental Protection Agency) to evaluate system hydrologic response and system hydraulics. The model was developed to represent existing gravity piping greater than or equal to 10 inches in diameter, regional and intertie pump stations, and WRRF influent pump stations. Only piping and infrastructure within the WES GIS were used to develop the model. Member city infrastructure was excluded unless specifically included in the WES GIS such as the Newell Creek Interceptor in Oregon City.

Attributes used to define model pipe geometry include spatial location, pipe diameter, manhole rim elevation, manhole invert elevation, pipeline upstream invert elevation, and pipeline downstream invert elevation. Model profiles were reviewed to ensure data accuracy. For intermittent data errors such as adverse slopes, elevation data were interpolated between accurate upstream and downstream data points. Missing rim elevations were populated to the model database by extraction from available topographic surface data.

Similar elevation, diameter, and spatial information were used to define force mains. Force mains were digitized and subdivided into 400-foot segments. Elevations at subdivided points were extracted from available topographic surface data and depths were estimated from available as-built drawings.

Pump stations were defined by curves representing wet well volume by depth, number of pumps, and manufacturer pump curves. Pump station operations were programmed into the model based on WES control narratives which primarily identify the water depth within the wet well to signal the pump(s) on or off. Variable frequency drive speed setting by wet well water depth were also programmed where appropriate.

The Intertie 2 Pump Station is controlled based on flow at the diversion location and the Intertie 2 wet well depth. The pump station has two sets of pump sizes (5 mgd, 10 mgd firm capacities). The unique operation was programmed into the model using a flow diversion curve located at the diversion from the Mount Scott Interceptor to the Intertie Pump Station (diversion at M35B), pump setting curves, and the wet well depth settings. The operations of the Intertie 2 Pump Station are described below.

- No pumping to small pump operation – Small pump ON when diversion flow is greater than 1 mgd and pump station wet well depth is greater than 13 feet for more than 5-minutes.
- Small pump to large pump operation – Large pump ON and small pump OFF, when small pump is operating at 99 percent speed or greater, diversion flow exceeds 1.25 mgd, and wet well depth is greater than 13.5 feet for more than 5-minutes.
- Large pump to small pump operation – Small pump ON and large pump OFF, when large pump is operating at 50 percent speed or less and flow diversion is less than 1.36 mgd for more than 5-minutes.
- Small pump to no pumping operation – Small pump OFF, when small pump is operating at 50 percent speed or less, flow diversion is less than 1.36 mgd, and wet well water surface is less than 9 feet for more than 5-minutes.

3.2.5 Model Flow Definition

The major components of the wastewater flow identified for the study area are described below and illustrated on Figure 3-2:

- **Base or Dry Weather Flow (DWF)** is wastewater from residential, commercial, institutional (e.g., schools, churches, hospitals), and industrial sources. The dry weather wastewater flow is a function of the population and land use and varies throughout the day in response to water usage.
- **Groundwater Infiltration (GWI)** is defined as groundwater entering the collection system unrelated to a specific rain event. GWI occurs when groundwater is above the sewer pipe invert, and infiltrates

through defective pipes, pipe joints, and manhole walls. This component of the wastewater flow is typically seasonal and higher during the winter months.

- **Wet Weather Flow (WWF, RDI/I)**, also known as *rainfall derived infiltration and inflow* (RDI/I), is stormwater that enters the collection system during or immediately following a rain event. Stormwater inflow reaches the collection system by direct connections, holes in manhole covers, or cross-connections with storm drains. Infiltration includes flow that enters defective pipes, pipe joints, and manhole walls after percolating through the soil during and immediately following a storm event.

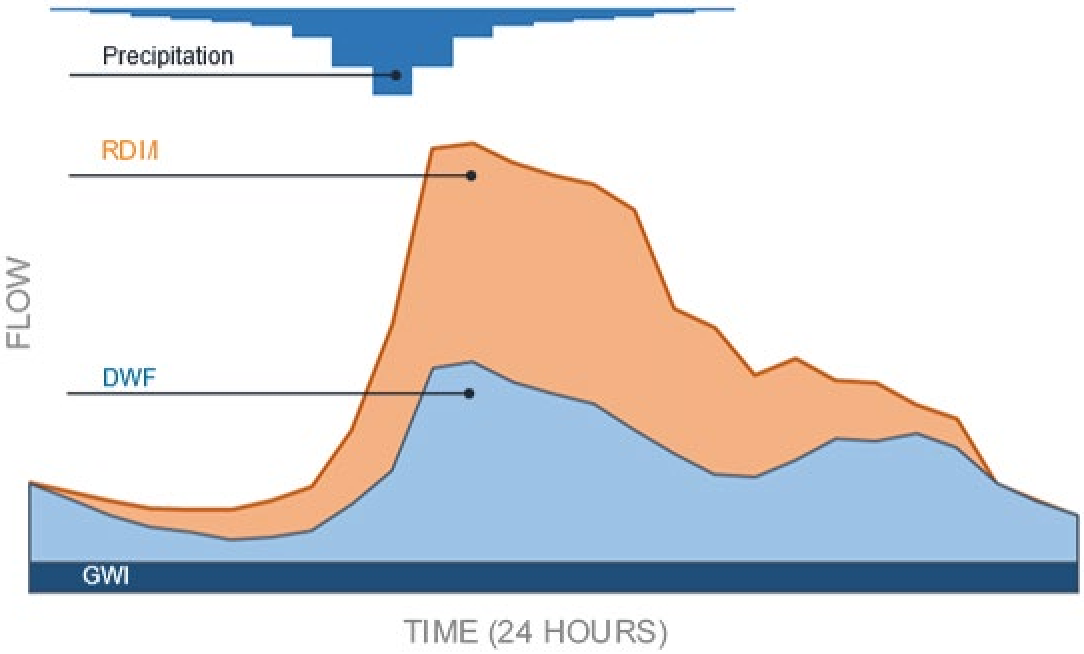


Figure 3-2. Flow Definition

3.2.6 Existing System Flow Calibration

The existing system flow rates were calibrated within the model for DWF, GWI, and RDI/I conditions at the 20+ meter locations. The model flow methodology is summarized as follows:

- The DWF component of the model consists of a base flow (daily average) and a normalized diurnal pattern that informs the model how to adjust the average flow throughout the day. Within each meter basin, the calculated base flows from the flowmeters are distributed to model manholes based on zoning classification, calibrated unit flow factors, and tax lot boundaries falling within the manhole service areas. The base flow represents wastewater during dry months of July, August, and September.
- The GWI component of the model includes a differential between the DWF during the summer months and nonrain periods for winter months as measured at each meter location.
- The RDI/I component of the model consists of a storm event, sewershed acreage (wet weather area of impact, approximate 100-foot buffer around piping), and RDI/I unit hydrograph. During the model calibration, actual precipitation data are used to perform the wet weather simulations and adjust unit hydrograph parameters. Once the model is calibrated, a design storm event is used to simulate design flow rates in the system using the calibrated unit hydrographs.

The flowmeter and SCADA data quality were determined as “good” to “fair,” and adequate to develop an accurate model calibration (see Table 3-4). During the calibration tasks, data anomalies such as flow spikes were ignored or eliminated to ensure that the model is not overly conservative. Additionally, where data gaps exist, secondary rainfall periods or alternate year dry periods were used to develop existing system wastewater flows.

Flow monitoring and SCADA data during several 2 to 3-week DWF periods were used to calibrate DWF and GWI components of the model. The average monthly flows are summarized for the period of record at the Kellogg and Tri-City Wastewater WRRF influent meters on Figures 3-3 and 3-4. Based on a review of the meter and precipitation data, the key time periods for DWF and GWI model calibration were selected from 2015 and 2016 including:

- DWF – July, August, and September 2015
- GWI – Nonrain periods in October, November 2015 and January, February 2016

Flow monitoring and SCADA data during the three largest precipitation months were considered for calibration with the largest event selected as the primary calibration event for RDI/I. Secondary events were used where inadequate flowmeter data were available during the primary calibration event.

- December 2015 (primary calibration event, 10+ year frequency event)
- January 18-22, 2012 (secondary calibration event)
- November 18-22, 2012 (secondary calibration event)

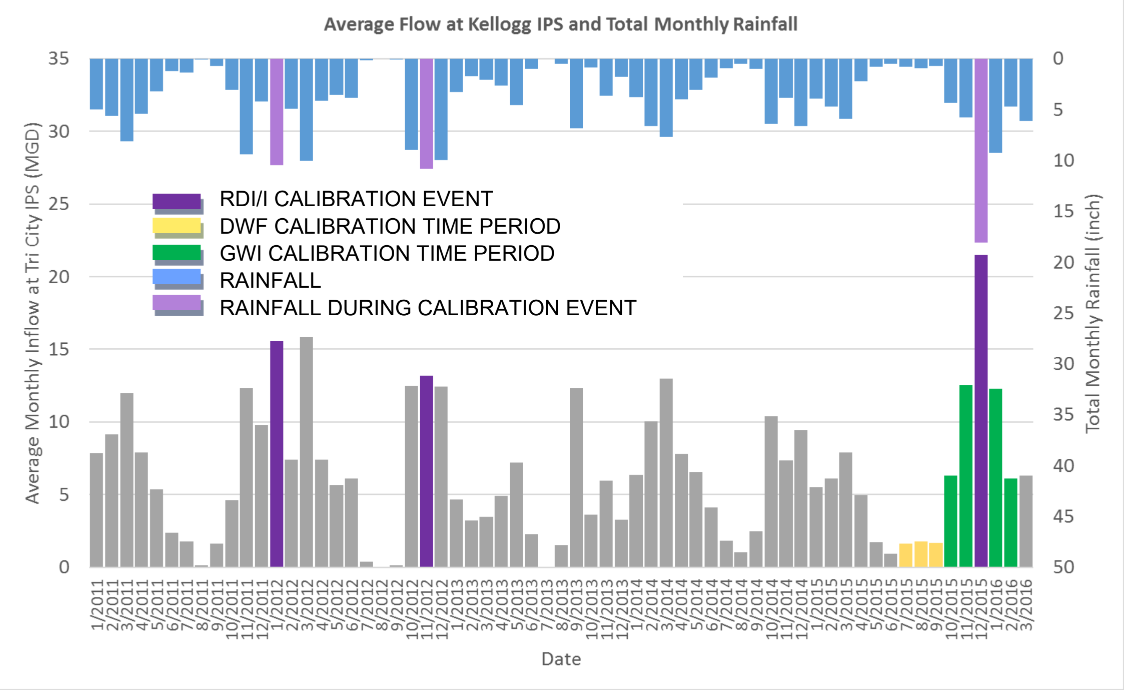


Figure 3-3. Average Monthly Flow and Total Precipitation Kellogg WRRF, 2011-2016

3.2.6.1 Dry Weather Flow Development and Calibration

Metro publishes household and employment estimates for existing and future time periods through 2040 by transportation analysis zone (TAZ) polygons. The estimates are based on the United States Census (2010). EcoNorthwest provided documentation of existing and future household and employee estimates for WES service boundaries and the study area in 5-year increments between 2015 and 2040 by Metro TAZ (*Population Forecasts for Clackamas County Service Districts*, August 2016). All flow estimates for existing and future planning horizons including the model calibration of existing flow rates were coordinated with data from the EcoNorthwest document. This section of the Master Plan references existing planning employment and household data, while Section 4 of the Master Plan references future planning data. The study area data for existing households and employees are 76,200 and 84,700 respectively.

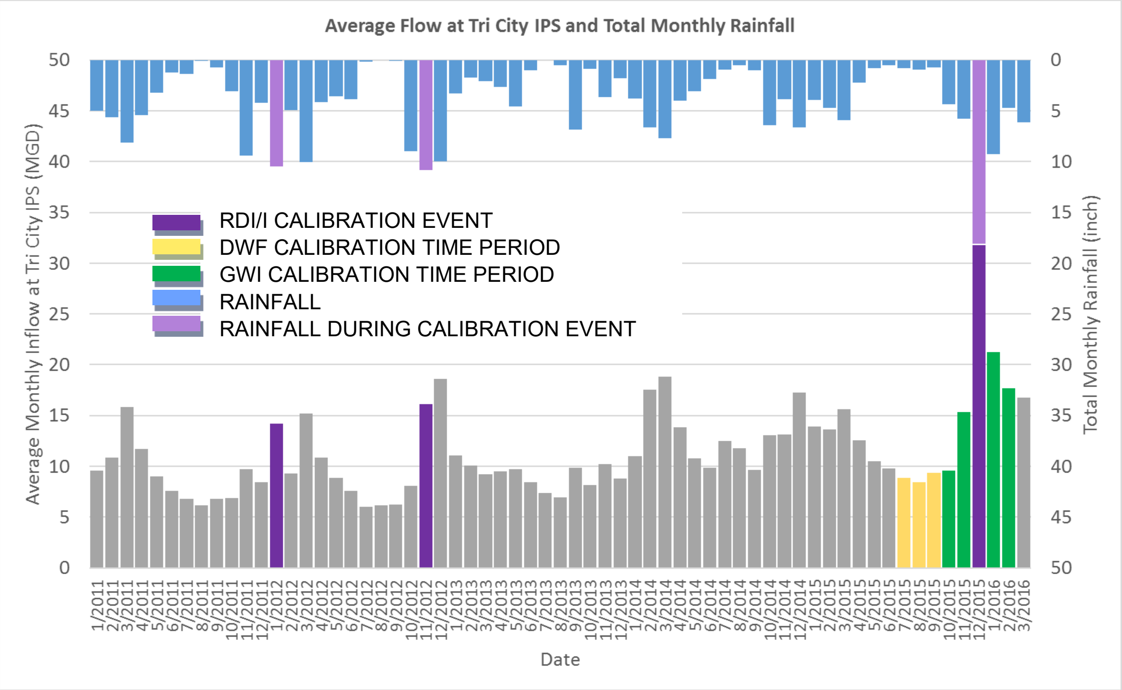


Figure 3-4. Average Monthly Flow and Total Precipitation Tri-City WRRF, 2011-2016

Before completing the DWF calibration, data were extracted from the flow monitoring data and reconciled with the planning estimates as follows:

- Average flow data and diurnal patterns were extracted from the flowmetering data using EPASSOAP (*United States Environmental Protection Agency*) for the July, August, and September 2015 time frame.
- Average DWF was developed from County land use/zoning data, Metro population and employment projections by TAZ polygon, and DWF factors. Per-capita average wastewater usage, per-employee average wastewater usage, and net acre factors were scaled to reconcile the planning estimates and metered average DWF. A summary of unit flow factors and summary DWF assumptions is presented in Tables 3-5 and 3-6.
- DWF was summarized at the parcel (tax lot) level and assigned to model junctions using delineated service area polygons.

The summertime DWF model was run for several iterations to achieve a target calibration criteria of matching modeled peak flow rates within +/- 10 percent of field measured peak flow rates. Each iteration refined the average flow and diurnal pattern inputs to the model. A summary of calibration results is presented in Table 3-7. The model calibrated within 8 percent of the measured field data for peak DWF.

Table 3-5. Calibrated Dry Weather Unit Flow Factors by Zoning Category

Zone Category	Description	Residential Density (units/acre)	Employment Density (employee/acre)	Unit Flow Factor (gpad)
SFR1	Single-family 1-acre tax lot	0	0	200
SFR2	Single-family ½-acre tax lot	0	0	300
SFR3	Single-family 10,000 sq.ft. lot	0	0	500
SFR4	Single-family 9,000 sq.ft. lot	0	0	600 - 700
SFR5	Single-family 7,000 sq.ft. lot	10	0	800

Table 3-5. Calibrated Dry Weather Unit Flow Factors by Zoning Category

Zone Category	Description	Residential Density (units/acre)	Employment Density (employee/acre)	Unit Flow Factor (gpad)
SFR6	Single-family 6,000 sq.ft. lot	10	0	900 – 1,000
SFR7	Single-family 5,000 sq.ft. lot	10	0	1,100 – 1,200
SFR8	Single-family 4,500 sq.ft. lot	10	0	1,200 – 1,300
SFR9	Single-family 4,000 sq.ft. lot	10	0	1,400 – 1,500
SFR10	Single-family 3,500 sq.ft. lot	10	0	1,500 – 1,700
SFR12	Single-family 2,900 sq.ft. lot	10	0	1,800 – 2,000
SFR14	Single-family 2,500 sq.ft. lot	10	0	2,100 – 2,300
SFR15	Single-family 2,300 sq.ft. lot	20	0	2,300 – 2,500
MFR1	Multifamily-Very Low Density	10	0	1,800 – 2,100
MFR2	Multifamily- Low Density	20	0	2,700 – 3,000
MFR3	Multifamily-Moderate Density	20	0	3,500 – 3,900
MFR4	Multifamily-Medium Density	30	0	4,400 – 4,900
MUR1	Mixed Use – Low Density	0 - 10	2 - 3	400 – 1,700
MUR3	Mixed Use – Low Density	10 - 20	0 - 20	2,100 – 3,500
MUR4	Mixed Use – Low Density	10 - 20	10 - 20	2,600 – 4,400
MUR5	Mixed Use – Medium Density	10 - 30	10 - 20	3,100 – 5,300
MUR6	Mixed Use – Medium Density	20 - 30	10 - 30	3,600 – 6,100
MUR7	Mixed Use – Medium Density	20 - 50	10 - 30	4,600 – 8,300
MUR8	Mixed Use – High Density	30 - 60	20 - 50	6,600 – 11,500
MUR9	Mixed Use – High Density	50 - 90	20 - 70	10,100 – 16,800
MUR10	Mixed Use – High Density	60 - 190	40 - 90	12,600 – 33,800
POS	Parks and Open Space	0	0	0
CC	Central Commercial	0	20	1,000 – 1,200
CG	General Commercial	0	20	1,000 – 1,200
CN	Neighborhood Commercial	0	20	1,000 – 1,200
CO	Office Commercial	0	20	1,000 – 1,200
RC	Rural Commercial	0	20	1,000 – 1,200
PF	Public Facilities	0	20	1,000 – 1,200
IC	Campus/Industrial/Business Park	0	20	1,000 – 1,200
IO	Industrial Office	0	20	1,000 – 1,200
IL	Light Industrial	0	20	1,000 – 1,200
IH	Heavy Industrial	0	20	1,000 – 1,200
RI	Rural Industrial	0	20	1,000 – 1,200

Notes:

gpad = gallons-per-acre-per-day

sq. ft. = square foot/feet

Table 3-6. Calibrated Dry Weather Flow Assumptions

Factor Name	Factor Value(s)	Typical Range	Note
Housing density per net acre	1 to 15 residential 12 to 30 multifamily	1 to 200	Established by Metro, varies by zoning/land use[a]
People per unit	2.1 to 3.0	1.5 to 3.0	Established by Metro, varies by City/Jurisdiction[b]
Residential wastewater usage per capita (gallons per capita per day)	54 to 67	50 to 100	Based on metered data and Metro population estimates[b], consistent with industry standards[c]
Employee density per acre	24	10 to 40	Based on metered data and Metro employment estimates[d], consistent with industry standards[c]
Wastewater usage per employee (gallons per employee per day)	40 to 46	10 to 50	Based on metered data and Metro employment estimates[b], consistent with industry standards[c]
Net acre factor (percent)	80+	50 to 85	Gross acres exclude environmentally sensitive lands, existing roadways, flood plains, and wetlands prior to application of net acre factor. Calibrated to Metro population and employment projections[b], confirmed with Metro methodology[e]
Mixed use factor (percent)	54 to 85 for residential 15 to 46 for commercial	50 to 85 for residential 10 to 50 for commercial	Based on metered data and mix of Metro population and employment estimates[b], consistent with Metro planning documents[e]

[a] *Regional Forecast Distribution Methodology & Assumptions* (Metro, 2012a). As used here, "zoning" means the land use zone designations assumed by Metro in growth projections.

[b] *Regional 2035 Forecast Distribution* (Metro, 2012b). www.oregonmetro.gov/regional-2035-forecast-distribution.

[c] *Wastewater Engineering, Treatment and Reuse* (Metcalf & Eddy, 2004) and *Recommended Standards for Wastewater Facilities* (Health Research, Inc., 2014).

[d] *Employment Demand Factors & Trends, Task 1 Report – Metro Employment & Economic Trends Analysis* (Metro, 2009a).

[e] *2009 – 2030 Urban Growth Report*, Appendix 6 (Metro, 2009b).

3.2.6.2 Groundwater Infiltration Calibration

The winter-time dry weather period was used to establish the GWI component of the model following a similar procedure to the summer-time dry weather loading.

- Average flow data were extracted from the flowmetering data using EPASSOAP (*United States Environmental Protection Agency*) for the October, November 2015 and January, February 2016 timeframe.
- GWI flows for each meter basin were calculated by subtracting the average summertime DWF from the average winter time DWF. A uniform diurnal pattern was assumed for GWI.
- GWI average flows were distributed to parcels in each meter basin using the ratio of parcel specific DWF to total meter basin DWF. GWI was assigned to model junctions using the service area polygon delineation.

The wintertime DWF+GWI model was run for several iterations to achieve the target calibration criteria of matching modeled peak flow rates within +/-10 percent of field measured peak flow rates. GWI scaling factors were used to adjust the model between iterations at the meter basin level. A summary of calibration results is presented in Table 3-7. Overall the model calibrated within 3 percent of the measured field data for peak DWF+GWI.

3.2.6.3 Wet Weather Flow (RDI/I) Calibration

The RDI/I component of the model utilizes the EPASWMM RTK unit hydrograph methodology. The unit hydrograph defines the amount of runoff which enters the system and the travel time. The unit hydrograph is broken into an initial, intermediate, and long-term hydrograph response. The unit hydrographs combine to form a composite unit hydrograph. Each of the unit hydrographs is defined by three parameters which are adjusted during model calibration until field and model flows match within a reasonable tolerance. The unit hydrograph parameters are described below and shown on Figure 3-5.

- Unit Hydrograph Parameter 1 - R1, R2, R3 - Response ratios for the short-term, intermediate-term, and long-term unit hydrograph responses, respectively.
- Unit Hydrograph Parameter 2 - T1, T2, T3 - Time to peak for the short-term, intermediate-term, and long-term unit hydrograph responses, respectively.
- Unit Hydrograph Parameter 3 - K1, K2, K3 - Recession limb ratios for short-term, intermediate-term, and long-term unit hydrograph responses, respectively.

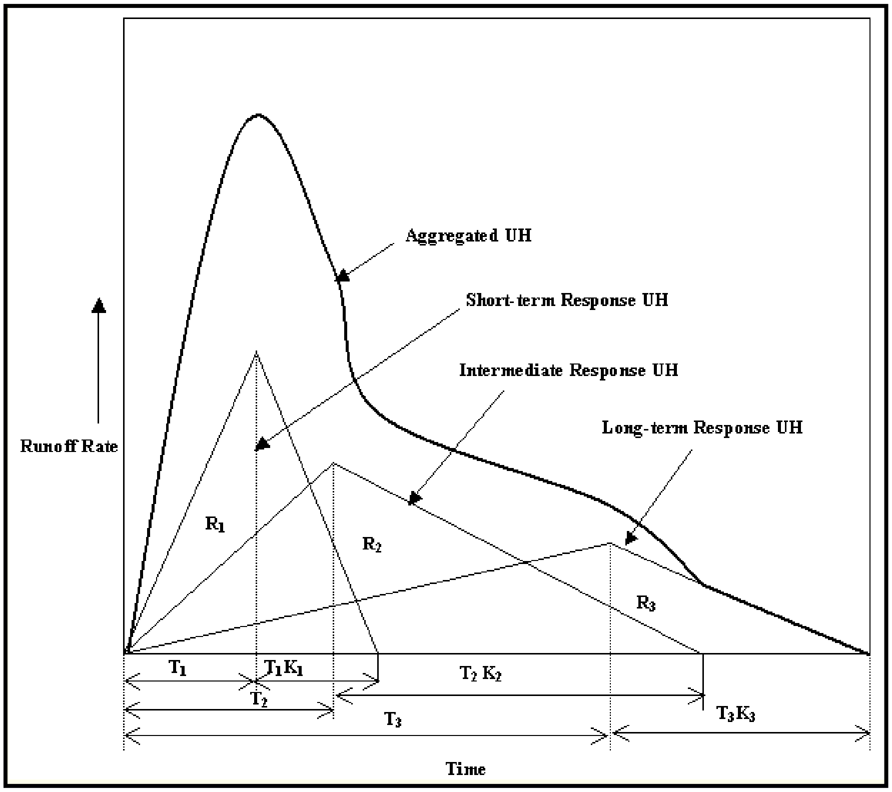


Figure 3-5. SWMM RTK Unit Hydrograph Description

In general, the “R” value will vary by storm event and antecedent moisture condition. For this reason, rainfall periods with the greatest impact to the system were selected as the primary calibration event (December 2015, 10+year frequency event). The RTK parameters initially were extracted for calibration using EPASSOAP and the meter data. Unit hydrograph parameters were then adjusted for each meter basin through several iterations.

The wet weather model was run for several iterations to achieve the target calibration criteria of matching modeled peak flow rates within +/-20 percent of field measured peak flow rates. The meter data used for the model calibration do not account for potential system overflows or relief to the system during the calibration storm event. The model was calibrated conservatively to account for the potential relief. A summary of calibration results and final RTK parameters is presented in Table 3-7. The model calibrated within 5 percent of the measured field data for peak RDI/I.

Table 3-7. Calibration and Peak Flow Summary by Basin

Meter Basin	R (%)	T (hours)	K (factor)	Peak DWF (mgd)	DWF Calibration Quality[b]	Peak DWF+ GWI (mgd)	DWF+GWI Calibration Quality[b]	Peak DWF+ GWI+ RDI/I (mgd)[a]	RDI/I Calibration Quality[b]
Agnes	R1-0.05, R2-0.029, R3-0.106	T1-2, T2-5, T3-10	K1-2, K2-3, K3-7	0.4	Fair	0.4	Good	1.9	Good
Agnes Main	R1-0.018, R2-0.085, R3-0.345	T1-2, T2-5, T3-10	K1-3, K2-3, K3-7	5.6	Good	9.2	Fair	52.8	Good
Bolton Pump Station	R1-0.073, R2-0.056, R3-0.047	T1-1.5, T2-5, T3-6	K1-2, K2-2.5, K3-4	0.6	Good	0.6	Good-Fair	6.1	Good
Clackamas Interceptor	R1-0.028, R2-0.015, R3-0.127	T1-1, T2-5, T3-10	K1-2, K2-3, K3-4	3.1	Good	4.0	Good	9.5	Good
Clackamas Pump Station	R1-0.112, R2-0.045, R3-0.726	T1-2, T2-4, T3-10	K1-2, K2-4, K3-7	0.6	Good	0.9	Good	2.8	Good
Gladstone Pump Station	R1-0.076, R2-0.152, R3-0.608	T1-0.2, T2-10, T3-14	K1-4, K2-5, K3-4.5	0.9	Good	1.0	Good	7.3	Fair
Harmony	R1-0.029, R2-0.03, R3-0.049	T1-1.5, T2-5, T3-10	K1-1, K2-2, K3-4	0.8	Good	1.3	Good	3.5	Good
Holly	R1-0.026, R2-0.202, R3-0.037	T1-1.5, T2-3, T3-10	K1-2, K2-2, K3-4	0.8	Good	0.9	Fair	9.7	Good
Kellogg IPS				6.6	Good	9.9	Good	37.4	Good
Mill Street	R1-0.072, R2-0.216, R3-0.432	T1-2, T2-4, T3-8	K1-2, K2-4, K3-6	1.6	Good	2.6	Fair	8.9	Good
Milwaukie	R1-0.04, R2-0.042, R3-0.167	T1-1.5, T2-3, T3-10	K1-2, K2-2, K3-4	1.7	Good	3.0	Fair	9.0	Good
Mount Talbert	R1-0.023, R2-0.04, R3-0.135	T1-1.5, T2-2.5, T3-4	K1-2, K2-3, K3-6	2.3	Good	3.2	Good	12.2	Good
Phillips Interceptor	R1-0.032, R2-0.034, R3-0.041	T1-1.8, T2-5, T3-6	K1-1, K2-3, K3-7	2.6	Good	3.5	Good	7.1	Good
River Street Pump Station	R1-0.042, R2-0.172, R3-0.26	T1-0.8, T2-3, T3-10	K1-1, K2-2, K3-6	0.1	Good	0.1	Good	0.9	Good
Tri-City IPS				12.0	Good	17.8	Good	80.7	Good
Unified Grocery	R1-0.007, R2-0.029, R3-0.032	T1-1.5, T2-3, T3-10	K1-2, K2-2, K3-6	4.1	Fair	5.3	Good	23.0	Fair
WI-22	R1-0.087, R2-0.308, R3-0.502	T1-1, T2-3, T3-9	K1-2, K2-2, K3-7	3.8	Fair	5.8	Good	41.9	Good

Table 3-7. Calibration and Peak Flow Summary by Basin

Meter Basin	R (%)	T (hours)	K (factor)	Peak DWF (mgd)	DWF Calibration Quality[b]	Peak DWF+ GWI (mgd)	DWF+GWI Calibration Quality[b]	Peak DWF+ GWI+ RDI/I (mgd)[a]	RDI/I Calibration Quality[b]
WI-40	R1-0.017, R2-0.083, R3-0.765	T1-2, T2-5, T3-3	K1-3, K2-3, K3-7	1.0	Good	1.7	Good	16.6	Fair
Willamette Pump Station	R1-0.05, R2-0.065, R3-0.144	T1-1, T2-3, T3-5	K1-2, K2-2, K3-3	1.3	Good	2.2	Good	5.5	Good

[a] Peak flow during December 2015 calibration period, which exceeds 10-year storm frequency.

[b] "Good' calibration quality indicates peak flow and volume compliance of 5 to 10-percent, "fair" calibration quality indicates peak flow and volume compliance of 10 to 15 percent.

3.2.7 Design Storm Selection

Oregon Department of Environmental Quality (DEQ) guidelines (*Oregon Administrative Rule 340-041-0009*) indicate that sanitary sewer overflows are prohibited except during a winter storm event exceeding the one in five-year frequency and a summer storm event exceeding the one in ten-year frequency.

A flow and precipitation frequency analysis was performed utilizing historic precipitation data and influent flow modeling at the Kellogg WRRF and Tri-City WRRF. Nineteen historic rainfall events were simulated in WES's calibrated hydraulic model. These large events were ranked from highest to lowest by downstream influent peak flow as shown on Figure 3-6a. The flow and precipitation recurrence intervals (frequency) of each event were estimated to determine the risk of occurrence. The trend indicates an increasing frequency of large storm events over the last decade as shown on Figure 3-6b. The storm events from 2006 to 2016 represent a 20-percent increase in flow frequency when compared with the largest storm event prior to 2006.

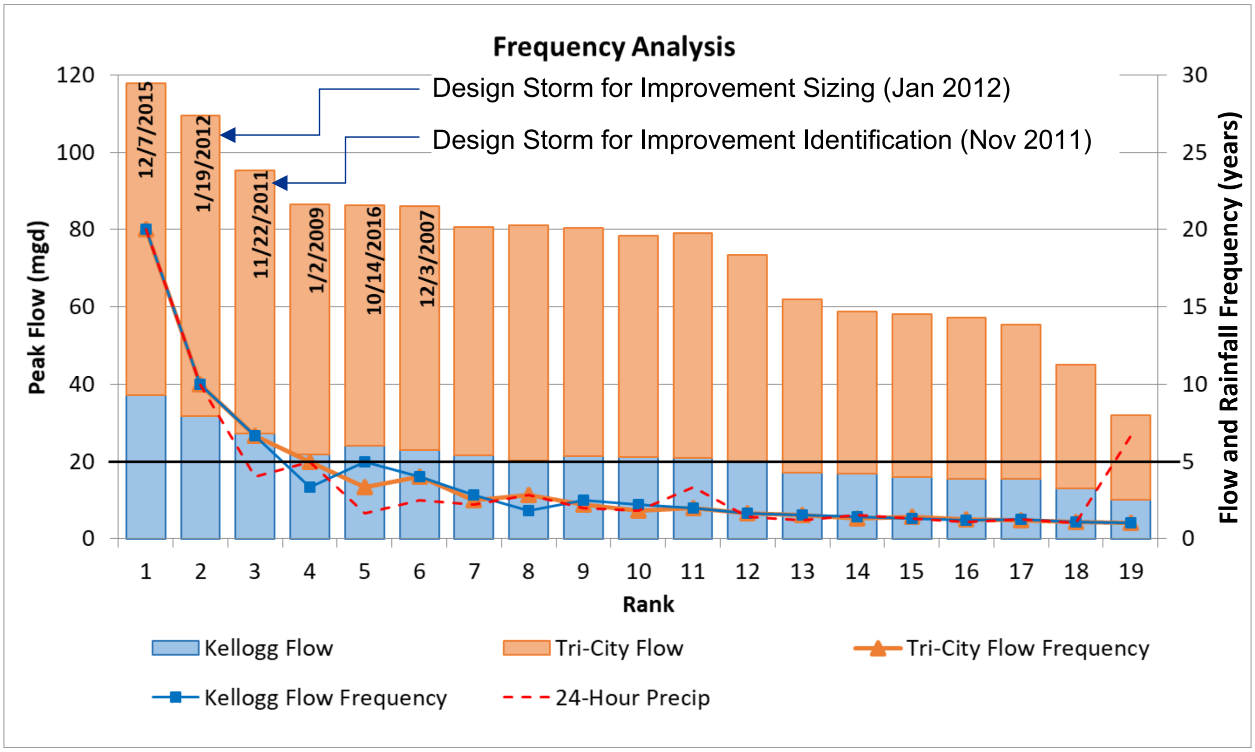


Figure 3-6a. Flow and Precipitation Frequency Analysis

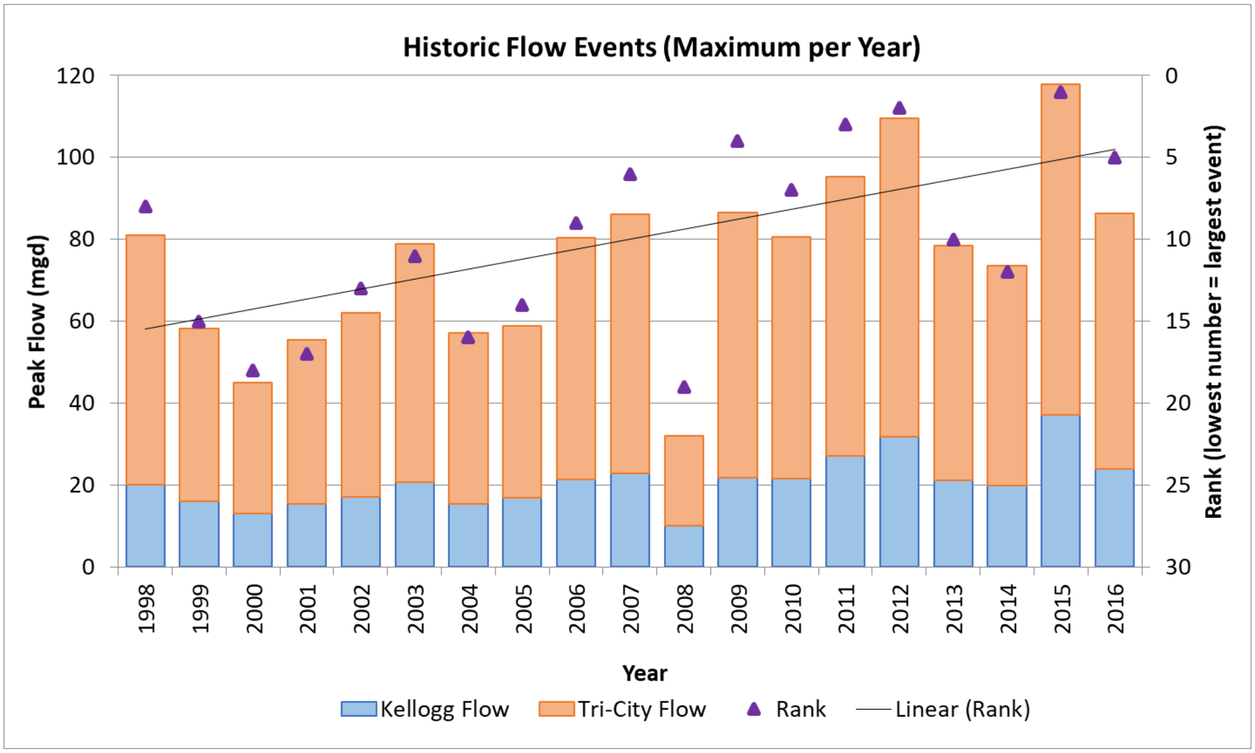


Figure 3-6b. Increasing Trend of System Response with Time

WES staff reviewed the flow and precipitation frequency analysis and selected design storm events that satisfy a 5-year flow frequency and precipitation frequency. The selected storm events are summarized below and presented on Figure 3-7.

- The historical storm event on November 22, 2011 was selected as the design storm to identify system deficiencies. The event exceeds 4.3-inches of precipitation over 60 hours. Because of the long storm duration and susceptibility of the system to RDI/I, the historic event produces an impact equal to or greater than the 5-year, 24-hour wintertime storm event.
- The historic storm event on January 19, 2012 was selected as the design storm to size system improvements. The event exceeds 5.4-inches of precipitation over 60 hours. The design storm maximum 24-hour precipitation equals a one in ten-year precipitation frequency. The event was selected because of the trend showing increased frequency of large storms over the last decade.

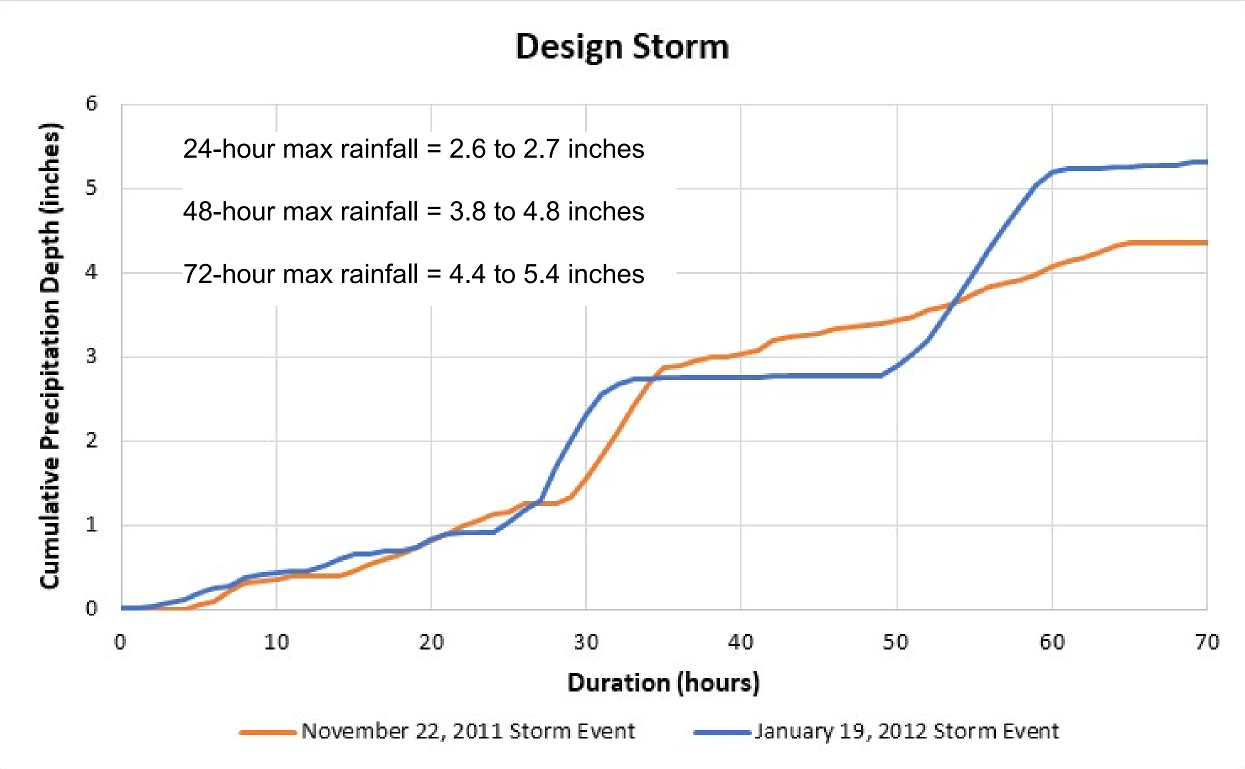


Figure 3-7. Flow and Precipitation Frequency Analysis

3.2.8 Design Criteria

The relevant design criteria applied to capacity deficiency identification and improvement sizing are consistent with WES design standards and DEQ regulations. The criteria include: system surcharge, freeboard and overflow constraints, maximum and minimum velocity constraints, and pump station firm capacity as summarized in Table 3-8.

Table 3-8. Capacity Design Criteria

Standard	Category	Design Standard
Primary (improvement required for existing infrastructure)	Maximum water depth[a]	Previous master plan criteria, 2-foot freeboard (rim elevation to water surface) during peak dry weather + design storm event.
	Design storm[b]	Overflows prohibited for 5-year frequency storm November thru May 21 and 10-year frequency storm May 22 thru October.
	Pump Station firm capacity[b]	Pump station has capacity to pump at flows greater than or equal to peak hour flows with largest pump out of service; Backup power required.
	Maximum force main velocity[d]	8 fps
Secondary (improvement considered for existing infrastructure; implemented for new infrastructure)	Maximum water depth[c]	Mainline Sanitary Sewer - 2/3 full flow (dry weather); Trunk Sanitary Sewer - full flow without surcharging (wet weather).
	Maximum gravity pipeline velocity[c]	< 15 fps or ductile iron or C900 PVC pipe material with anchoring provisions and protection of manholes against erosion and shock displacement
	Minimum cleansing/scouring velocity, gravity pipeline[c]	2 fps mean velocity when flowing half full

Table 3-8. Capacity Design Criteria

Standard	Category	Design Standard
	Minimum cleansing/scouring velocity of force mains and inverted siphons[b]	3 fps at average dry weather flow
	Pipeline (slope and roughness)[c]	0.0100 ft/ft minimum or; 0.0045 ft/ft at half full for 8-inch; 0.0033 ft/ft at half full for 10-inch; 0.0027 ft/ft at half full for 12-inch; 0.0022 ft/ft at half full for 15-inch; 0.0017 ft/ft at half full for 18-inch; case-by-case > 18-inch; 8-inch minimum diameter; Manning's roughness n = 0.013
	Manhole, miscellaneous criteria[c]	minimum 0.2 ft drop across manhole; minimum manhole size of 48-inches; 500 feet manhole spacing or less; incoming to outgoing flow angle > 90-degrees

[a] CCSD#1 Sanitary Sewer Master Plan, 2009.

[b] Oregon Department of Environmental Quality (OAR 340-041-0009).

[c] Clackamas County Sanitary Standards, 2013. (www.clackamas.us/wes/sanitarystandards.html).

[d] Recommended Standards for Wastewater Facilities (10 State Standards), 2014.

Notes:

fps = feet per second

ft/ft = feet per foot

3.3 Findings

The existing collection system was evaluated during the November 22, 2011 design storm and evaluated for flow depth, freeboard, velocity, and firm capacity deficiencies based on WES design criteria. Results of the capacity analysis are presented on Figure 3-8. Flow estimates for the existing system at each WRRF and RDI/I contributions (peak RDI/I per net acre by basin and peak RDI/I volume) are presented in Tables 3-9 and 3-10, respectively.

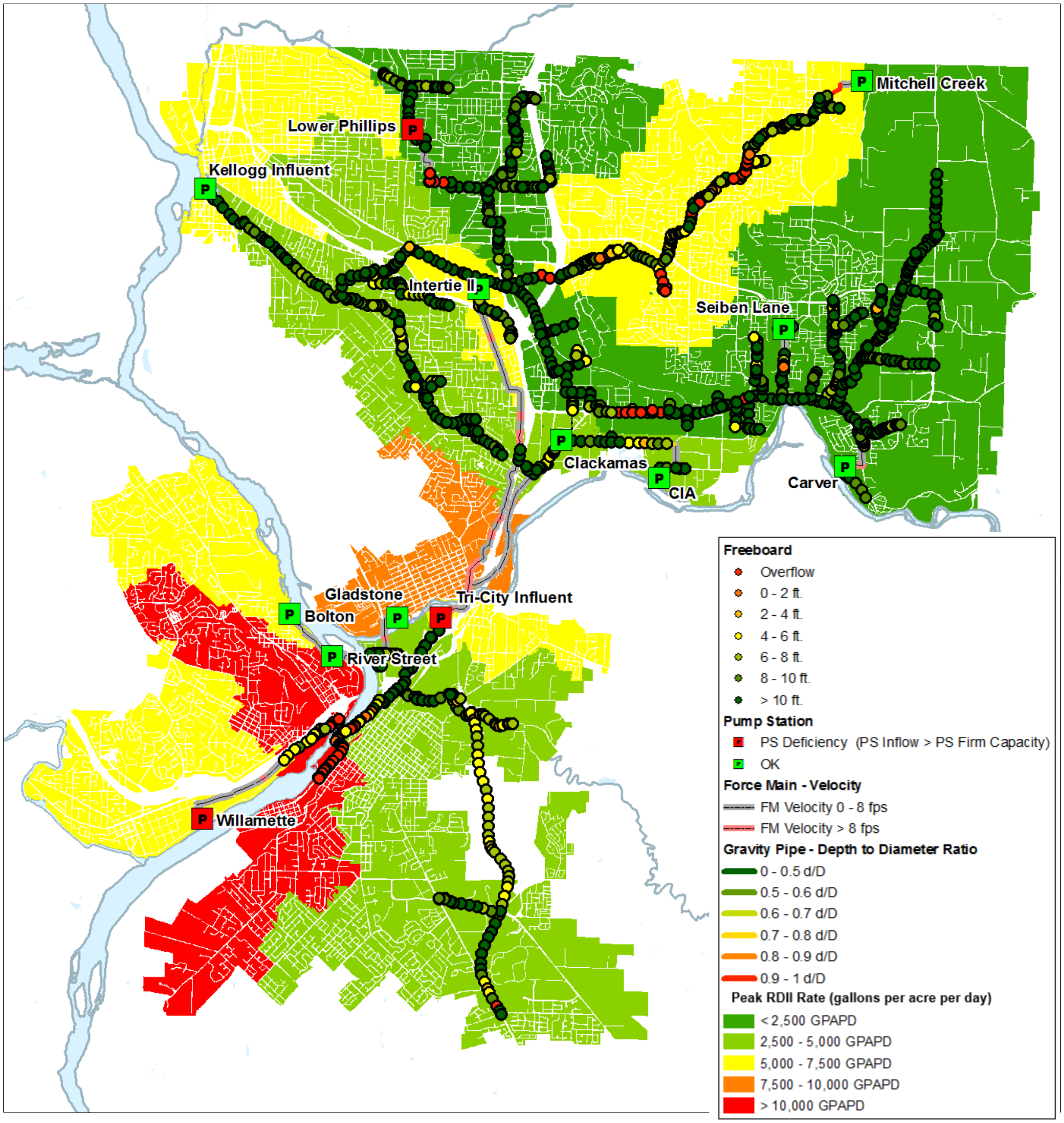


Figure 3-8. Existing System Capacity Deficiencies and RDI/I Rates

Table 3-9. Existing System Flow Estimates by Treatment Basin

Treatment Basin	Average DWF (mgd)	Peak DWF (mgd)	Peak DWF + GWI (mgd)	Peak DWF + GWI + RDI/I (mgd)[b]
Kellogg WRRF	5.5	6.6	9.9	30.0
Tri-City WRRF[a]	8.8	12.0	17.8	73.3

[a] Includes diversion flow rates from the Clackamas Pump Station and Intertie 2 Pump Station, excludes - mgd deficit from Kellogg WRRF.

[b] Peak RDI/I during 11/2011 design storm, capacity exceedance at WRRFs.

Table 3-10. Existing Design Storm Rainfall Derived Infiltration and Inflow Summary by Basin

Basin	Existing RDI/I rate (gallons per net acre per day)	RDI/I Volume (million gallons per day)
Agnes	3,500	1.2
Agnes Main	3,200	7.2
Bolton Pump Station	6,900	3.4
Clackamas Interceptor	2,100	5.2
Clackamas Pump Station	4,100	1.6
Gladstone Pump Station[a]	8,600	4.5
Harmony	3,200	2.0
Holly	16,600	7.1
Lower Kellogg	3,200	4.0
Mill Street	20,500	2.6
Milwaukie	6,300	5.6
Mount Talbert	8,000	9.7
Phillips Interceptor	2,800	3.3
River Street Pump Station	12,400	0.6
Unified Grocery	3,900	1.6
WI 40	20,600	11.7
Willamette Pump Station	6,700	5.0

[a] Gladstone Pump Station Basin flow monitoring is limited by upstream gravity capacity. Direct overflow connections from the stormwater system to the sanitary sewer system occur upstream of a monitored overflow location to the Willamette River and upstream of the pump station. Rates increase to 20,000 gallons per net acre per day if the direct stormwater is included in the RDI/I estimate.

The existing system has capacity to convey both DWF and GWI associated with winter season antecedent moisture conditions. During the design storm event, the existing system exceeds gravity, pumping, and treatment capacity. The capacity deficiencies result in predicted overflows at multiple locations. Peak flow rates are caused by high RDI/I which indicates potential needs for rehabilitation and reduction. System deficiencies at key locations are further summarized in Table 3-11.

Table 3-11. Existing System Deficiency Summary

Location/Infrastructure	Description
Holly, Mill Street, and WI 40 Basins	RDI/I rates in excess of 15,000 gpad are typically an indication of local condition issues within the collection system and may result in both local and downstream capacity deficiencies in the near-term.
Agnes, Bolton Pump Station, Gladstone Pump Station, Milwaukie, Mount Talbert, River Street Pump Station, Unified Grocery, and Willamette Pump Station Basins	RDI/I rates between 5,000 gpad and 15,000 gpad are an indication of system deterioration and may result in both local and downstream capacity deficiencies within a 20-year planning horizon.
Gladstone Pump Station Basin	A monitored overflow is located upstream of the pump station wet well. Estimated RDI/I rates exclude stormwater that discharges from the system at the overflow location.

Table 3-11. Existing System Deficiency Summary

Location/Infrastructure	Description
Willamette Interceptor, West Linn Interceptor, Clackamas Interceptor, Mount Talbert Interceptor, and Happy Valley Interceptor	During the design storm event, the system freeboard criteria of 2 feet is violated at approximately 70 manhole locations
Clackamas Interceptor	Deficiencies are attributed to growth and were further reviewed to confirm available capacity within the existing time frame and potential overflow risks in future time frames (see Section 4 for future analysis).
Mount Talbert and Happy Valley Interceptors	Based on review of flow monitoring data and discussions with WES Operations and Maintenance staff, the deficiencies in the Mount Talbert and Happy Valley interceptors may be attributed to direct ground water and surface water influences from Mount Scott Creek. Additional flowmetering was performed in both the Mount Talbert and Happy Valley interceptors to confirm modeled wet weather flows.
Willamette Interceptor and West Linn Interceptor	Deficiencies are attributed to high RDI/I.
Lower Phillips Pump Station	Pump station exceeds capacity by less than 20 gallons per minute during the design storm event with the conclusion that the pump station is near capacity. Based on the capacity limitation, further review of flow diversions to the City of Portland were implemented in the future system analysis (see Section 4).
Willamette Pump Station	Pump Station exceeds capacity by 0.6 mgd (5 mgd peak flow vs 4.4 mgd firm capacity) during the design storm event. The deficiency is attributed to high RDI/I.
Kellogg WRRF & Intertie 2 Pump Station	Kellogg WRRF exceeds capacity by 12 mgd during the existing time frame (30 mgd vs 18 mgd maximum existing capacity). The capacity limitation includes a maximum diversion of 10 mgd at the Intertie 2 Pump Station. Near-term improvements at the Kellogg WRRF are anticipated to increase capacity from 18 mgd to a maximum capacity of 25 mgd leaving a deficit of 5 mgd. Improvements at the Intertie 2 Pump Station are required to eliminate the 5 mgd deficit and send the additional 5 mgd to the Tri-City WRRF.
Tri-City WRRF	Tri-City WRRF exceeds capacity by 10 mgd during the existing time frame which includes the additional 5 mgd diversion from the Intertie 2 Pump Station to minimize improvements at the Kellogg WRRF (73 mgd without additional diversion, 78 mgd with additional diversion vs 68 mgd maximum existing capacity).

4. Future System Flow Projections and Capacity Evaluation

Section 4 provides information to summarize future system capacity including documentation of household and employment projections within the study area, description of future dry and wet weather flow methodologies, and presentation of future system deficiencies. The future system flow rates and deficiencies are evaluated in 5-year increments until 2040. Flow rates and deficiencies are also estimated for buildout conditions although the impacts associated with buildout are beyond the planning horizon of this Master Plan. Critical elements of the future system evaluation rely on definitions, assumptions, criteria, and sources documented in Section 3, “Existing System Flow Development and Capacity Evaluation.”

4.1 Objectives

The objectives of this section include:

- Summary of future household and employment projections
- Documentation of future dry weather flow (DWF) methodology
- Documentation of future groundwater infiltration (GWI) methodology
- Documentation of future wet weather flow methodology including increase of rainfall derived infiltration and inflow (RDI/I) response with system age
- Presentation of future system capacity deficiencies

4.2 Methodology and Analysis

4.2.1 Household and Employment Projections

The Metro household and employment projections by 2040 and within the Master Plan study area provide the basis for growth assumptions in this Master Plan. The growth estimates were documented for WES by EcoNorthwest (*Population Forecasts for Clackamas County Service Districts*, August 2016). Buildout household and employment were calculated using maximum densities by zoning category within the study area. Maximum household and employment densities are documented in Section 3, Table 3-5. The buildout time frame of 2087 was extrapolated using the Metro linear growth trend between 2015 and 2040. The study area estimates for 2040 households and employees are 102,600 and 123,000, respectively, as shown on Figure 4-1.

4.2.2 Future Dry Weather Flow Methodology

Future average DWF was calculated on a parcel basis for buildout using Clackamas County specific residential, commercial, public, or industrial zoning classifications and calibrated unit flow factors multiplied by net acres. Developed and developable parcels excluded environmentally sensitive lands, existing roadways, flood plains, and wetlands. Unit flow factors for each zoning classification and associated planning assumptions are documented in Section 3, Tables 3-5 and 3-6. These unit flow factors are presented as a range that reflects variability in Metro published household and employment densities by transportation analysis zone (TAZ) and zoning classification. Buildout DWF estimates were scaled to reflect Metro household and employment estimates in 5-year increments between the existing time frame and 2040. These 5-year incremental estimates were verified at the TAZ polygon level for accuracy.

Finalized DWF estimates were summarized at the parcel level for each 5-year increment and buildout time frames. The DWF loading was assigned to hydraulic model junctions using delineated service area polygons. Future peak DWF for each time frame was calculated in the InfoSWMM (Innovyze) model using calibrated hourly diurnal patterns. Peaking factors associated with calibrated diurnal patterns range from 1.2 to 1.9 with an average peaking factor of 1.4. A summary of future average DWF flow projections by general zoning classification is presented in Table 4-1 for each 5-year timeframe and buildout.

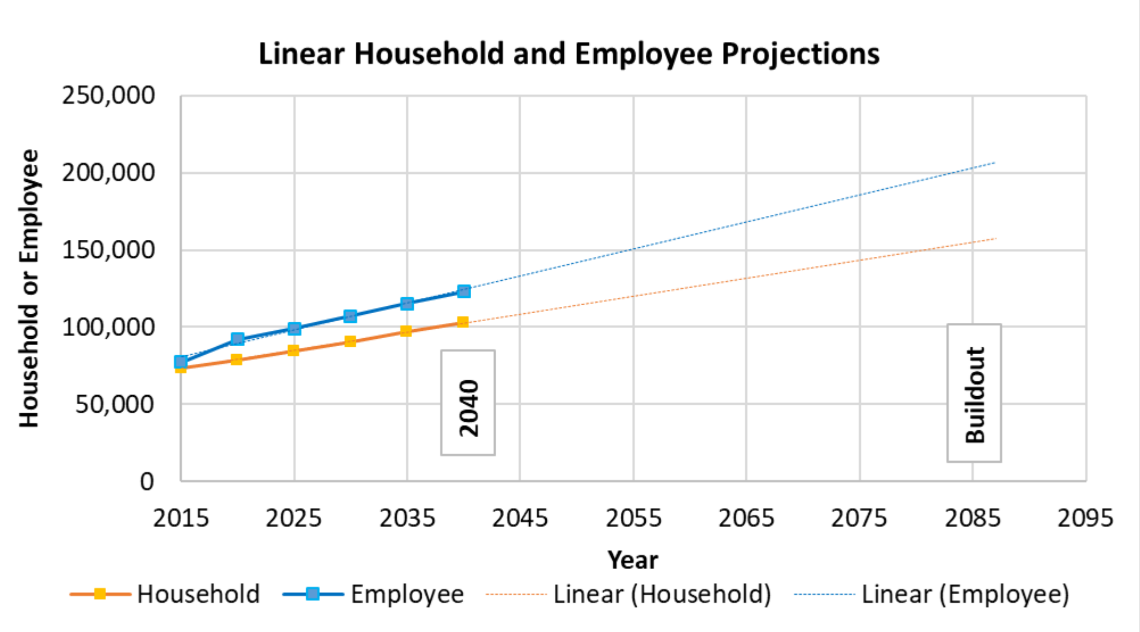


Figure 4-1. Household and Employment Projections

Table 4-1. Summary of Average Dry Weather Flow Loading

	Average DWF (mgd)						
General Zoning	**Existing**	**2020**	**2025**	**2030**	**2035**	**2040**	**Buildout**
Commercial	0.4	0.5	0.5	0.5	0.6	0.6	0.7
Future Urban Development	0.0	0.2	0.3	0.3	0.4	0.4	0.4
Industrial	1.6	1.8	1.8	1.9	2.0	2.1	3.1
Multifamily Residential	1.9	2.0	2.0	2.1	2.1	2.2	2.6
Mixed Use	2.7	3.1	3.4	3.8	4.0	4.3	9.6
Public, Open Space	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rural	0.4	0.6	0.7	0.9	1.1	1.3	2.5
Single-family Residential	7.7	7.8	8.0	8.3	8.4	8.6	9.4
Total	**14.7**	**16.0**	**16.8**	**17.8**	**18.7**	**19.5**	**28.3**

4.2.3 Future Groundwater Infiltration Methodology

The influence of groundwater on the collection system is a combination of both system condition and hydrologic soils conditions including groundwater depth. Future GWI projections utilized the differential between existing DWF and existing DWF+GWI during winter months and assumed a similar differential for future conditions. This differential expressed as a ratio is approximately 2:1 (DWF:GWI) for the system and ranges from 10:1 to 1:1 for specific meter basins. Future GWI was extrapolated using the future average DWF estimates for each 5-year period and buildout using meter basin specific DWF:GWI ratios.

A uniform pattern (no peaking) was applied to GWI estimates. The overall portion of the peak flow associated with GWI when compared to peak DWF and peak RDI/I is estimated at less than 10 percent for existing and future conditions.

4.2.4 Future Wet Weather Flow Methodology

As described in Section 3, the RDI/I portion of the system model utilizes the EPASWMM RTK methodology, which includes the selected design storm, sewershed area (wet weather area of impact), and calibrated unit hydrograph. A peak RDI/I estimate for future development was calculated by extrapolating a sewershed area at approximately 30-percent of the net area for each developable parcel. The sewershed percentage is based on the ratio of existing net area to existing pipelines buffered by an area of 100 feet. A unit hydrograph with lower RDI/I response was selected from the composite set of calibrated meter basin unit hydrographs to represent new development at approximately 2,500 gallons-per-acre-per-day (gpad) on a net area basis. The new development unit hydrograph and the selected design storm were applied to the parcel sewershed area to generate wet weather system response.

4.2.5 System Degradation and Rainfall-derived Infiltration and Inflow

A flow degradation methodology was applied to the RDI/I component of the system flow to account for system aging and associated increases in RDI/I over time. The degradation methodology utilizes RDI/I rates at the meter basin level and applies a degradation curve to the RDI/I rate. The degraded RDI/I is applied at the parcel level and accumulated through the model pipe network to generate degraded RDI/I. This process was performed outside of the InfoSWMM model application.

To derive the degradation curve, RDI/I rates were correlated with available pipe age and condition information as shown on Figures 4-2 and 4-3. In meter basins where pipe age was not available, the correlation was also used to establish an existing system age using the basin existing RDI/I rate and a zero-age RDI/I assumption of 2,500 gpad. The flow degradation curve is based on an envelope of two aging trend lines representing rapid RDI/I increase with system age and slow RDI/I increase with system age. The composite curve was generated from the envelope and assumes rapid RDI/I increases up to 3.3-percent degradation per year by age 45 and slow RDI/I increases down to 1.1-percent degradation per year by age 100. The resulting degradation is 0.1-percent to 10-percent per year for a pipeline lifecycle of 100-years. RDI/I degradation approaches are commonly applied to system planning by large sewer districts in the Pacific Northwest where the district does not have full control over investment in infrastructure rehabilitation, repair, and replacement at the local level. For example, King County, Washington applies a 7-percent degradation rate per decade *(Updated Planning Assumptions for Wastewater Flow Forecasting*, July 2014, King County Department of Natural Resources and Parks, Wastewater Treatment Division).

Existing developed parcels were degraded on an annual basis from the point on the curve representing the associated basin existing age. Future developed parcels were degraded assuming a zero age and 2,500 gpad RDI/I rate at time of development. Existing and degraded RDI/I rates are summarized in Table 4-2 by basin.

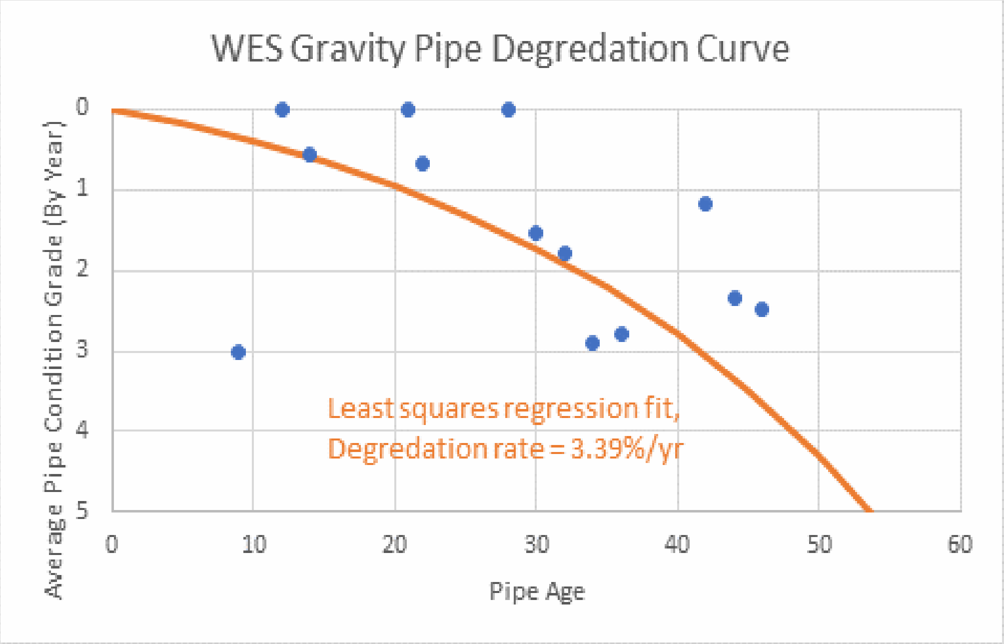


Figure 4-2. Pipe Age and Condition Correlation

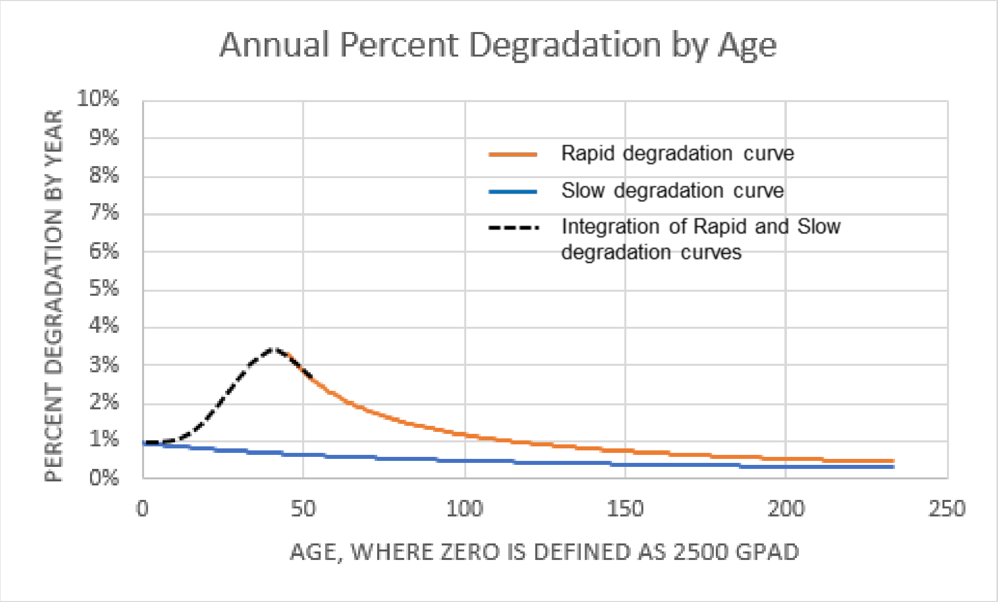


Figure 4-3. System Age and RDI/I Rate Degradation Curve

Table 4-2. Summary of Rainfall Derived Infiltration and Inflow Degraded Rates by Basin

Basin	Degraded RDI/I Rate (gallons per net acre per day)						
	Existing	2020	2025	2030	2035	2040	Buildout
Agnes	3,500	5,800	8,000	10,200	12,400	14,500	35,000
Agnes Main	3,200	5,400	7,600	9,700	11,900	14,100	34,500
Bolton Pump Station	6,900	9,300	11,500	13,700	15,800	18,000	38,500
Clackamas Interceptor	2,100	2,200	2,300	2,500	2,600	2,700	17,600
Clackamas Pump Station	4,100	6,300	8,400	10,600	12,800	15,000	35,400
Gladstone Pump Station	8,600	10,600	12,800	15,000	17,100	19,300	39,800
Harmony	3,200	5,400	7,600	9,700	11,900	14,100	34,500
Holly	16,600	18,900	21,100	23,200	25,400	27,600	48,000
Lower Kellogg	3,200	5,400	7,600	9,700	11,900	14,100	34,500
Mill Street	20,500	22,800	25,000	27,100	29,300	31,500	51,900
Milwaukie	6,300	8,400	10,600	12,800	15,000	17,100	37,600
Mount Talbert	8,000	10,200	12,400	14,500	16,700	18,900	39,300
Phillips Interceptor	2,800	2,900	3,600	5,800	8,000	10,200	30,600
River Street Pump Station	12,400	14,500	16,700	18,900	21,100	23,200	43,700
Unified Grocery	3,900	6,300	8,400	10,600	12,800	15,000	35,400
WI 40	20,600	22,800	25,000	27,100	29,300	31,500	51,900
Willamette Pump Station	6,700	8,900	11,000	13,200	15,400	17,600	38,000
Future Development	2,500	2,600	2,700	2,900	3,000	4,500	25,000

4.3 Findings

The existing collection system capacity was evaluated for deficiencies with future flows in 5-year increments up to 2040 and for the buildout timeframe. The capacity evaluation utilized the November 22, 2011 design storm assuming system degradation (5-year design storm). The system was evaluated for flow depth, freeboard, velocity, and firm capacity deficiencies based on WES design criteria as documented in Section 3, Table 3-8. System deficiencies by 2040 are presented on Figure 4-4.

Additional results of the future capacity analysis are presented on Figures 4-5 through 4-10 for each 5-year increment up to 2040 and the buildout timeframe. These additional figures illustrate locations of pipe and pump station upsizing required to eliminate system deficiencies.

Flow estimates for the future timeframes at each WRRF are presented in Table 4-3 including a summary of Intertie 2 Pump Station diversion upgrades assuming a maximum capacity at the Kellogg WRRF of 25 mgd. Flow estimates and capacity results in this section exclude any potential RDI/I reduction. A cost effectiveness analysis incorporating optimum levels of RDI/I reduction is presented in Section 5, "Rainfall Derived Infiltration and Inflow Cost Effectiveness Evaluation."

Table 4-3. Future Flow Estimates

Time	Flow Rate (mgd)	Kellogg WRRF	Intertie 2 PS	Tri-City IPS	Tri-City WRRF[a]
Existing	Average DWF	5.5	3.2	5.2	8.8
	Peak DWF	6.6	5.1	6.4	12.0
	Peak DWF + GWI	9.9	5.9	11.0	17.8
	Peak DWF + GWI + RDI/I[b]	25.0	14.5	62.3	78.3
	Peak Degraded DWF + GWI + RDI/I[c]	25.0	14.5	62.3	78.3
2020	Average DWF	5.8	4.4	5.6	10.3
	Peak DWF	7.2	5.5	8.0	14.1
	Peak DWF + GWI	11.4	6.4	12.2	19.4
	Peak DWF + GWI + RDI/I[b]	25.0	16.7	62.6	81.9
	Peak Degraded DWF + GWI + RDI/I[c]	25.0	25.9	69.6	98.4
2025	Average DWF	6.1	4.7	5.9	10.9
	Peak DWF	7.7	5.6	8.5	14.7
	Peak DWF + GWI	12.0	6.7	12.5	19.9
	Peak DWF + GWI + RDI/I[b]	25.0	19.6	63.6	86.0
	Peak Degraded DWF + GWI + RDI/I[c]	25.0	37.2	76.3	117.1
2030	Average DWF	6.5	4.9	6.1	11.5
	Peak DWF	8.2	6.2	8.7	15.2
	Peak DWF + GWI	12.7	6.9	13.3	21.0
	Peak DWF + GWI + RDI/I[b]	25.0	21.4	64.7	88.8
	Peak Degraded DWF + GWI + RDI/I[c]	25.0	48.5	84.2	137.1
2035	Average DWF	6.8	5.2	6.4	12.1
	Peak DWF	8.7	6.4	9.2	15.8
	Peak DWF + GWI	13.4	7.2	13.6	21.5
	Peak DWF + GWI + RDI/I[b]	25.0	21.7	64.8	89.3
	Peak Degraded DWF + GWI + RDI/I[c]	25.0	58.0	91.9	155.0
2040	Average DWF	7.2	5.5	6.6	12.6
	Peak DWF	9.2	6.6	9.2	16.2
	Peak DWF + GWI	14.2	7.4	14.1	22.3
	Peak DWF + GWI + RDI/I[b]	25.0	22.0	66.0	90.8
	Peak Degraded DWF + GWI + RDI/I[c]	25.0	70.3	99.5	175.7
Buildout	Average DWF	11.0	7.1	9.7	17.7
	Peak DWF	13.9	7.9	13.8	22.6
	Peak DWF + GWI	21.2	8.9	20.1	30.5
	Peak DWF + GWI + RDI/I[b]	25.0	29.1	74.4	108.0
	Peak Degraded DWF + GWI + RDI/I[c]	25.0	230.7	187.8	433.7

[a] Includes diversion flow rates from the Clackamas Pump Station and Intertie 2 Pump Station.

[b] Peak RDI/I during 11/2011 design storm, nondegraded flow rate.

[c] Peak RDI/I during 11/2011 design storm, degraded flow rate, no RDI/I reduction. Degraded flow rates by buildout are theoretical assuming no investment in replacement and repair of the system.

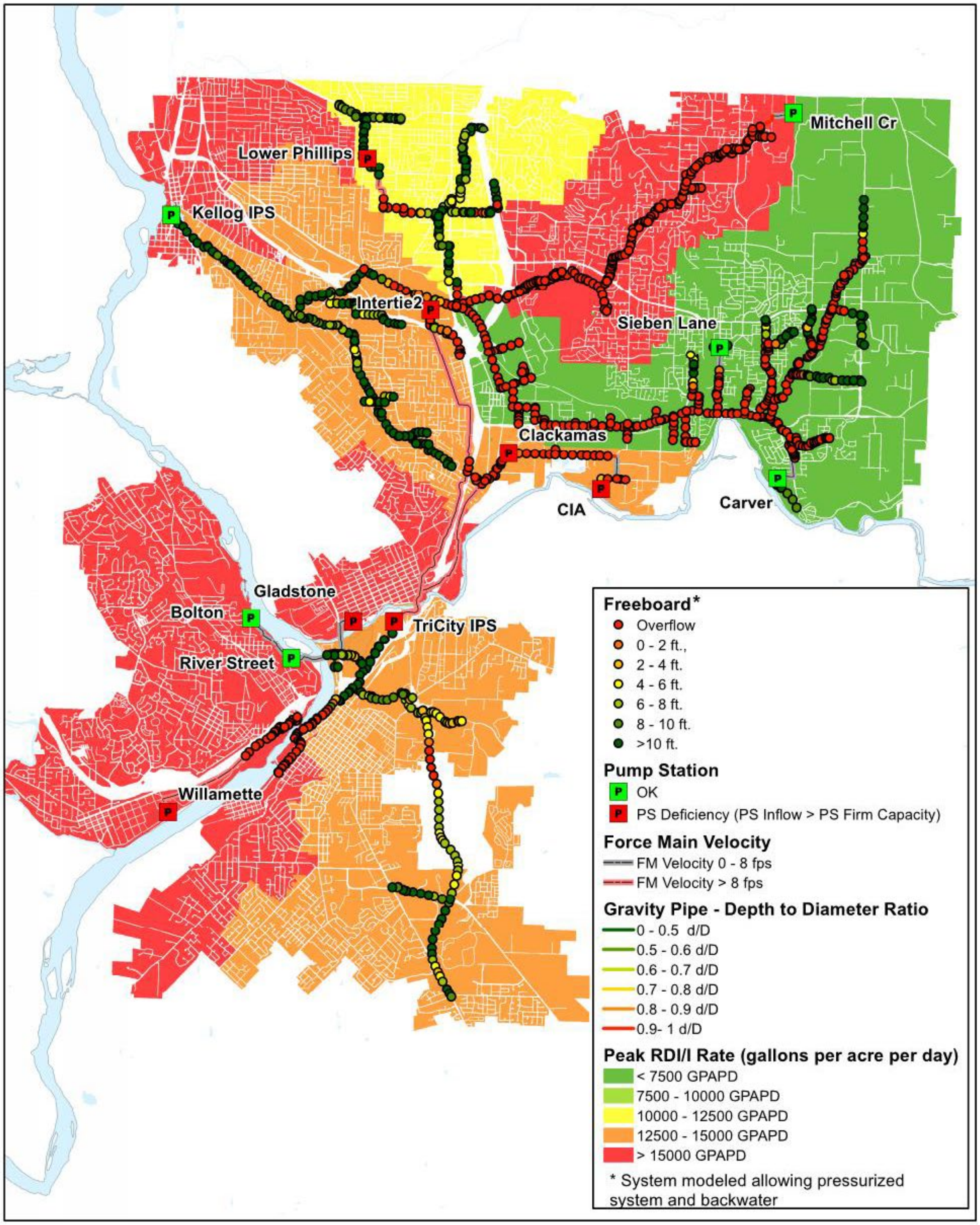


Figure 4-4. Existing System Deficiencies with 2040 Peak Flow and Degraded RDI/I

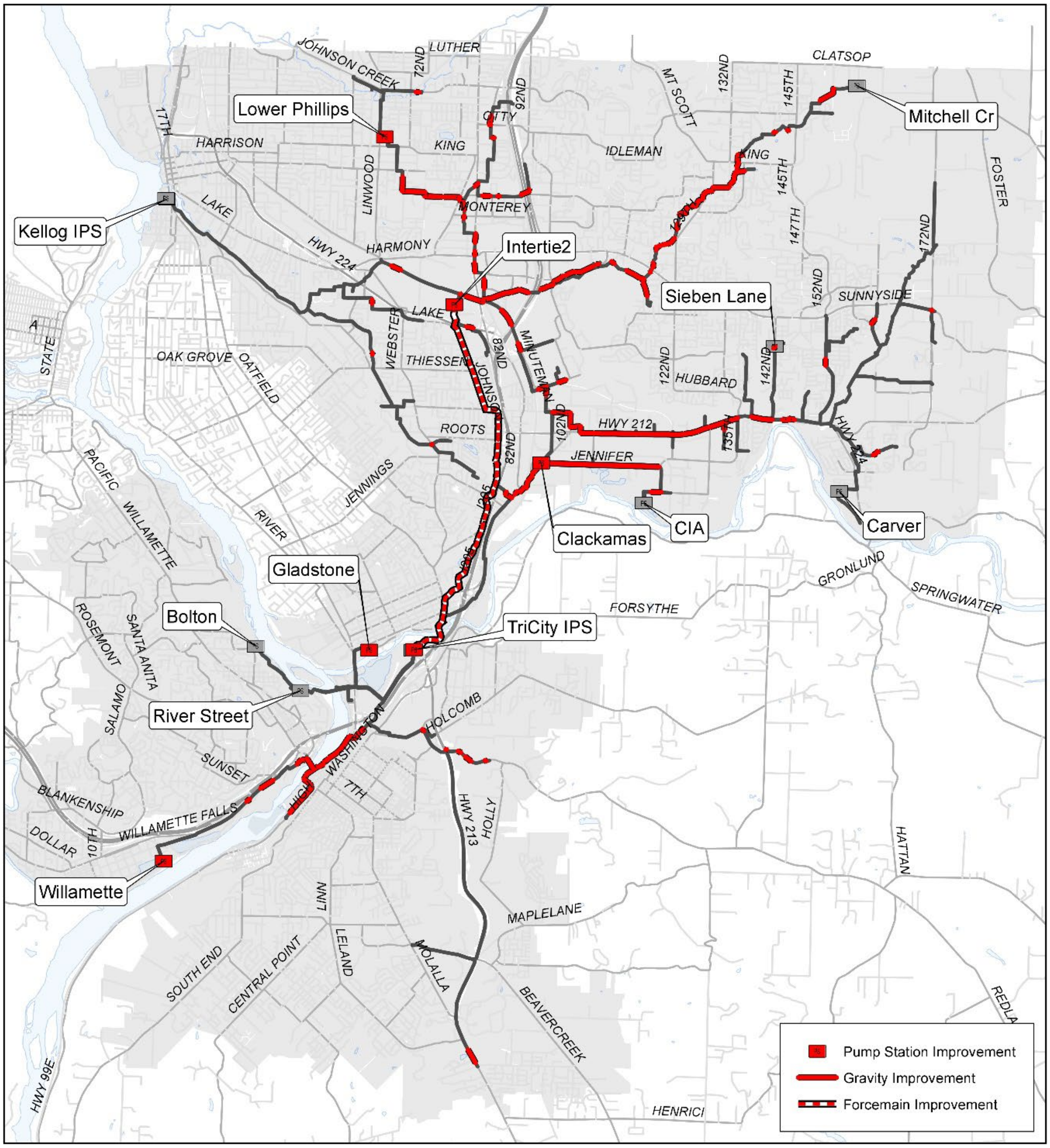


Figure 4-5. Pipeline and Pump Station Upsizing to Address System Deficiencies, 2020

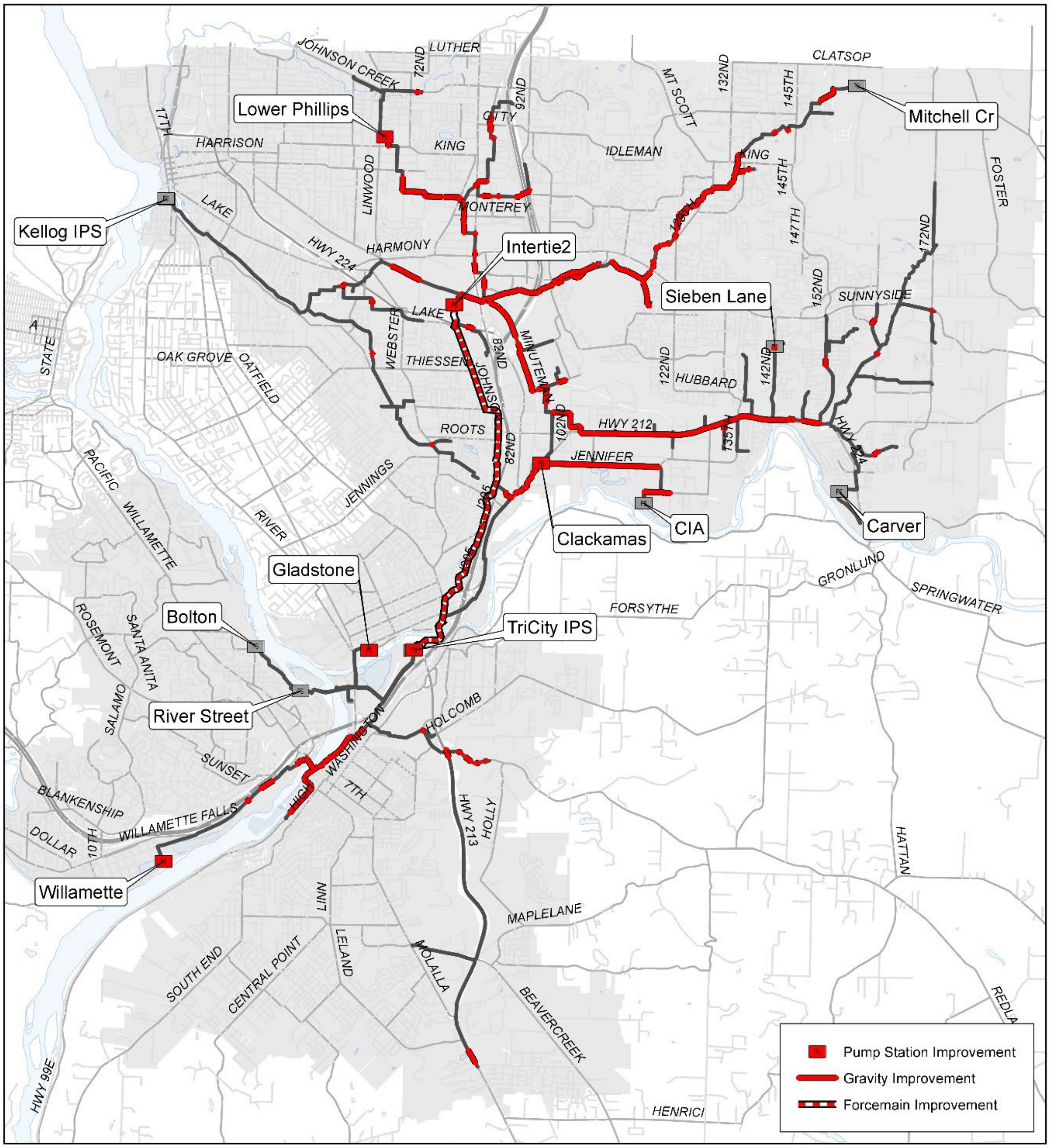


Figure 4-6. Pipeline and Pump Station Upsizing to Address System Deficiencies, 2025

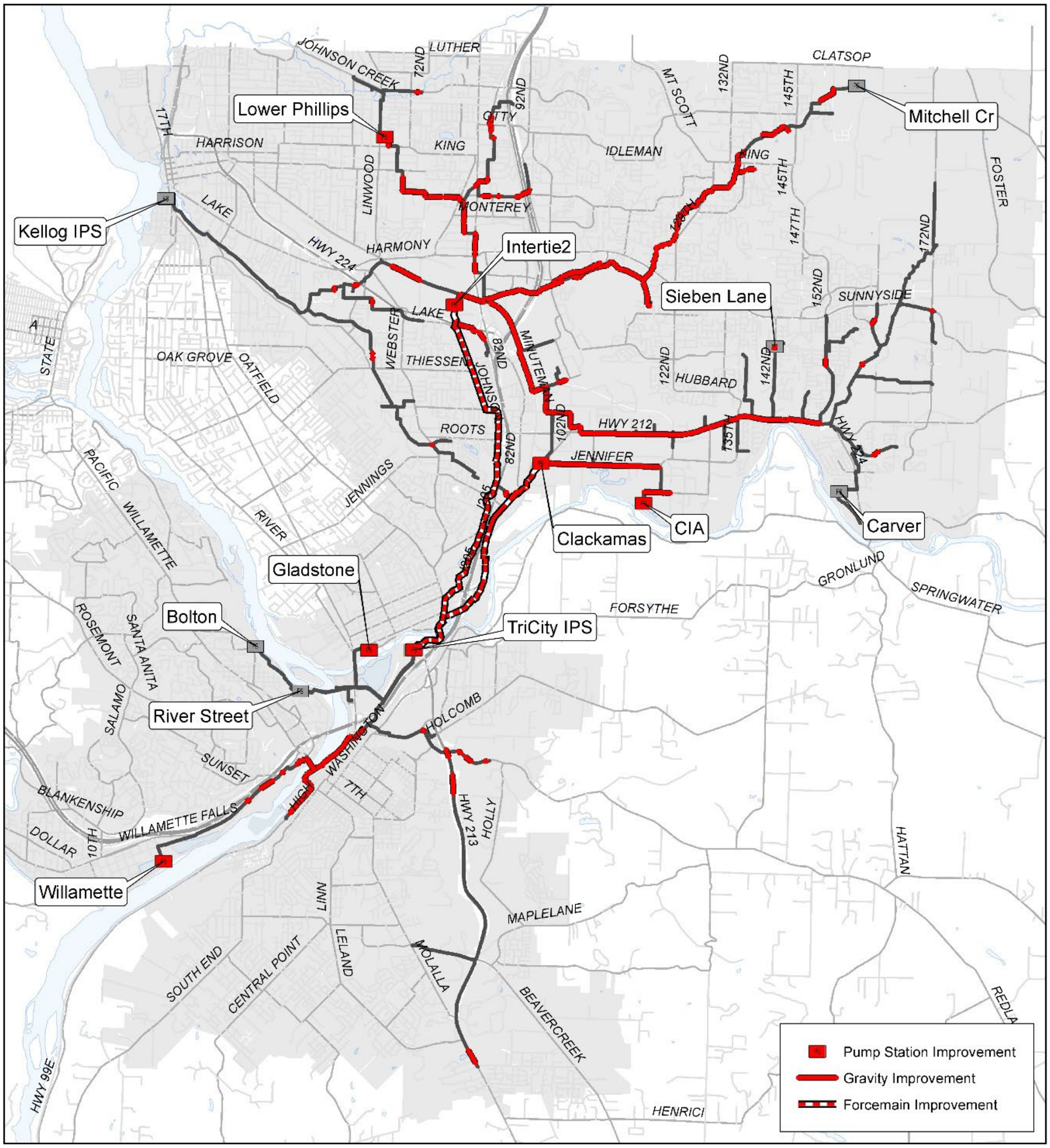


Figure 4-7. Pipeline and Pump Station Upsizing to Address System Deficiencies, 2030

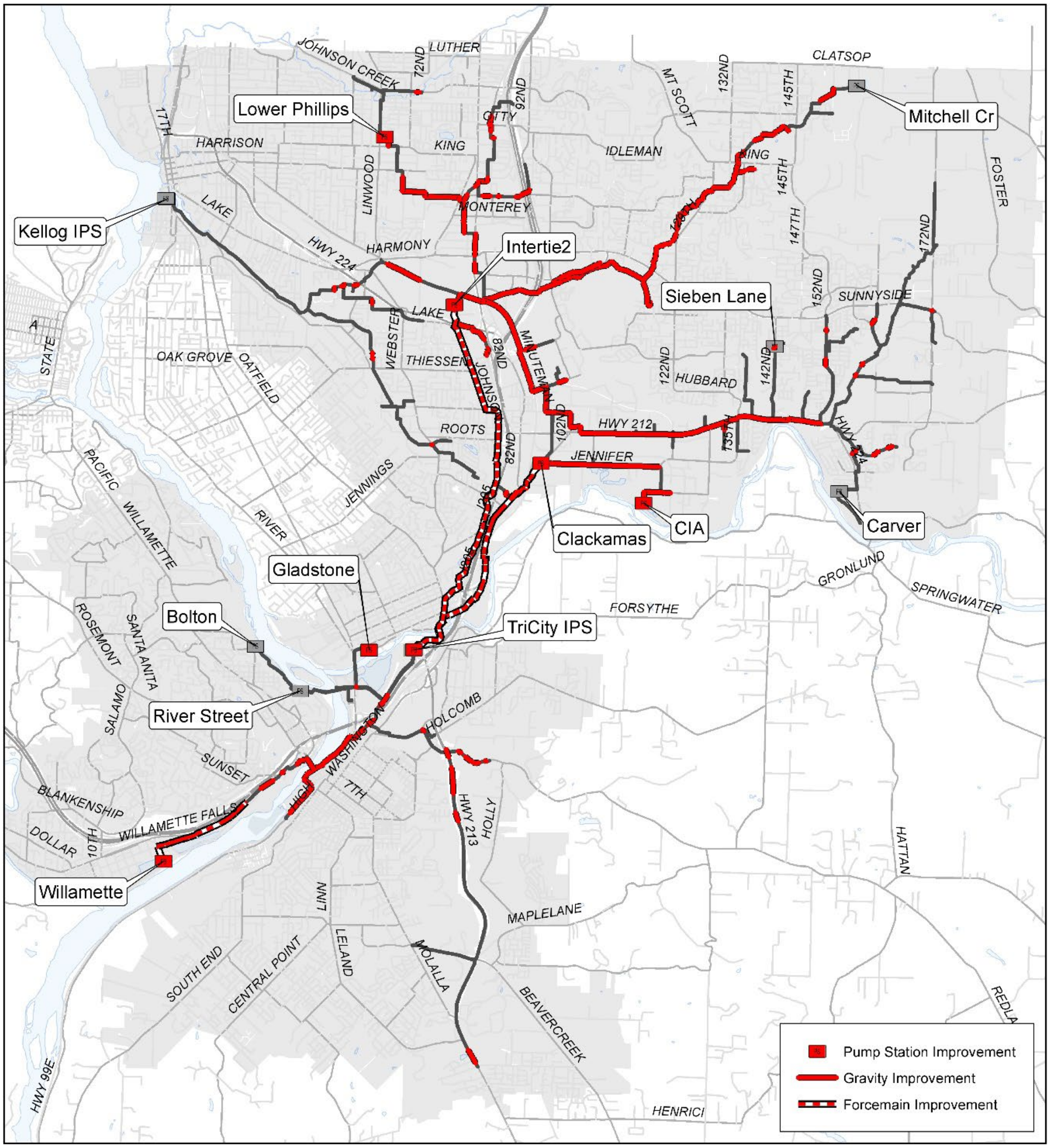


Figure 4-8. Pipeline and Pump Station Upsizing to Address System Deficiencies, 2035

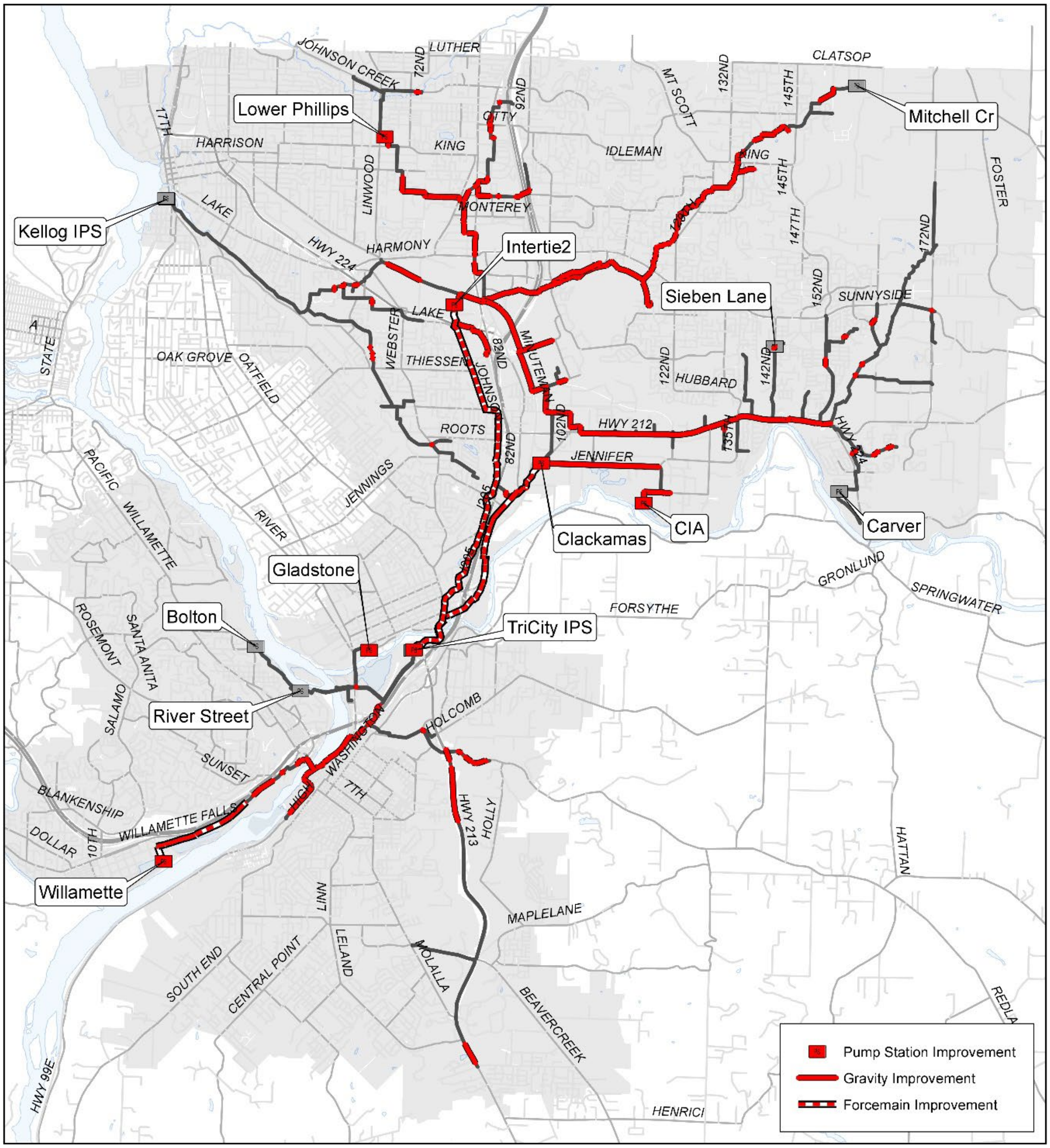


Figure 4-9. Pipeline and Pump Station Upsizing to Address System Deficiencies, 2040

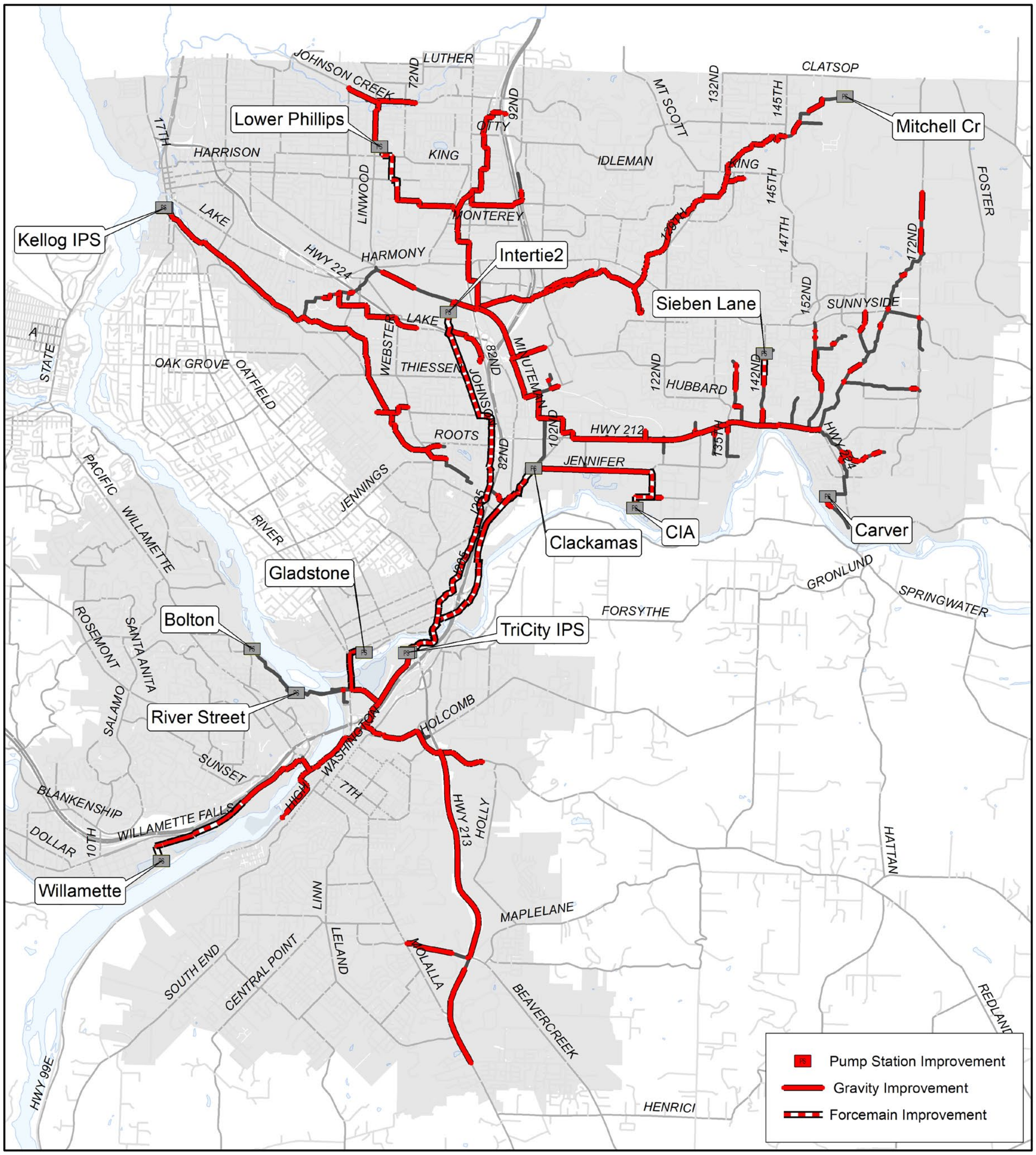


Figure 4-10. Pipeline and Pump Station Upsizing to Address System Deficiencies, Buildout

Future DWF, GWI, and RDI/I peak flow estimates including degraded RDI/I cause system hydraulic deficiencies. The most substantial deficiencies occur during the design storm event and are the result of high RDI/I. System deficiencies at key locations are further summarized in Table 4-4 including reference to deficiency timing.

Table 4-4. Future System Deficiency Summary

Location/Infrastructure	Description
Holly, Mill Street, River Street Pump Station, and WI-40 Basins	RDI/I rates in excess of 20,000 gpad are an indication of significant local condition issues within the collection system and significantly contribute to both local and downstream capacity deficiencies.
Bolton Pump Station, Gladstone Pump Station, Clackamas Pump Station, Milwaukie, Mount Talbert, Unified Grocery, Willamette Pump Station, Lower Kellogg, Harmony, Agnes, and Agnes Main Basins	RDI/I rates in excess of 14,000 gpad are an indication of system deterioration and contribute significantly to both local and downstream capacity deficiencies.
Upper portions of the Clackamas Interceptor, Jennifer Main, Clackamas Pump Station, large segments of the Mount Talbert and Happy Valley interceptors, Lower Phillips Pump Station, Gladstone Pump Station, upper portions of the Willamette Interceptor, Willamette Pump Station, and lower portions of the West Linn Interceptor	Infrastructure with capacity deficiencies by 2020.
Lower portions of the Clackamas Interceptor, the Lower Phillips Interceptor, and the Country Village Trunk	Infrastructure with capacity deficiencies by 2025. The timing of the Lower Phillips Interceptor is delayed to 2025 based on a maximum flow diversion of 500 equivalent dwelling units to the City of Portland.
CIA Pump Station and the Clackamas Pump Station force main	Infrastructure with capacity deficiencies by 2030.
Newell Creek Interceptor, middle portions of the Willamette Interceptor, and limited segments of the Mount Scott Interceptor	Infrastructure with capacity deficiencies by 2035.
Kellogg WRRF, Intertie 2 Pump Station, and Tri-City WRRF	The future system analysis assumes that the Kellogg WRRF capacity is increased to 25 mgd. Flow rates in excess of the 25 mgd are diverted via the Intertie 2 Pump Station to the Tri-City WRRF. The Intertie 2 Pump Station and force main are identified as deficient for the required flow diversion prior to 2020. The Tri-City WRRF is also identified as deficient prior to 2020. The Tri-City Influent Pump Station is identified as deficient in the 2020 to 2025 timeframe.

5. Rainfall-derived Infiltration and Inflow Reduction Cost-Effectiveness Evaluation

Once the existing and future flow projections and capacity evaluations were completed as presented in Sections 3 and 4, a system-wide cost effectiveness evaluation was performed to identify optimum levels of rainfall derived infiltration and inflow (RDI/I) reduction. The goal of the RDI/I reduction evaluation is to identify the least cost capital, operations, and maintenance investment across the system, including local infrastructure rehabilitation (tributary collection and local laterals), trunk line gravity conveyance upsizing, regional and intertie pump station upsizing, and wastewater treatment expansion. All costs are based on lifecycle costs as described in Sections 5.2.2.3 and 5.2.2.4. This section documents the cost effectiveness evaluation to establish RDI/I reduction levels and target dates.

5.1 Objectives

The objectives of this section include:

- Documentation of RDI/I reduction cost effectiveness approach
- Summary of improvements and costs with varied levels of RDI/I reduction at 5-year increments and buildout
- Recommendation of target RDI/I reduction by timeframe and levels of reduction
- Documentation of future flow rates and preliminary system improvements with the application RDI/I reduction targets

5.2 Methodology and Analysis

5.2.1 RDI/I and Program Definitions

RDI/I is defined as stormwater that enters the collection system during or immediately following a rain event. Stormwater inflow reaches the collection system by direct connections, such as roof downspouts connected to sanitary sewers, yard and area drains, holes in manhole covers, cross-connections with storm drains or catch basins, and pipeline defects. Rainfall-derived infiltration includes stormwater that enters defective pipes, pipe joints, and manhole walls after percolating through the soil.

RDI/I in sewer systems can cause many problems that ultimately result in increased costs. Problems include the following:

- Increased operational and capital costs in the collection system and at treatment plants
- Reduced sewer conveyance and treatment capacity leading to increased potential for sanitary sewer overflows, flooding, and pollution
- Reduced sewer conveyance and treatment capacity restricting future development
- Soil flow into sewers causing structural damage and associated operational problems
- Lowering of groundwater levels leading to detrimental effects on local water resources

An RDI/I Rehabilitation Program is a common method to reduce capital expenditures when compared to conveyance and treatment expansion depending on the extent of RDI/I influence. Rates of RDI/I reduction through rehabilitation are highly variable and cost recovery for successful programs typically occur over a number of years. The most effective programs eliminate RDI/I contributions from a combination of main lines, lateral connections, and private laterals. The program focuses on the locations of excess water entering the collection system based on meter data, stormwater cross-connections identified through smoke testing, and locations of structural failure identified through CCTV field investigation. In some cases, newer piping may require rehabilitation, if high RDI/I is present. An effective

RDI/I Rehabilitation Program requires cooperation of stakeholders within the service area, including member cities and private landowners.

In addition to an RDI/I Rehabilitation Program, a city or local jurisdiction-implemented Repair and Replacement (R&R) Program is required to extend the useful life of the collection system by repairing or replacing aging infrastructure. The R&R Program proactively rehabilitates sewers prior to failure. There can be significant overlap between a RDI/I Rehabilitation Program and an R&R Program, as structural and hydraulic failures in a pipeline can contribute to higher RDI/I rates.

5.2.2 Cost-Effectiveness Approach

The system-wide cost-effectiveness evaluation compared the cost of an RDI/I Rehabilitation Program to the cost of conveyance and treatment for varied reduction levels at 5-year incremental timeframes. The evaluation identified the most cost-effective RDI/I reduction level and the timeframe for implementation.

Steps in the cost effectiveness evaluation are generally introduced below and illustrated in Figure 5-1. Additional detail on the methodology and associated steps are discussed throughout this section.

1) Step 1 - Delineate RDI/I subbasin boundaries from local city and county master plans or flowmetering data. Apply local RDI/I information to distribute WES meter basin RDI/I rates to local subbasins.
2) Step 2 - Estimate rehabilitation capital cost by subbasin and time frame for RDI/I rehabilitation throughout the system (subbasin sequencing scenarios). Order subbasins from highest to lowest RDI/I rate per length of potential pipe rehabilitated for the sequencing.
3) Step 3 - Apply rehabilitation costs at 20-percent, 30-percent, and 65-percent RDI/I reduction as defined in Section 5.2.2.2. Divide costs between the RDI/I Rehabilitation Program and the R&R Program based on average subbasin infrastructure age. The RDI/I Rehabilitation Program (Category 2 per Section 5.2.2.4) costs were used for the cost effectiveness evaluation. Reduction was capped at a minimum RDI/I rate of 2,500 gallons per net acre per day (gpad).
4) Step 4 – Reduce flow rates and accumulate the flow rates in the downstream infrastructure. Use the reduced peak flow rates to identify system deficiencies; size conveyance and treatment capital projects; and estimate capital, operation, and maintenance costs for each combination of reduction alternative, subbasin sequencing scenario, and time frame.
5) Step 5 - Summarize capital, operations, and maintenance costs for the combination of RDI/I rehabilitation, conveyance upsizing, and treatment expansion for each alternative, scenario, and time frame. The summary was used to plot the system-wide cost effectiveness curve for each alternative and time frame.
6) Step 6 – From the collective set of cost effectiveness curves, select an RDI/I reduction target from the three reduction alternatives, and a timeframe for implementation. Utilize the selected reduction flow rates for conveyance system improvement alternatives evaluation.

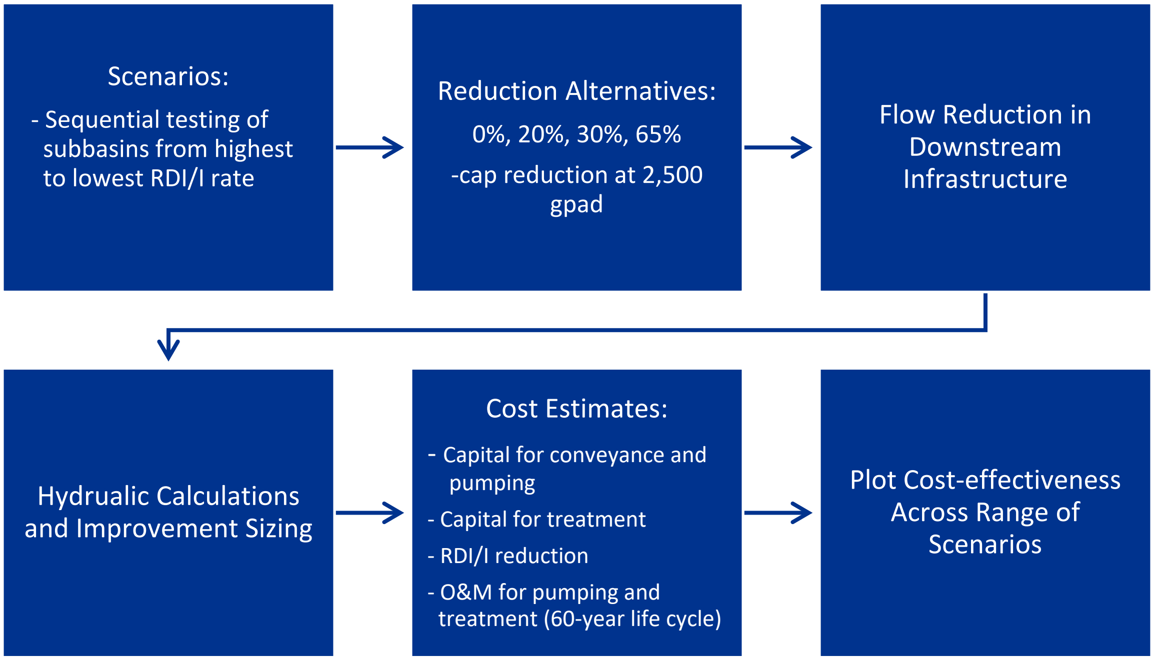


Figure 5-1. Cost-effectiveness Evaluation Approach

5.2.2.1 Subbasin Delineation and Degraded RDI/I Rates

Local piping and laterals within members cities and the county were used to establish RDI/I reduction costs and perform the cost effectiveness evaluation at a subbasin level. WES meter basins were subdivided into 43 local subbasins. WES meter basin RDI/I volumes were distributed at the subbasin level by referencing metering and associated RDI/I rates from member city master plan documents or localized flow monitoring. The degradation methodology described in Section 4 was applied to the subbasin RDI/I rates. Subbasin delineation is presented on Figure 5-2 and degraded RDI/I rates during WES design storm are summarized in Table 5-1. The sources of information used to reference subbasin RDI/I rates are further summarized below.

- Oregon City (*Sanitary Sewer Master Plan,* June 2014): The Oregon City Master Plan identified local metering in Oregon City subbasins 5, 8, 10, and 12 as contributing the highest RDI/I rates at 7,600 to 16,400 gallons per sewershed acre per day. Other subbasins were identified as contributing 5,200 to 6,200 gallons per sewershed acre per day. The local RDI/I rates were summarized on a per sewershed basis and were converted to a net acreage basis by comparing the pipe length and buffer area to total net acreage in each subbasin.
- Gladstone (*Sanitary Sewer Master Plan*, April 2017): The Gladstone Master Plan identified local metering basins 1_10100 and 2_20400 as contributing the highest RDI/I rates at greater than 20,000 gpad. To account for bypass flows to the Clackamas River, metering was performed downstream and upstream of the bypass location and the Gladstone system model was calibrated to predict the volume of potential overflows. The higher rate is caused in part by stormwater overflow connections to the sanitary system. Controlled overflow locations to the Clackamas River prevent a significant volume of stormwater from impacting the downstream WES infrastructure. In addition to the stormwater infiltration and inflow components in the system, there are other factors that influence wet weather contributions, including:
    - The restrictions in the existing piping into the Gladstone Pump Station (the piping into the Gladstone Pump Station is significantly undersized and does not have capacity to convey direct stormwater overflows into the sanitary system).
    - Uncertain timing of stormwater improvements in the Gladstone system;

  - Existing sanitary sewer overflows in the Gladstone system under certain wet weather conditions that serve to limit the peak flow rate to the Gladstone Pump Station and the downstream system.
  - Based on these factors, the Gladstone RDI/I rates for metering basins 1_10100 and 2_20400 were adjusted to approximate removal of direct stormwater connections. The adjustment is based on the maximum flow from metering upstream of the likely storm connections or the limiting pipe capacity downstream of the direct storm connections. Other subbasins are less impacted by direct stormwater connections and contribute RDI/I rates in the range of 1,000 to 5,600 gpad.

- West Linn (*Sanitary Sewer Master Plan Update*, December 1999; Flow Monitoring in 2016): The West Linn Master Plan is currently being updated to reflect localized flow monitoring data collected in 2016. The 2016 flow monitoring data were provided by the City of West Linn at 10 locations and was evaluated through the same process as WES meters to define RDI/I rates on a net acreage basis during WES design storm (see Section 3). The RDI/I rates range from 2,900 to 20,000 gpad with major portions of the West Linn system contributing greater than 15,000 gpad on a net acreage basis.
- Clackamas County, Happy Valley, Johnson City, and Milwaukie: WES flowmetering from 2015–2016 indicate peak RDI/I rate of 6,300 to 8,000 gpad in the Milwaukie and Mount Talbert meter basins. The RDI/I rates were calculated from the current analysis of WES flow monitoring and modeling of the selected design storm as described in Section 3. Other subbasins were identified as contributing 2,100 to 4,100 gpad on a net acreage basis.

Table 5-1. Summary of Rainfall-derived Infiltration and Inflow Degraded Rates by Subbasin for the Design Storm

Subbasin	Map ID	Jurisdiction	Basin	Degraded RDI/I Rate (gallons per net acre per day)						
				Exist	2020	2025	2030	2035	2040	Buildout[a]
Clackamas_Int	1	Clackamas Co/ Happy Valley	Clackamas_Int	2,100	2,200	2,300	2,500	2,600	2,700	17,600
Clackamas_PS	2	Clackamas Co	Clackamas_PS	4,100	6,300	8,400	10,600	12,800	15,000	35,400
Harmony	3	Clackamas Co	Harmony	3,200	5,400	7,600	9,700	11,900	14,100	34,500
Lower Kellogg	4	Clackamas Co	Lower Kellogg	3,200	5,400	7,600	9,700	11,900	14,100	34,500
Mount_Talbert	5	Clackamas Co /Happy Valley	Mount_Talbert	8,000	10,200	12,400	14,500	16,700	18,900	39,300
Phillips_Int	6	Clackamas Co	Phillips_Int	2,800	2,900	3,600	5,800	8,000	10,200	30,600
Unified Grocers	7	Clackamas Co	Unified_Grocer	3,900	6,300	8,400	10,600	12,800	15,000	35,400
1_10100	8	Gladstone	Gladstone_PS	14,600	16,700	18,900	21,100	23,200	25,400	45,900
2_20400	9	Gladstone	Gladstone_PS	12,700	15,000	17,100	19,300	21,500	23,700	44,100
2_20770	10	Gladstone	Gladstone_PS	600	700	800	1,000	1,100	1,200	2,300
2_20940	11	Gladstone	Gladstone_PS	4,400	6,700	8,900	11,000	13,200	15,400	35,800
2_22800	12	Gladstone	Gladstone_PS	2,800	2,900	3,200	5,400	7,600	9,700	30,200
3_30100DS1	13	Gladstone	Gladstone_PS	1,400	1,500	1,600	1,700	1,800	2,000	4,100
4_40200	14	Gladstone	Gladstone_PS	1,800	2,000	2,100	2,200	2,300	2,400	12,800
5_50100	15	Gladstone	Gladstone_PS	1,600	1,700	1,800	1,900	2,100	2,200	8,000
82ND DR PS	16	Gladstone	Gladstone_PS	3,100	5,000	7,100	9,300	11,500	13,700	34,100
UNMETERED	17	Gladstone	Gladstone_PS	2,600	2,700	2,800	2,900	4,100	6,300	26,700
US_1_10100&DS_2_20400	18	Gladstone	Gladstone_PS	17,300	19,300	21,500	23,700	25,800	28,000	48,500

Table 5-1. Summary of Rainfall-derived Infiltration and Inflow Degraded Rates by Subbasin for the Design Storm

Subbasin	Map ID	Jurisdiction	Basin	Degraded RDI/I Rate (gallons per net acre per day)						
				Exist	2020	2025	2030	2035	2040	Buildout[a]
Milwaukie	19	Milwaukie	Milwaukie	6,300	8,400	10,600	12,800	15,000	17,100	37,600
OC_M01	20	Oregon City	Agnes	3,500	5,800	8,000	10,200	12,400	14,500	35,000
OC_M02	21	Oregon City	Agnes_Main	4,500	6,700	8,900	11,000	13,200	15,400	35,800
OC_M03	22	Oregon City	Agnes_Main	2,000	2,100	2,300	2,400	2,500	2,600	16,300
OC_M04	23	Oregon City	Agnes_Main	1,300	1,500	1,600	1,700	1,800	1,900	3,600
OC_M05	24	Oregon City	Agnes_Main	8,400	10,600	12,800	15,000	17,100	19,300	39,800
OC_M08	25	Oregon City	Agnes_Main	43,900	45,900	48,000	50,200	52,400	54,600	75,000
OC_M10	26	Oregon City	Agnes_Main	36,900	38,900	41,100	43,200	45,400	47,600	68,100
OC_M12	27	Oregon City	Agnes_Main	13,600	15,800	18,000	20,200	22,400	24,500	45,000
OC_M13	28	Oregon City	Agnes_Main	2,100	2,200	2,400	2,500	2,600	2,700	18,000
OC_M14	29	Oregon City	WI-40	1,100	1,200	1,400	1,500	1,600	1,700	2,800
OC_M15	30	Oregon City	WI-40	2,100	2,200	2,300	2,400	2,500	2,600	16,700
OC_M16	31	Oregon City	WI-40	3,400	5,400	7,600	9,700	11,900	14,100	34,500
Hwy_43	32	West Linn	Bolton_PS	17,300	19,300	21,500	23,700	25,800	28,000	48,500
Mapleton	33	West Linn	Bolton_PS	4,800	7,100	9,300	11,500	13,700	15,800	36,300
River_Street	34	West Linn	Bolton_PS	12,400	14,500	16,700	18,900	21,100	23,200	43,700
W_Willamette	35	West Linn	Holly	2,900	3,600	5,800	8,000	10,200	12,400	32,800
Willamette 9C-3	36	West Linn	Holly	9,900	11,900	14,100	16,300	18,400	20,600	41,100
WL_2	37	West Linn	Holly	20,500	22,800	25,000	27,100	29,300	31,500	51,900
9A-14	38	West Linn	Mill_Street	6,000	8,000	10,200	12,400	14,500	16,700	37,200
Bolton_3A-8	39	West Linn	River_St_PS	7,000	9,300	11,500	13,700	15,800	18,000	38,500
Buck_Street_2A-19	40	West Linn	Willamette_PS	16,900	18,900	21,100	23,200	25,400	27,600	48,000
Holly	41	West Linn	Willamette_PS	13,800	15,800	18,000	20,200	22,400	24,500	45,000
Mill_Street	42	West Linn	Willamette_PS	9,000	11,000	13,200	15,400	17,600	19,700	40,200
WL_1_2B-1-0	43	West Linn	Willamette_PS	10,400	12,800	15,000	17,100	19,300	21,500	41,900

[a] Buildout timeframe estimated in 2087.

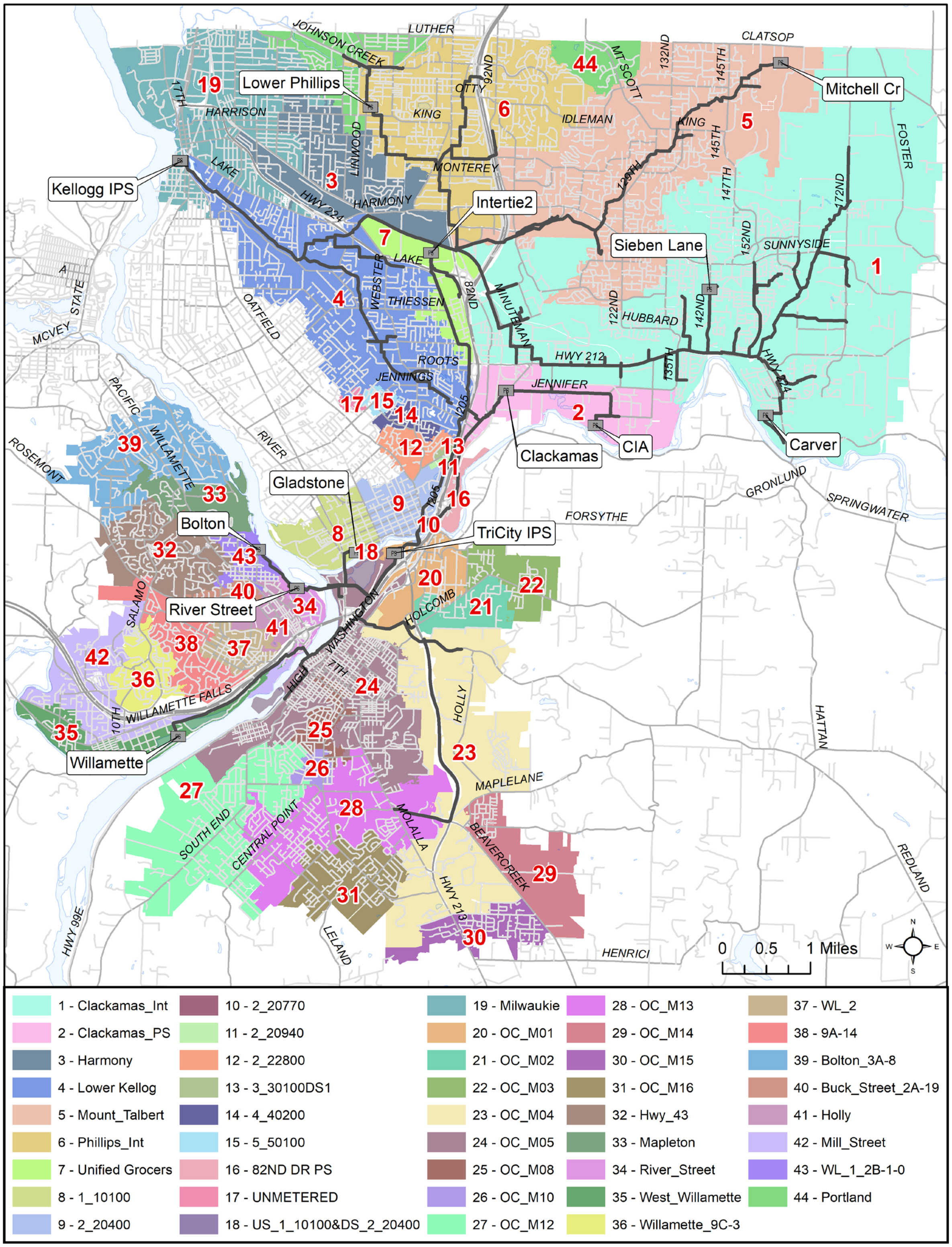


Figure 5-2. Subbasin Delineation

5.2.2.2 RDI/I Reduction Alternatives

Three levels of RDI/I reduction were applied as alternatives in the cost-effectiveness analysis including:

- 20 percent reduction: rehabilitation or replacement of mainlines only (no public or private laterals)
- 30 percent reduction: rehabilitation or replacement of mainlines and the service laterals located in the public right-of-way
- 65 percent reduction: rehabilitation or replacement of mainlines, and the service laterals located in both the public right-of-way pipe and on private property

The target removal percentages were based on several pilot studies and projects in Sweet Home and McMinnville, Oregon. The work consisted of rehabilitation of sewer mains, rehabilitation of the mains and lateral in the public right-of-way, and rehabilitation of the mains and laterals to the building (public right-of-way and private property). Because the most significant contribution of RDI/I typically occurs at the service lateral, these pilot studies are easily scalable to larger communities and basins.

Minimum RDI/I levels were capped at 2,500 gpad, if the existing degraded rate exceeded 2,500 gpad. This means that minimum subbasin RDI/I rates, if reduced, contribute no less than 2,500 gpad given the practicalities of achieving and maintaining lower levels. Reductions were applied to existing RDI/I rates only. All future development RDI/I rates were assumed to contribute 2,500 gpad initially with degradation over time.

The 20-percent, 30-percent, and 65-percent reduction levels were used for planning purposes to identify targeted flows for capital improvement sizing. The actual methods for achieving reduction will vary by subbasin and will be informed by work to identify inflow sources, review local pipe and lateral condition, and coordinate with local sewer customers.

5.2.2.3 Cost Basis

Unit cost rates used for the cost effectiveness evaluation are consistent with Class 5 budget estimates, as established by the *American Association of Cost Engineers* (AACE). This preliminary estimate class is used for conceptual screening and assumes project definition maturity level below two percent. The expected accuracy range is -20 to -50 percent on the low end, and +30 to +100 percent on the high end. The cost estimates are consistent with the definition of OAR 660-011-0005(2) and OAR 660-011-035. Cost estimates are intended to be used as guidance in establishing funding requirements at the project planning level based on information available at the time of the estimate. Estimates exclude land acquisition, financing, and inflation. The unit costs were developed in 2017 dollars as documented in the *Cost Basis and Assumptions Technical Memorandum* (Appendix A). Cost details for treatment, pumping, conveyance, and rehabilitation are summarized as follows:

- Capital costs for the expansion of the Tri-City WRRF were estimated by WES (*Estimated Cost to Treat Projected Peak Wet Weather Flow at Tri-City WRRF*, December 4, 2017). The cost estimates were represented by a step curve up to a maximum capacity of 108 mgd and extrapolated linearly for degraded peak flow rates greater than 108 mgd. Operations and maintenance costs for the Tri-City WRRF were estimated based on the operations costs for 2016-2017, as provided by the WES operations team, and were estimated as present-worth costs using a 3-percent discount rate over 60 years.
- Pump station costs were estimated for a 60-year life cycle and include capital costs, replacement pump/electrical/mechanical costs at 20-year increments, and present value annual operations and power costs. Pump station cost curves were developed from Clean Water Services and Portland area specific capital, operations, and maintenance projects.
- Conveyance costs were developed for force mains, gravity pipes, and rehabilitation of existing pipelines and laterals. Costs for excavation in Oregon City were increased by 25 percent to account for expected rock excavation. The cost effectiveness evaluation assumed pipeline upsizing rather than parallel piping, unless otherwise noted. An environmental factor of 40 percent was applied to

construction in sensitive areas to account for environmental permitting, surface restoration, and construction matting.

- The force main unit costs include pipe materials, installation costs, and surface restoration. Unit costs assume that force mains are installed at no more than 10 ft depths, using AWWA C900 pipe and restrained joints. The force main costs were derived from previous projects, ODOT, and City of Portland cost referencing.
- Gravity sewer unit costs include pipe material (assumed to be PVC for diameters up to 36-inch and reinforced concrete pipe for larger pipes), installation, manholes at an average interval of 300 feet and surface restoration. Material costs are based on City of Portland cost referencing and Ogden Oldcastle quotes. Installation and surface restoration costs are based on previous project experience in the area including ODOT, WSDOT and City of Portland project costs.
- Pipeline rehabilitation unit costs assume CIPP lining of existing sewers and lateral replacement. The costs for bypass pumping are included in replacement and rehabilitation unit cost estimates. Pipe rehabilitation costs were estimated from similar projects for the City of Portland, Mount Angel, Sheridan, and St. Helens. For lateral rehabilitation, laterals were divided into two segments: from the sewer main to the property line and from the property line to the private connection. An inventory of mainlines by diameter, length, and number of service connections were estimated and summarized for each subbasin from city and county GIS data for application of unit costs to rehabilitate local sanitary piping and replace lateral connections.
- All costs were marked up using a uniform cost basis for factors and fees as shown in Table 5-2 including a composite contingency and indirect construction cost multiplier of 2.054. Treatment costs

Table 5-2. Contingency and Indirect Cost Multipliers

Cost Item	Rehabilitation, Conveyance and Pump Station Cost Basis	Treatment Cost Basis[a]
Construction Contingency	**30%**	**30%**
Indirect Costs:		
Design	20%	20%
Construction Management	15%	13%
Public Involvement/Permitting	3%	0%
General Conditions	20%	10%
Contractor Overhead & Profit		15%
Total Indirect Costs	**58%**	**58%**
Contingency and Indirect Construction Cost Multiplier	***2.054***	***2.054***

[a] Original estimates for treatment costs include a multiplier of 1.73, which assumes general conditions and contractor overhead/profit within the premultiplier costs for labor and construction. These categories were subtracted from the treatment labor and construction costs and added back as a multiplier for consistency with conveyance cost estimates.

5.2.2.4 R&R Program and RDI//I Reduction Program

The piping improvement costs for each subbasin are divided into the following two categories based on pipe age:

- Category 1 – Costs of an R&R Program to invest in aging infrastructure funded by local rate payers and administered by local cities or jurisdictions. The result is a cost-effectiveness analysis that incorporates the reduction of RDI/I due to local asset management actions. Therefore, the costs for Category 1 pipe repair or replacement were excluded from the RDI/I cost-effectiveness evaluation because the local investment is assumed to be built into local rate structures for improvement of piping that reaches the end of its useful design life.
- Category 2 – Costs were developed for additional RDI/I reduction to supplement the Category 1 reduction including costs to effectively minimize system peak flow rates and reduce conveyance and

treatment costs. Category 2 costs were included in the RDI/I cost-effectiveness analysis as rehabilitation costs (CIPP lining and lateral repair/replacement) to reduce overall system conveyance and treatment improvements to optimal cost-effective levels.

A correlation between pipe age and RDI/I rates was developed for areas of the system where age information is available. In each subbasin, the proportion of Category 1 to Category 2 costs were estimated by comparing the average age of piping in the subbasin to a 100-year design life. One minus the ratio of average age to 100 years was applied to total pipe length and lateral rehabilitation costs to represent the eligible costs for Category 2. Where pipe age information was unavailable, the correlation was used to extrapolate the subbasin pipe age based on the metered RDI/I rates and modeled design storm as described in Section 4.

5.3 Findings

5.3.1 Cost Effectiveness Curves and Mapping by Target Level and Date

The cost effectiveness evaluation was performed applying rehabilitation to subbasins sequentially from highest to lowest RDI/I impact, for the three rehabilitation alternatives (20-, 30-, and 65-percent reduction), and for varied target dates. Results of the evaluation are presented as improvement maps and cost summaries on Figures 5-3 through 5-9 for each 5-year target date to 2040 and buildout. All costs include present value life cycle estimates over 60-years including capital, operations, and maintenance assuming the system is improved to satisfy the reduction target at the specified time. The information presented in the figures includes preliminary pipeline and pump station upsizing. The preliminary improvements and associated costs were used to select a target RDI/I level and target reduction date. The selected RDI/I level and date were subsequently used for alternatives evaluations to finalize capital improvement recommendations as documented in Sections 8 and 9.

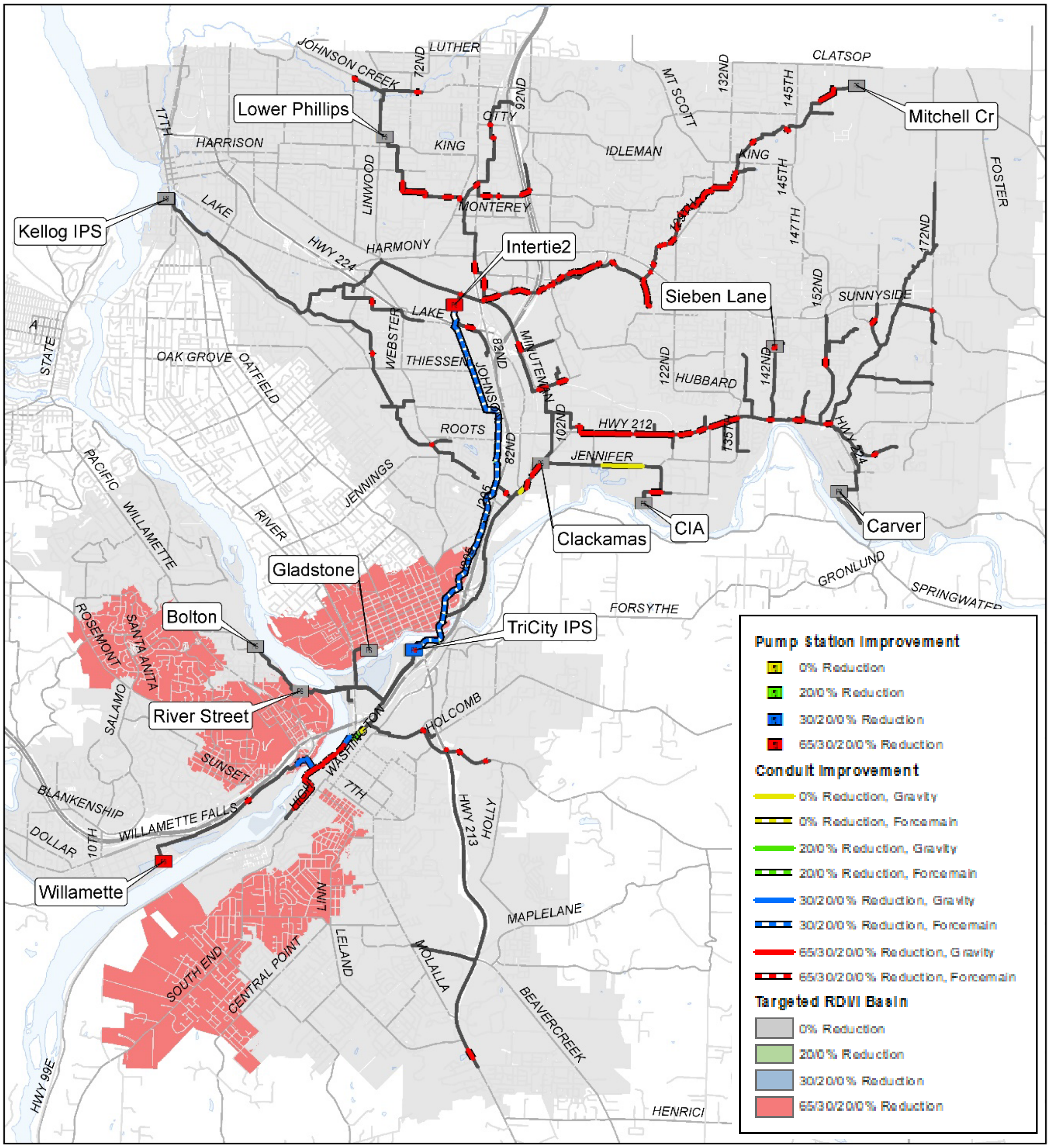
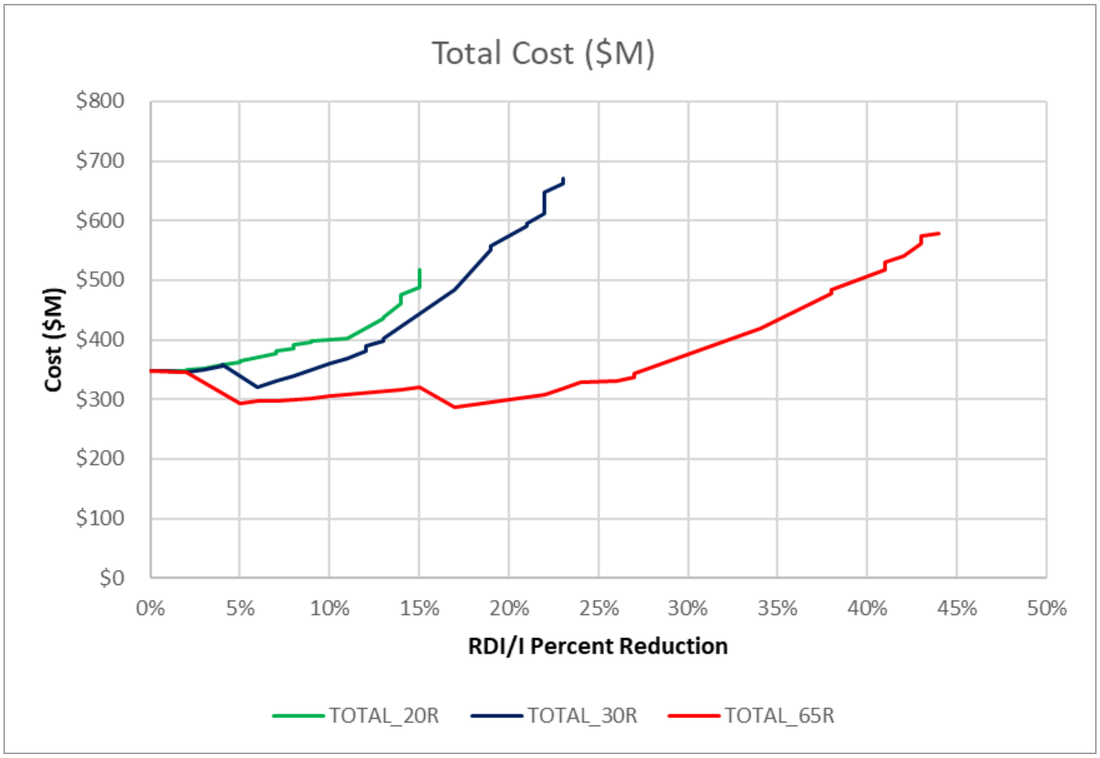


Figure 5-3a. Cost-Effective RDI/I Reduction and Capital Improvement Locations, Optimal RDI/I Reduction for 2018 Target Reduction Date

Note: Infrastructure is color-coded to represent all target levels at which an improvement is required. Red infrastructure indicates that an improvement is required for 0, 20, 30, and 65-percent reduction. Blue infrastructure indicates that an improvement is required for 0, 20, and 30-percent reduction, but not required for 65-percent reduction. Green infrastructure indicates that an improvement is required for 0 and 20-percent reduction, but not required for 30 and 65-percent reduction. Yellow infrastructure indicates that an improvement is required for 0-percent reduction, but not required for 20, 30, and 65-percent reduction. Improvement maps include preliminary upsizing of pipelines and pump stations for the cost-effectiveness analysis and are not intended to represent final capital improvement mapping.



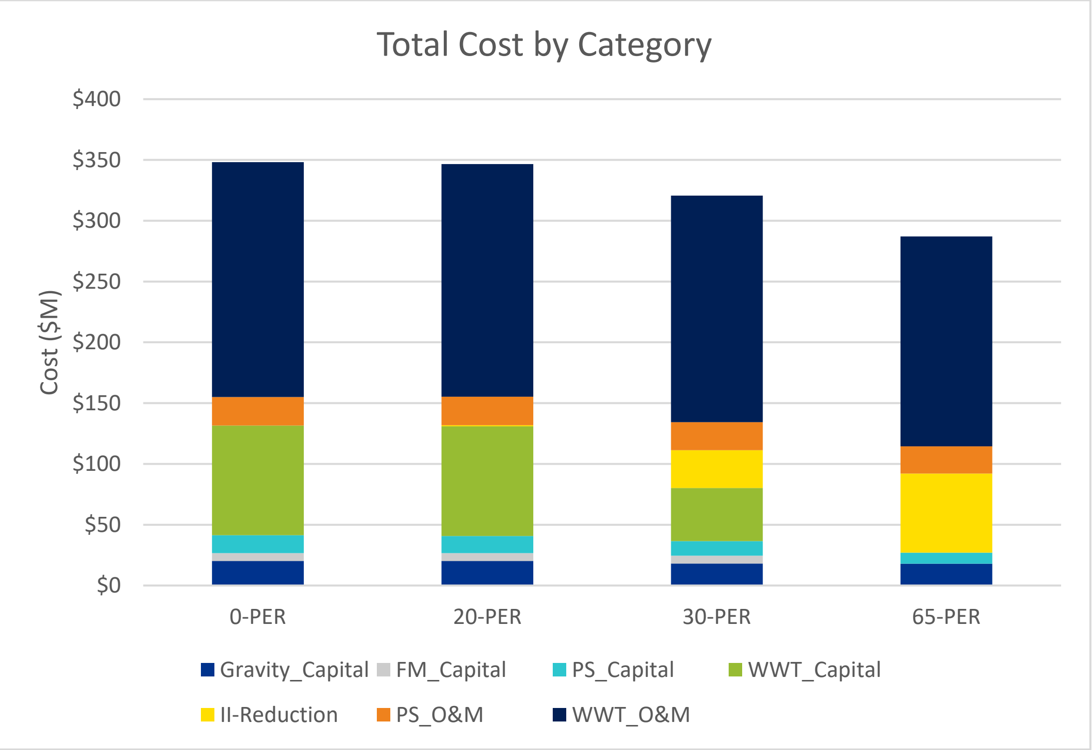


Figure 5-3b. Cost Effectiveness Curves (line-graph) and Lowest Life-Cycle Costs (bar chart), Optimal RDI/I Reduction for 2018 Target Reduction Date

Note: Percent reduction on x-axis of line graph represents system-wide total peak flow reduction when applying 0, 20, 30, or 65-percent reduction to specific subbasins. Total costs exclude Category 1 R&R Program costs and include Category 2 RDI/I Rehabilitation Program costs.

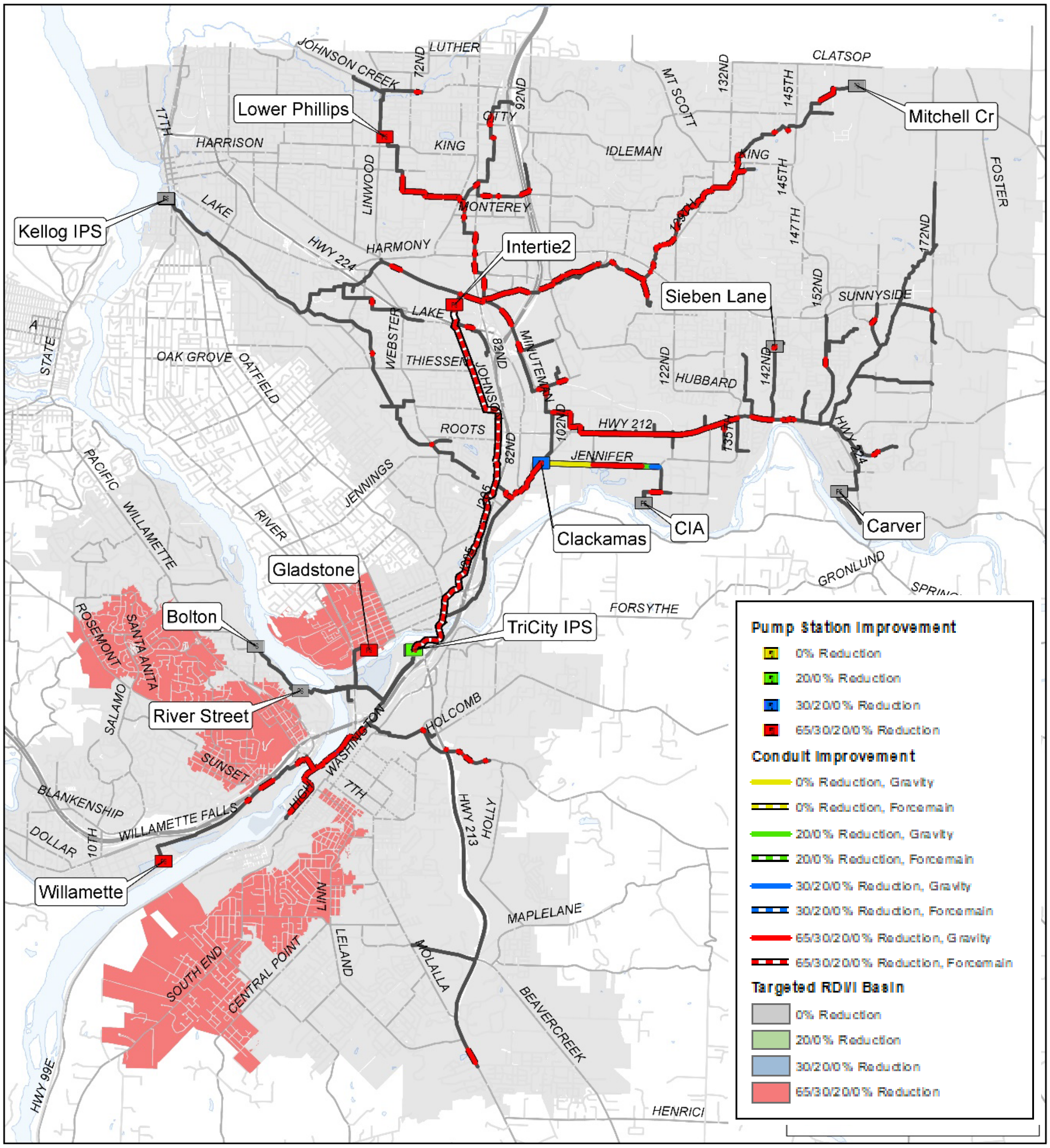
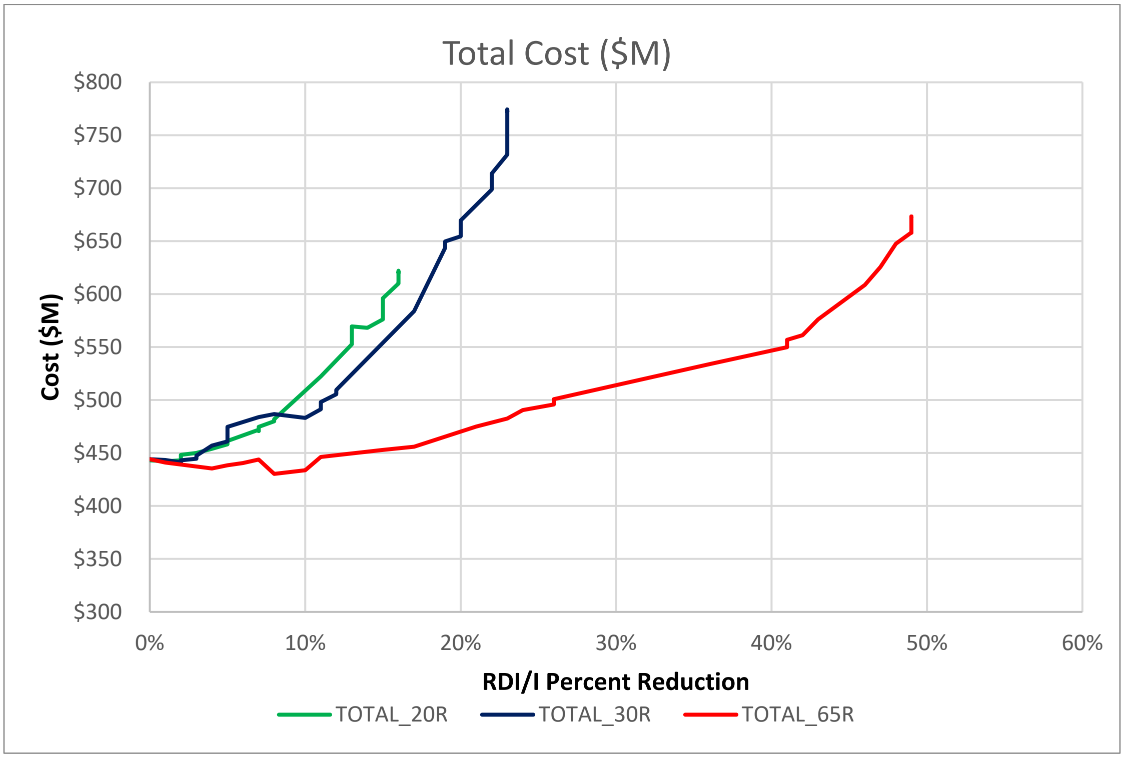


Figure 5-4a. Cost-Effective RDI/I Reduction and Capital Improvement Locations, Optimal RDI/I Reduction for 2020 Target Reduction Date

Note: Infrastructure is color-coded to represent all target levels at which an improvement is required. Red infrastructure indicates that an improvement is required for 0, 20, 30, and 65-percent reduction. Blue infrastructure indicates that an improvement is required for 0, 20, and 30-percent reduction, but not required for 65-percent reduction. Green infrastructure indicates that an improvement is required for 0 and 20-percent reduction, but not required for 30 and 65-percent reduction. Yellow infrastructure indicates that an improvement is required for 0-percent reduction, but not required for 20, 30, and 65-percent reduction. Improvement maps include preliminary upsizing of pipelines and pump stations for the cost-effectiveness analysis and are not intended to represent final capital improvement mapping.



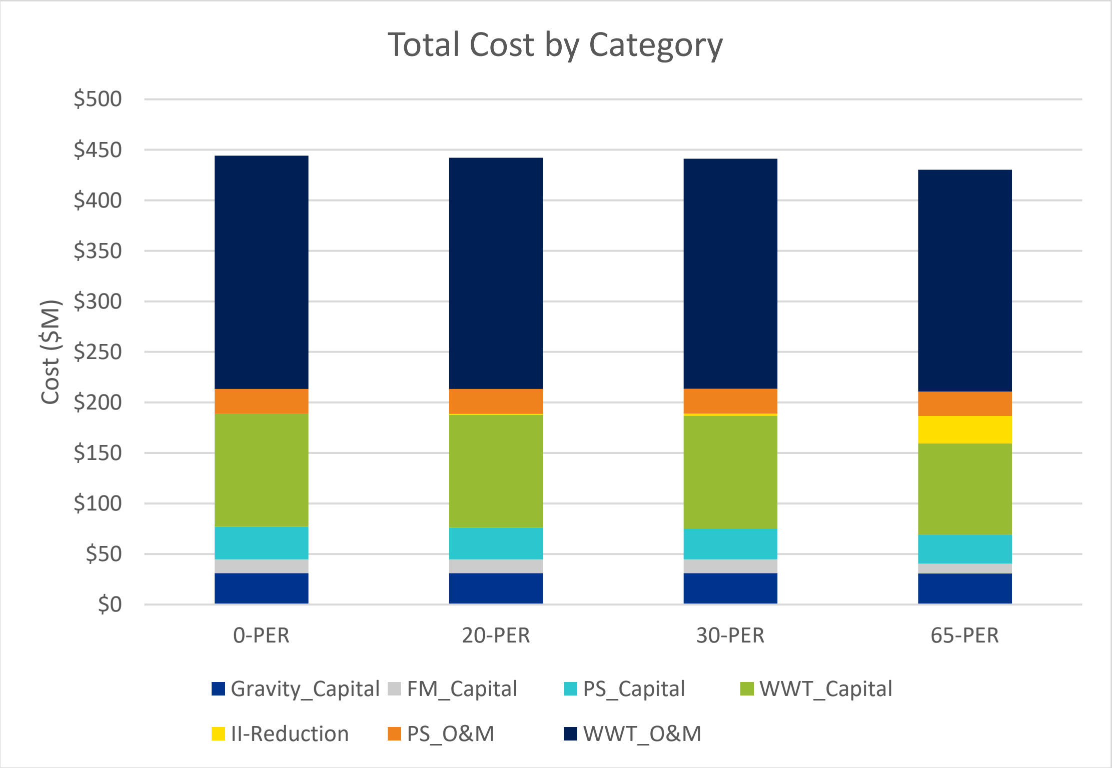


Figure 5-4b. Cost Effectiveness Curves (line-graph) and Lowest Life-Cycle Costs (bar chart), Optimal RDI/I Reduction for 2020 Target Reduction Date

Note: Percent reduction on x-axis of line graph represents system-wide total peak flow reduction when applying 0, 20, 30, or 65-percent reduction to specific subbasins. Total costs exclude Category 1 R&R Program costs and include Category 2 RDI/I Rehabilitation Program costs.

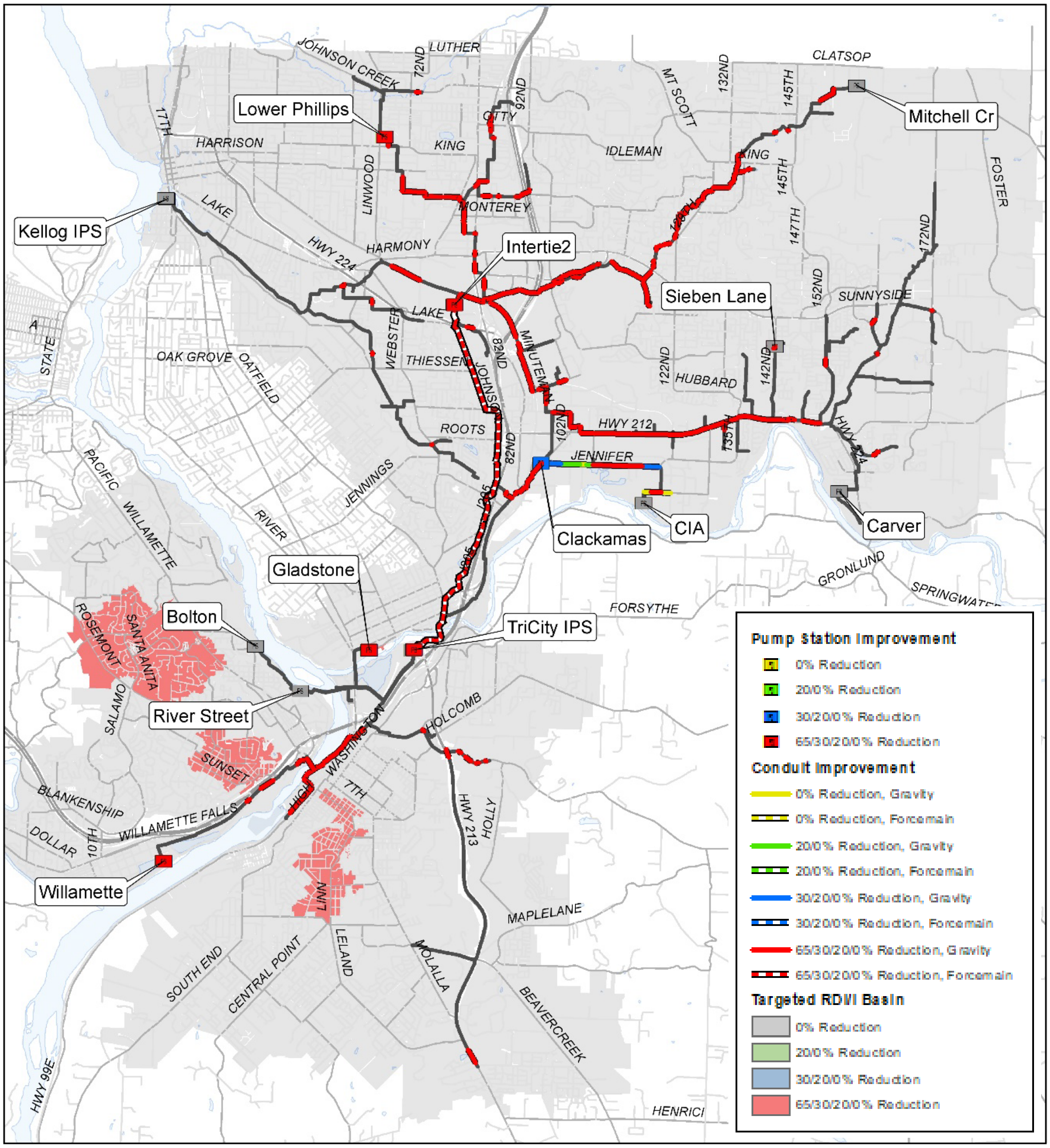
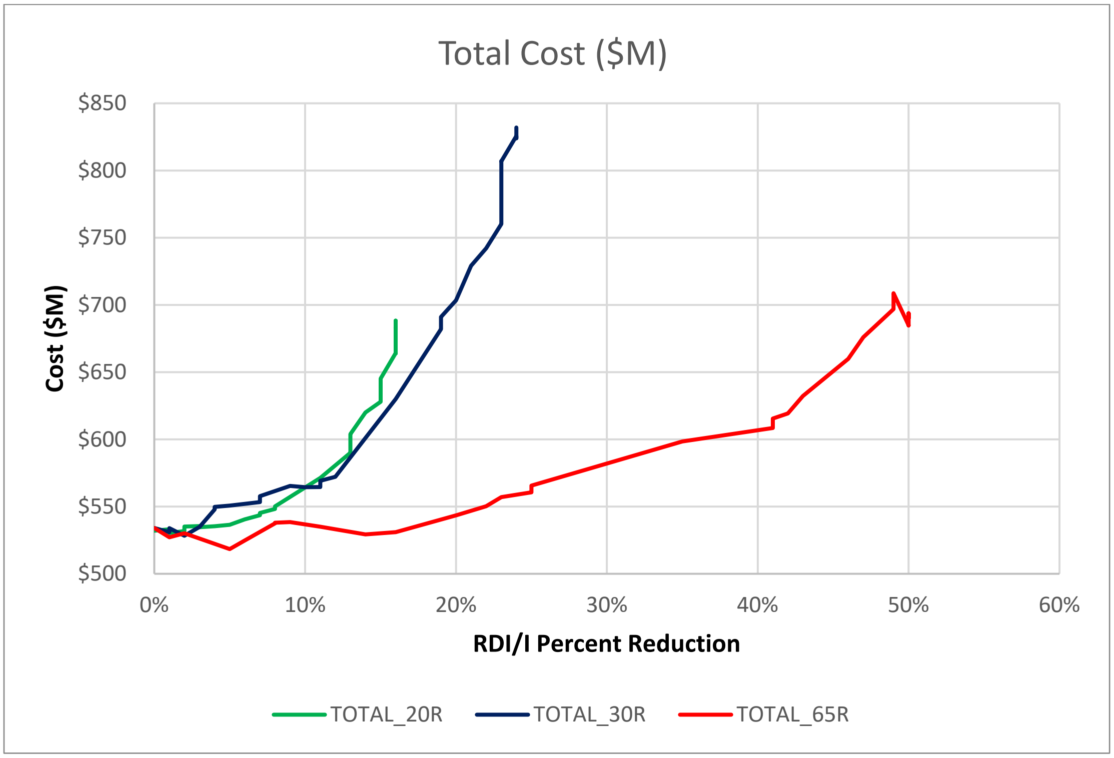


Figure 5-5a. Cost-Effective RDI/I Reduction and Capital Improvement Locations, Optimal RDI/I Reduction for 2025 Target Reduction Date

Note: Infrastructure is color-coded to represent all target levels at which an improvement is required. Red infrastructure indicates that an improvement is required for 0, 20, 30, and 65-percent reduction. Blue infrastructure indicates that an improvement is required for 0, 20, and 30-percent reduction, but not required for 65-percent reduction. Green infrastructure indicates that an improvement is required for 0 and 20-percent reduction, but not required for 30 and 65-percent reduction. Yellow infrastructure indicates that an improvement is required for 0-percent reduction, but not required for 20, 30, and 65-percent reduction. Improvement maps include preliminary upsizing of pipelines and pump stations for the cost-effectiveness analysis and are not intended to represent final capital improvement mapping.



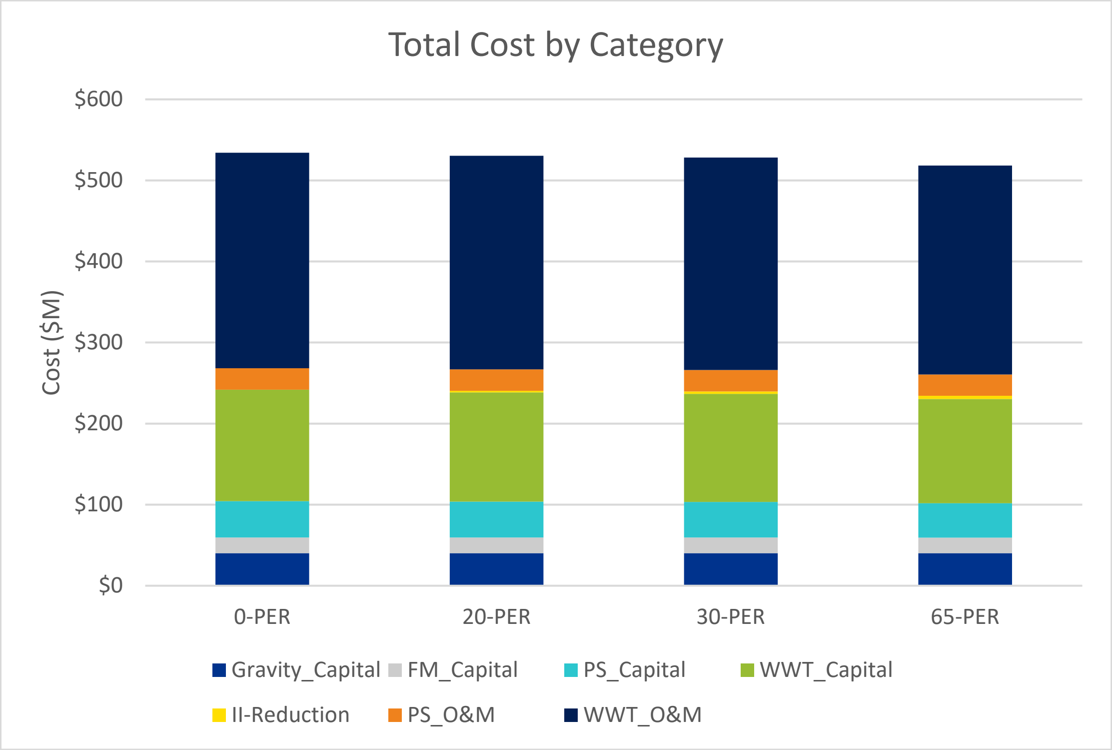


Figure 5-5b. Cost Effectiveness Curves (line-graph) and Lowest Life-Cycle Costs (bar chart), Optimal RDI/I Reduction for 2025 Target Reduction Date

Note: Percent reduction on x-axis of line graph represents system-wide total peak flow reduction when applying 0, 20, 30, or 65-percent reduction to specific subbasins. Total costs exclude Category 1 R&R Program costs and include Category 2 RDI/I Rehabilitation Program costs.

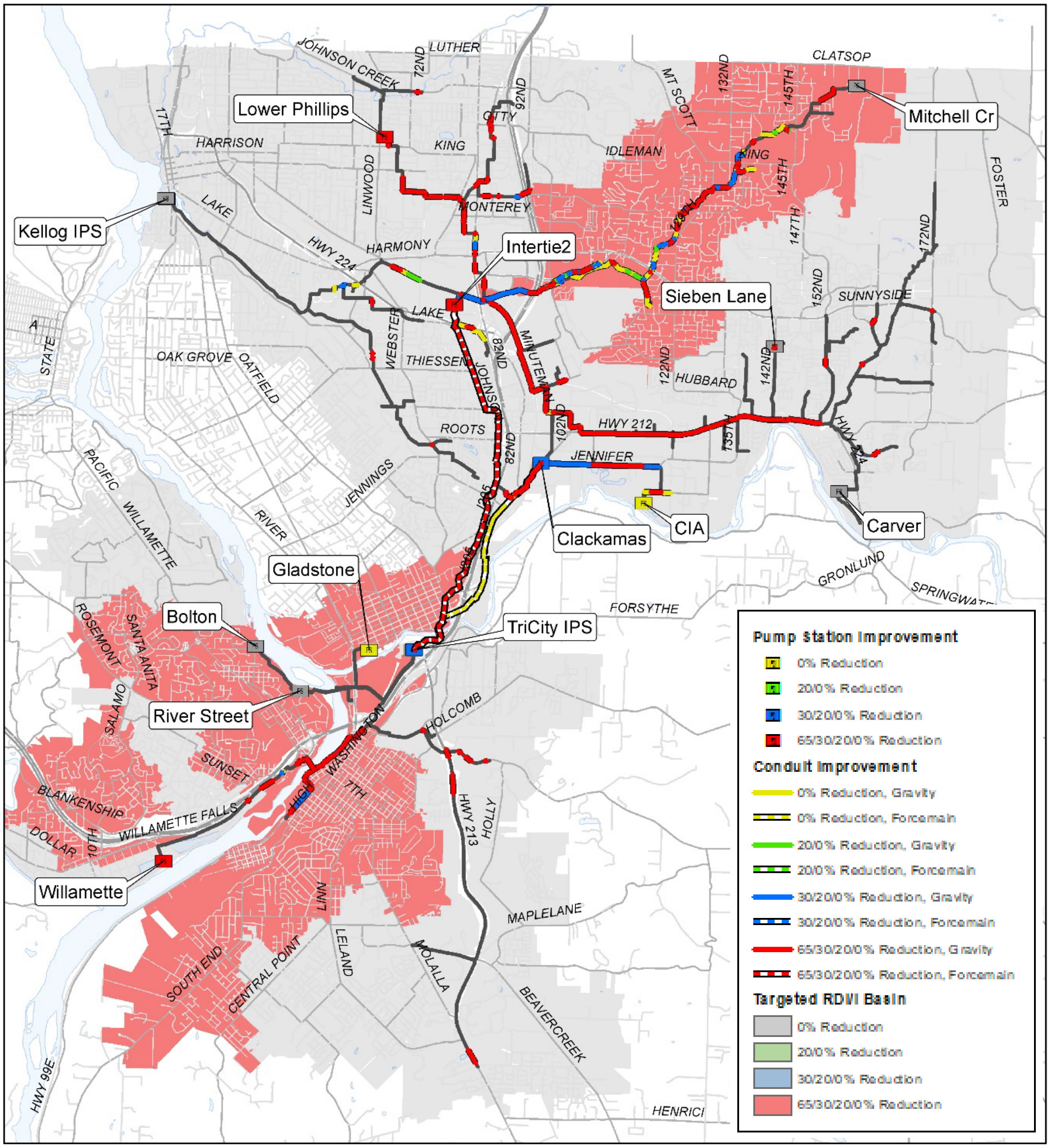
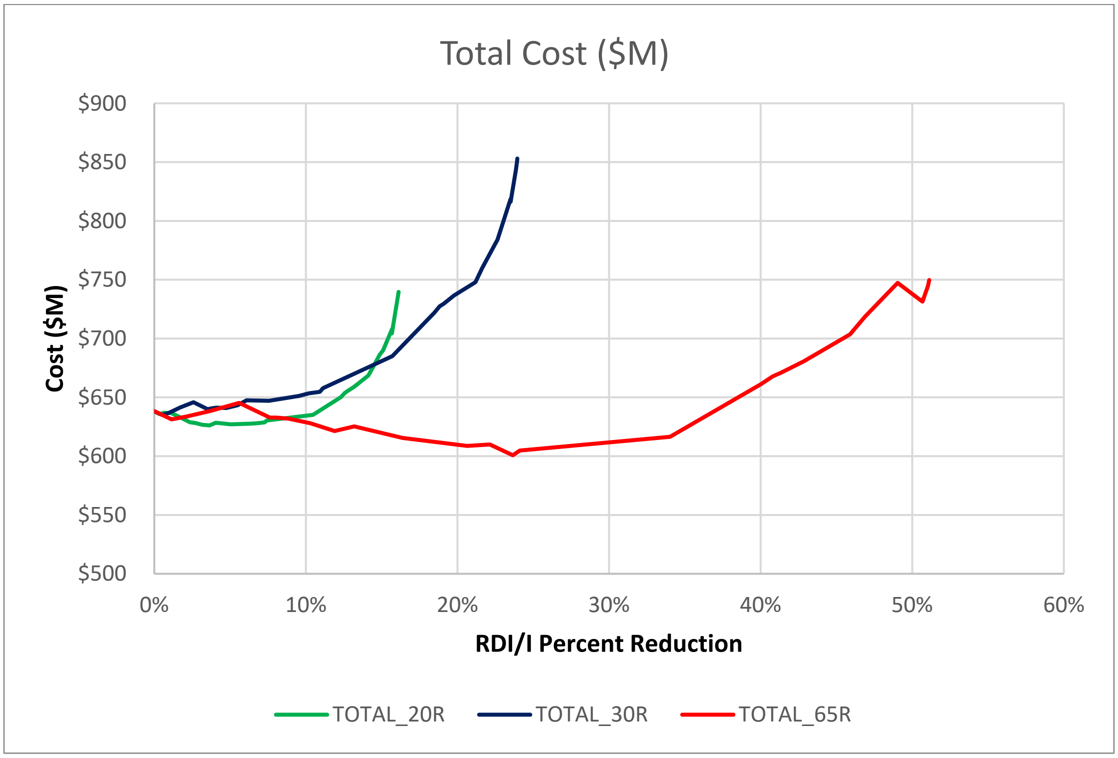


Figure 5-6a. Cost-Effective RDI/I Reduction and Capital Improvement Locations, Optimal RDI/I Reduction for 2030 Target Reduction Date

Note: Infrastructure is color-coded to represent all target levels at which an improvement is required. Red infrastructure indicates that an improvement is required for 0, 20, 30, and 65-percent reduction. Blue infrastructure indicates that an improvement is required for 0, 20, and 30-percent reduction, but not required for 65-percent reduction. Green infrastructure indicates that an improvement is required for 0 and 20-percent reduction, but not required for 30 and 65-percent reduction. Yellow infrastructure indicates that an improvement is required for 0-percent reduction, but not required for 20, 30, and 65-percent reduction. Improvement maps include preliminary upsizing of pipelines and pump stations for the cost-effectiveness analysis and are not intended to represent final capital improvement mapping.



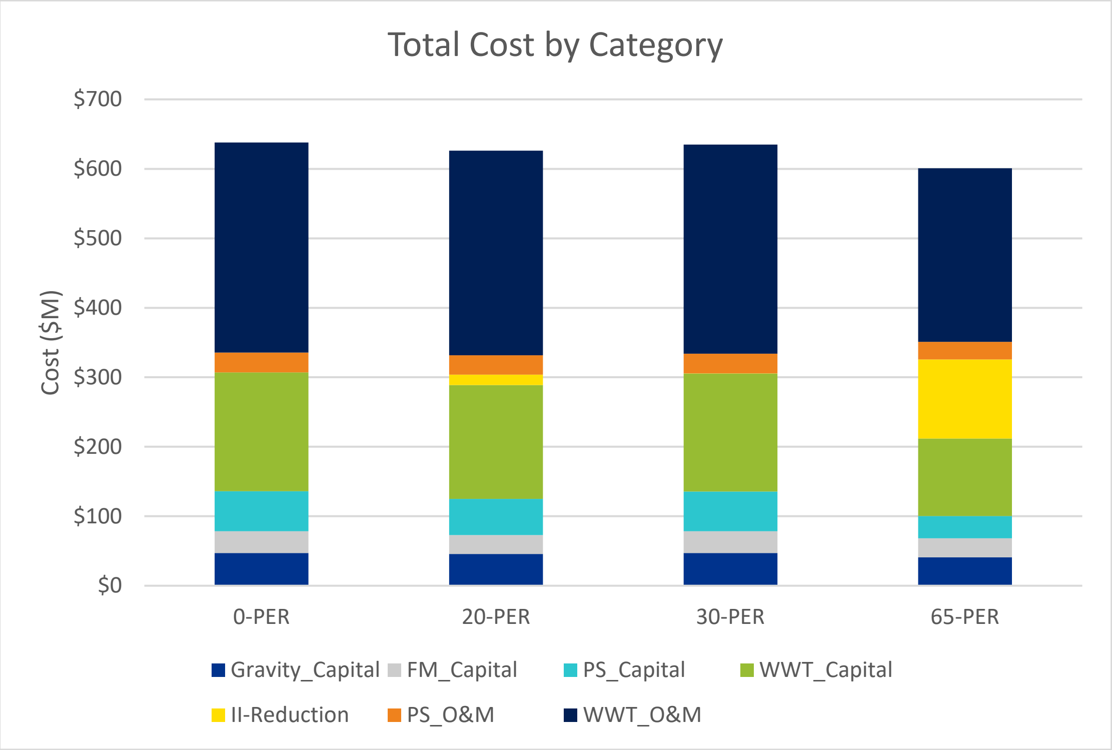


Figure 5-6b. Cost Effectiveness Curves (line-graph) and Lowest Life-Cycle Costs (bar chart), Optimal RDI/I Reduction for 2030 Target Reduction Date

Note: Percent reduction on x-axis of line graph represents system-wide total peak flow reduction when applying 0, 20, 30, or 65-percent reduction to specific subbasins. Total costs exclude Category 1 R&R Program costs and include Category 2 RDI/I Rehabilitation Program costs.

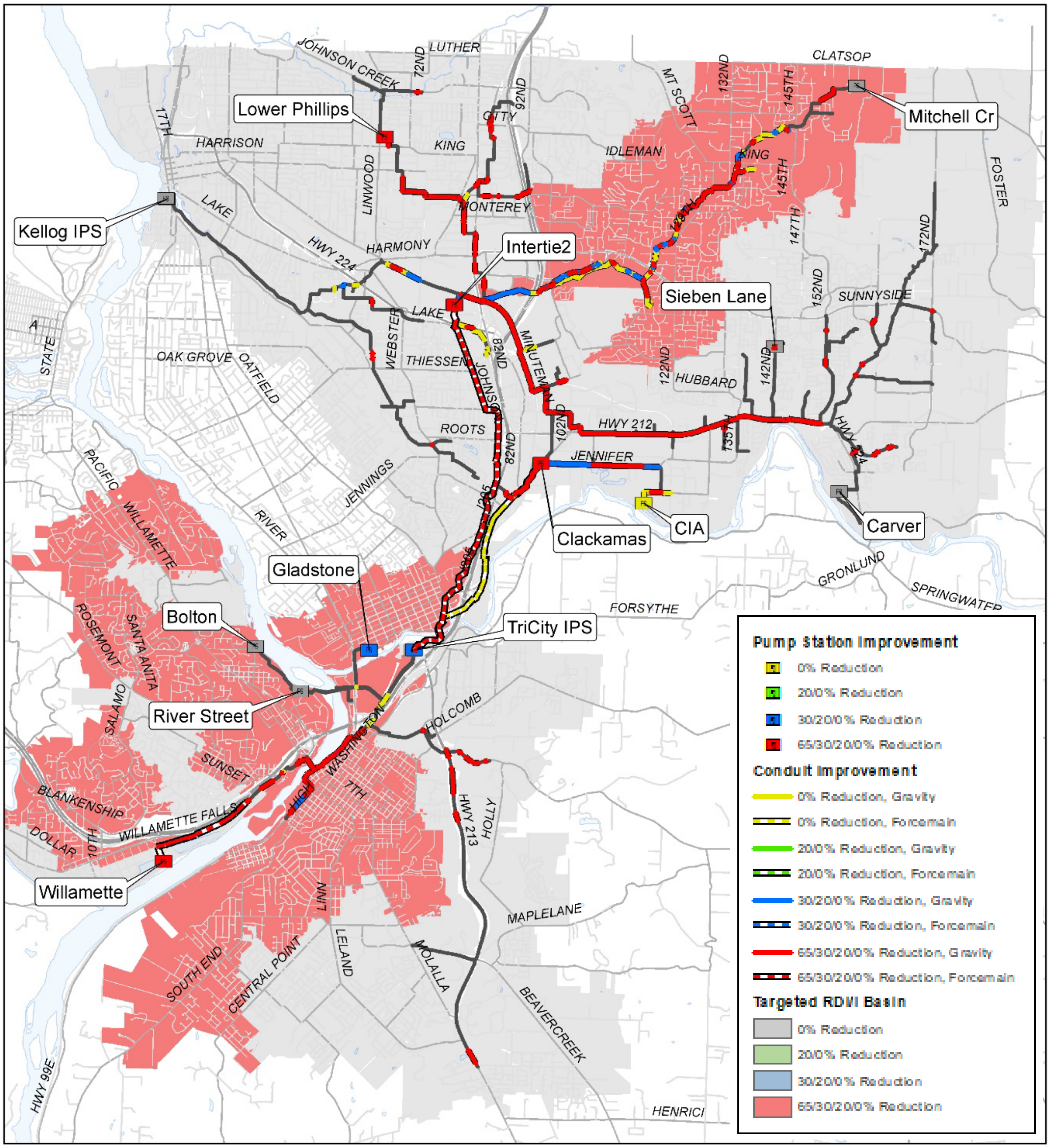
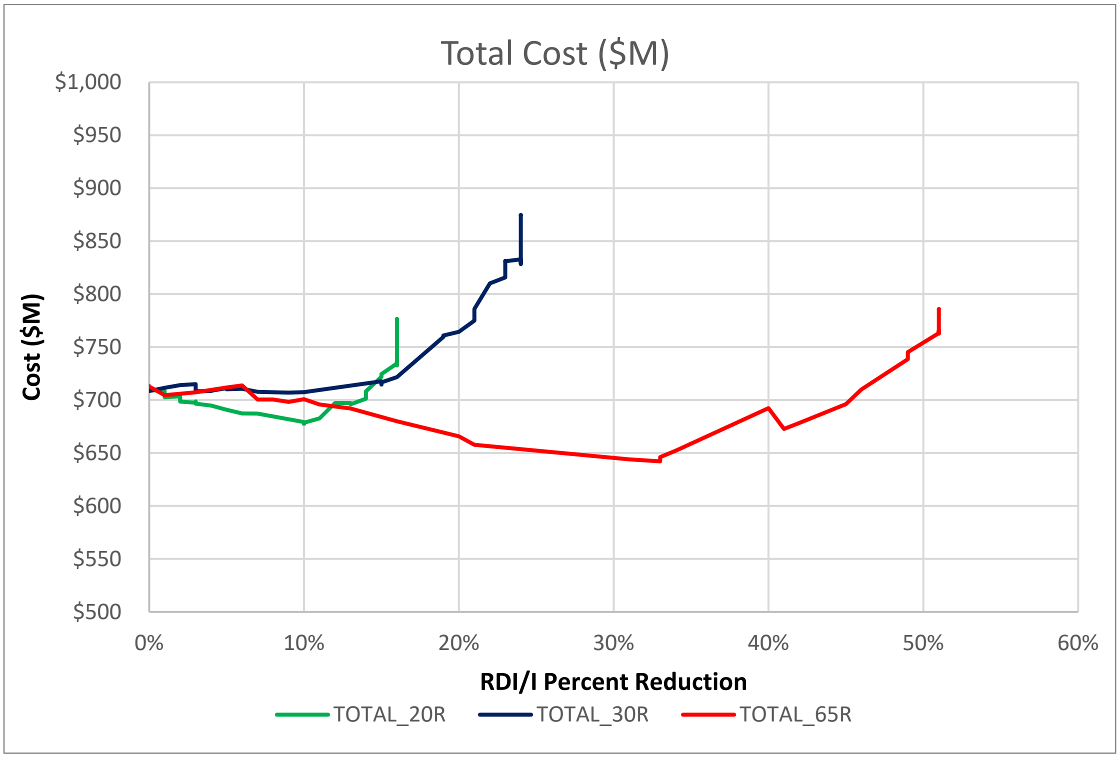


Figure 5-7a. Cost-Effective RDI/I Reduction and Capital Improvement Locations, Optimal RDI/I Reduction for 2035 Target Reduction Date

Note: Infrastructure is color-coded to represent all target levels at which an improvement is required. Red infrastructure indicates that an improvement is required for 0, 20, 30, and 65-percent reduction. Blue infrastructure indicates that an improvement is required for 0, 20, and 30-percent reduction, but not required for 65-percent reduction. Green infrastructure indicates that an improvement is required for 0 and 20-percent reduction, but not required for 30 and 65-percent reduction. Yellow infrastructure indicates that an improvement is required for 0-percent reduction, but not required for 20, 30, and 65-percent reduction. Improvement maps include preliminary upsizing of pipelines and pump stations for the cost-effectiveness analysis and are not intended to represent final capital improvement mapping.



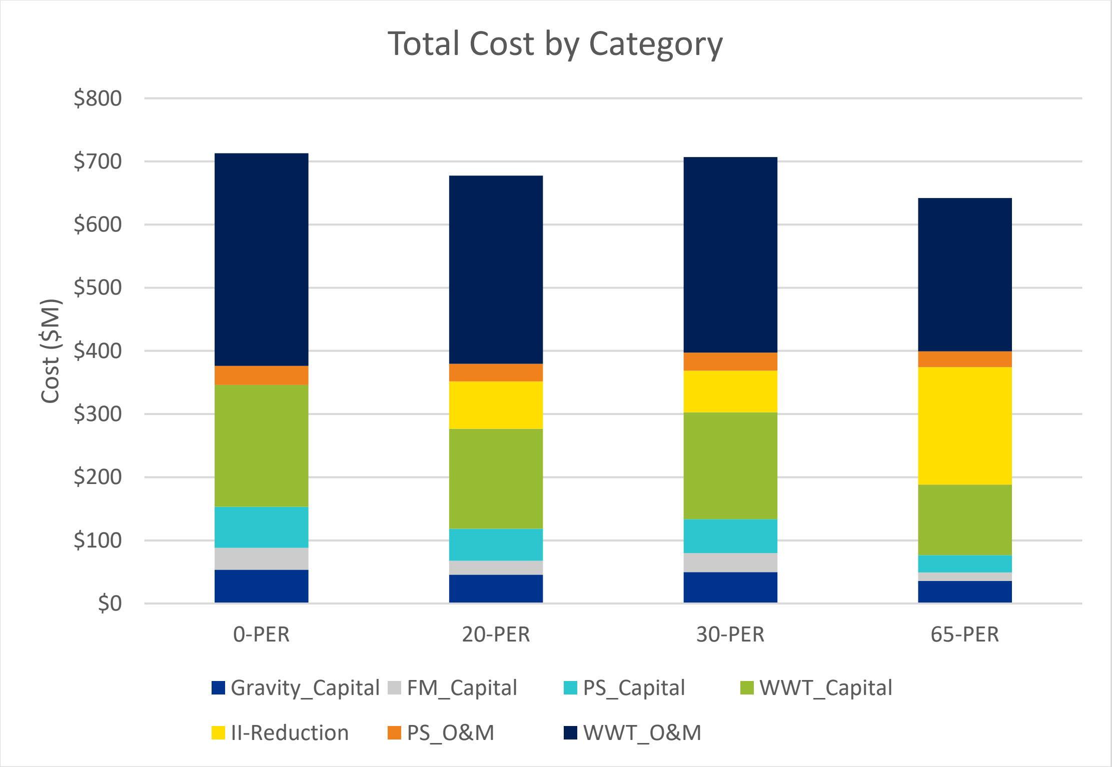


Figure 5-7b. Cost Effectiveness Curves (line-graph) and Lowest Life-Cycle Costs (bar chart), Optimal RDI/I Reduction for 2035 Target Reduction Date

Note: Percent reduction on x-axis of line graph represents system-wide total peak flow reduction when applying 0, 20, 30, or 65-percent reduction to specific subbasins. Total costs exclude Category 1 R&R Program costs and include Category 2 RDI/I Rehabilitation Program costs.

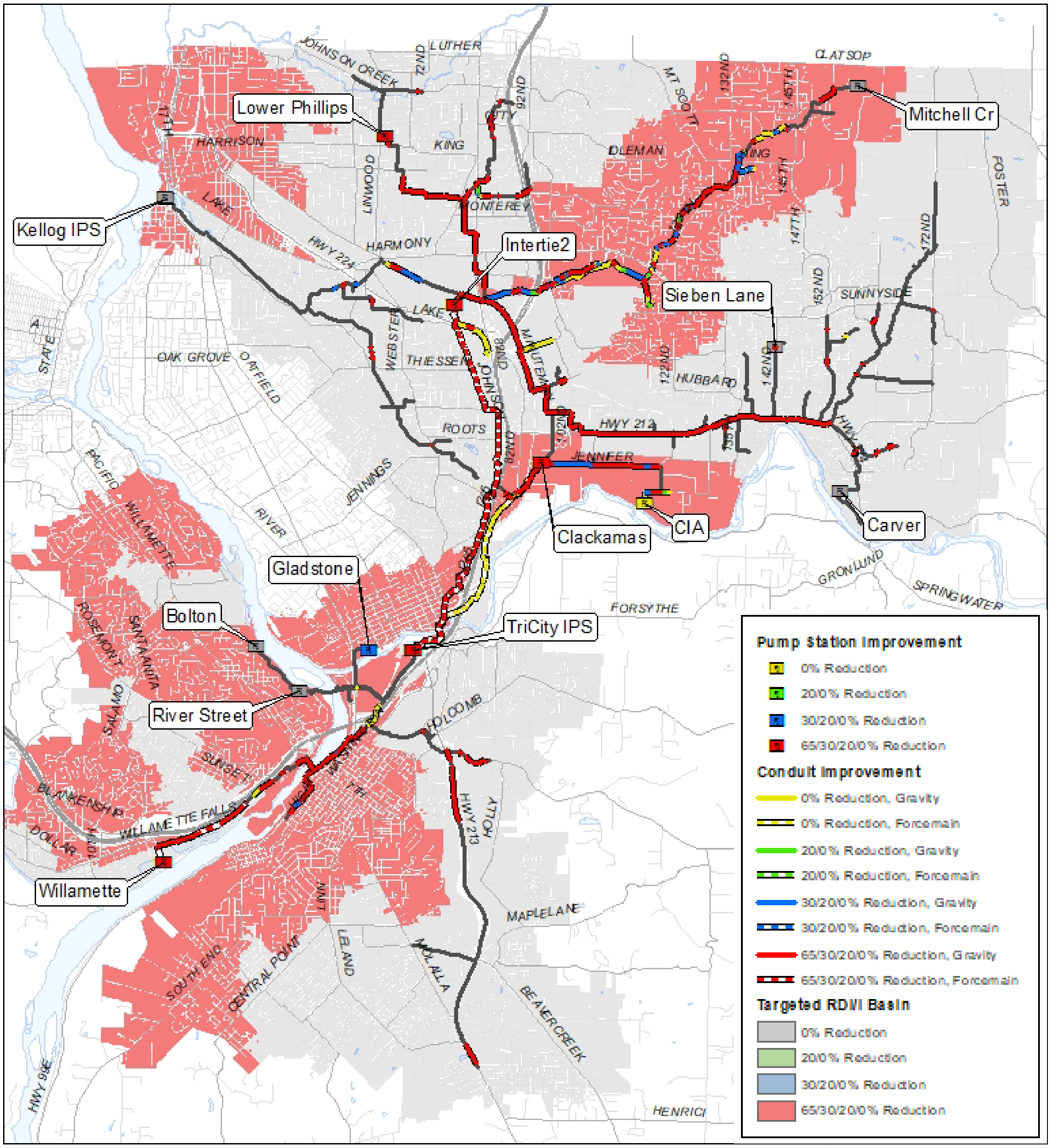
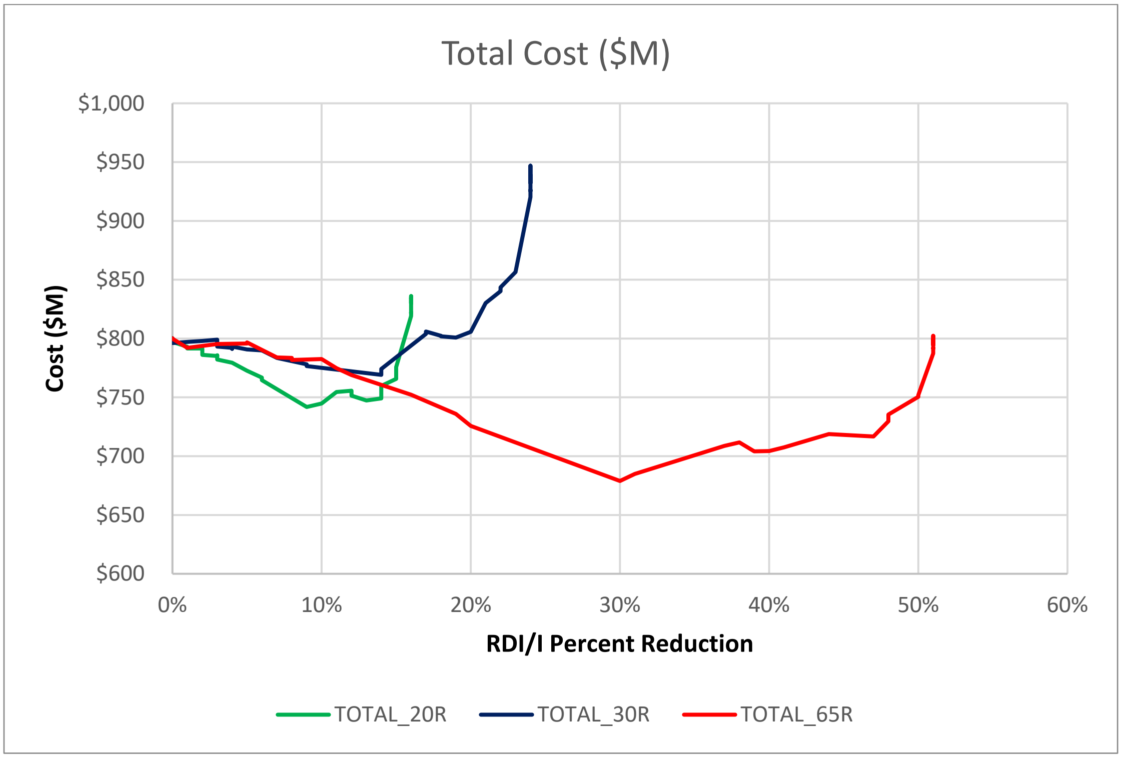


Figure 5-8a. Cost-Effective RDI/I Reduction and Capital Improvement Locations, Optimal RDI/I Reduction for 2040 Target Reduction Date

Note: Infrastructure is color-coded to represent all target levels at which an improvement is required. Red infrastructure indicates that an improvement is required for 0, 20, 30, and 65-percent reduction. Blue infrastructure indicates that an improvement is required for 0, 20, and 30-percent reduction, but not required for 65-percent reduction. Green infrastructure indicates that an improvement is required for 0 and 20-percent reduction, but not required for 30 and 65-percent reduction. Yellow infrastructure indicates that an improvement is required for 0-percent reduction, but not required for 20, 30, and 65-percent reduction. Improvement maps include preliminary upsizing of pipelines and pump stations for the cost-effectiveness analysis and are not intended to represent final capital improvement mapping.



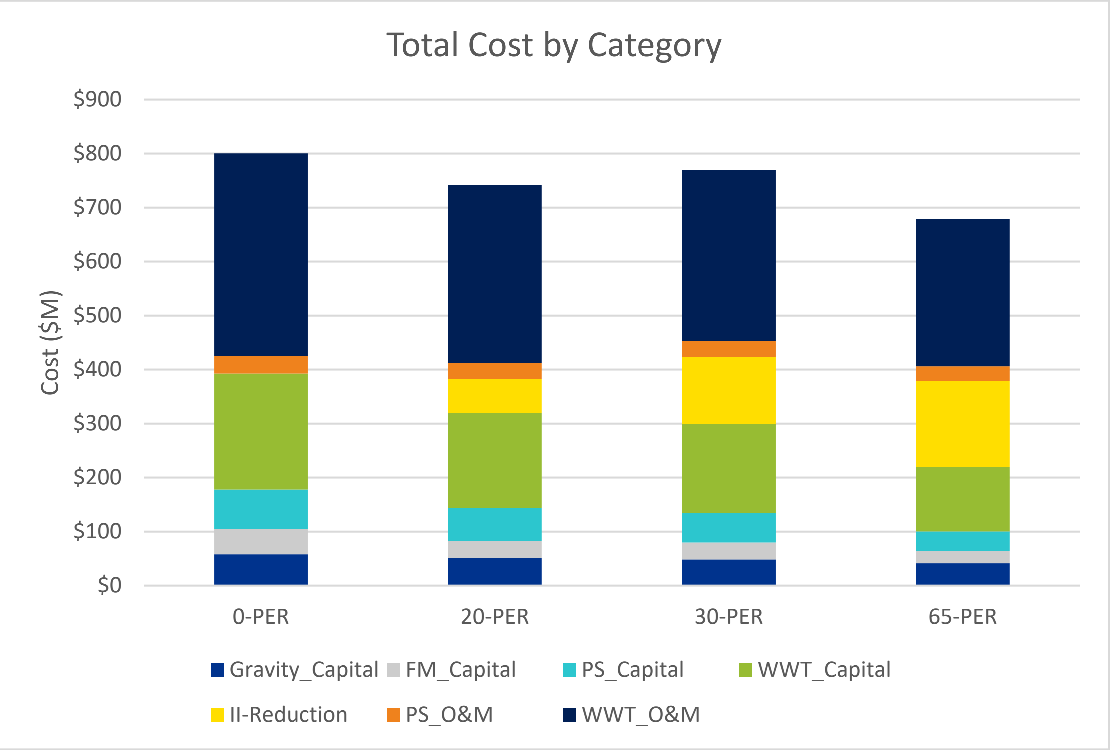


Figure 5-8b. Cost Effectiveness Curves (line-graph) and Lowest Life-Cycle Costs (bar chart), Optimal RDI/I Reduction for 2040 Target Reduction Date

Note: Percent reduction on x-axis of line graph represents system-wide total peak flow reduction when applying 0, 20, 30, or 65-percent reduction to specific subbasins. Total costs exclude Category 1 R&R Program costs and include Category 2 RDI/I Rehabilitation Program costs.

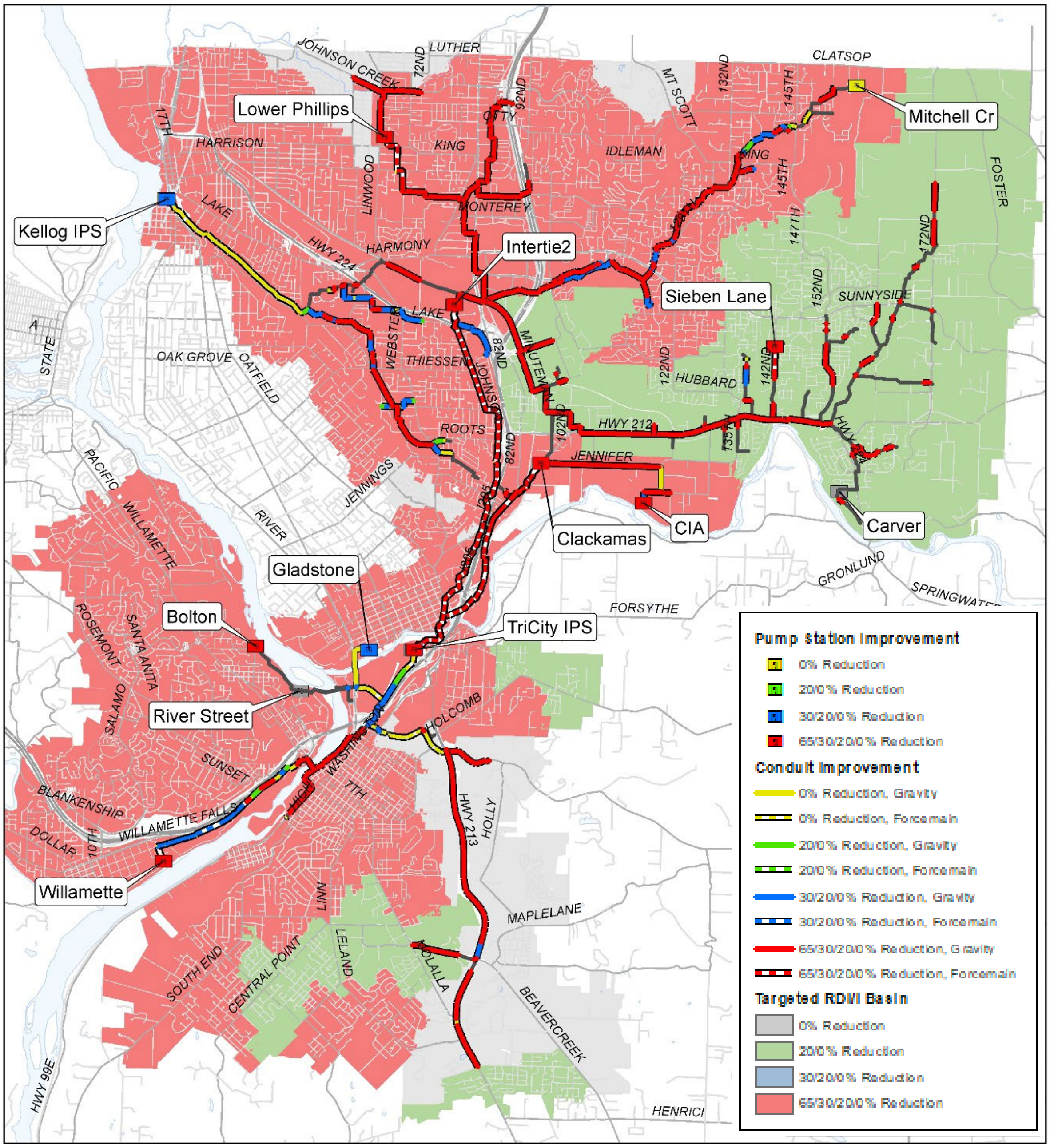
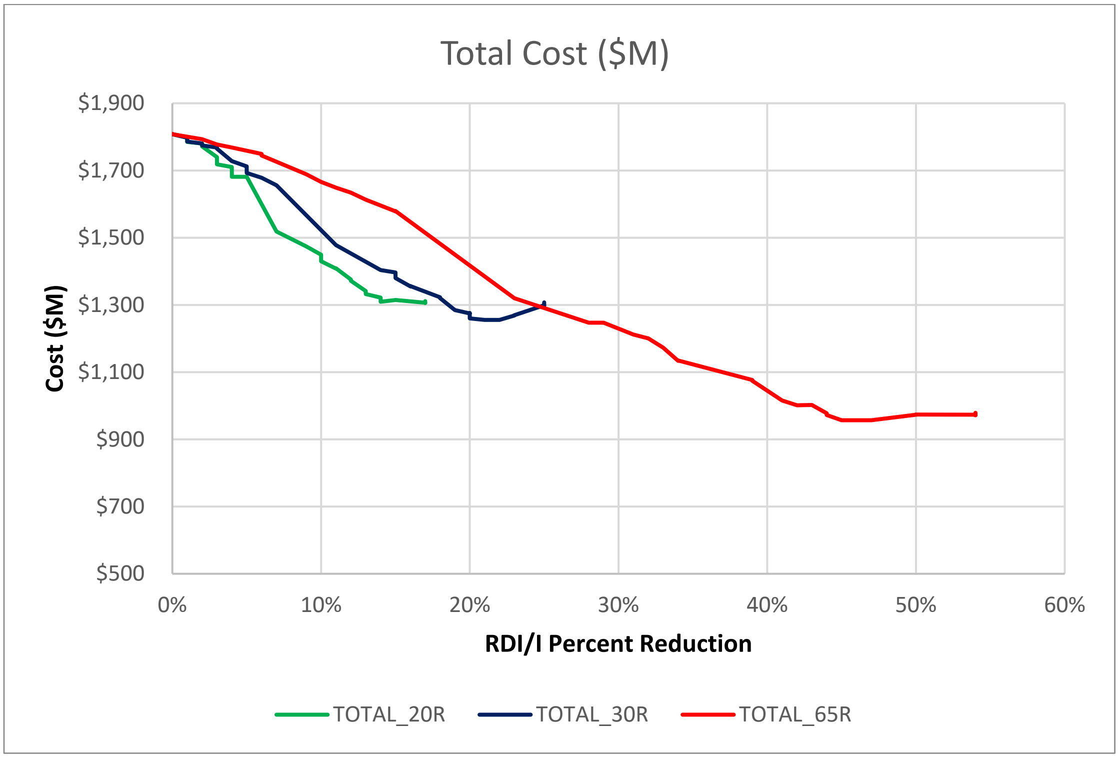


Figure 5-9a. Cost-Effective RDI/I Reduction and Capital Improvement Locations, Optimal RDI/I Reduction for Buildout Target Reduction Date

Note: Infrastructure is color-coded to represent all target levels at which an improvement is required. Red infrastructure indicates that an improvement is required for 0, 20, 30, and 65-percent reduction. Blue infrastructure indicates that an improvement is required for 0, 20, and 30-percent reduction, but not required for 65-percent reduction. Green infrastructure indicates that an improvement is required for 0 and 20-percent reduction, but not required for 30 and 65-percent reduction. Yellow infrastructure indicates that an improvement is required for 0-percent reduction, but not required for 20, 30, and 65-percent reduction. Improvement maps include preliminary upsizing of pipelines and pump stations for the cost-effectiveness analysis and are not intended to represent final capital improvement mapping.



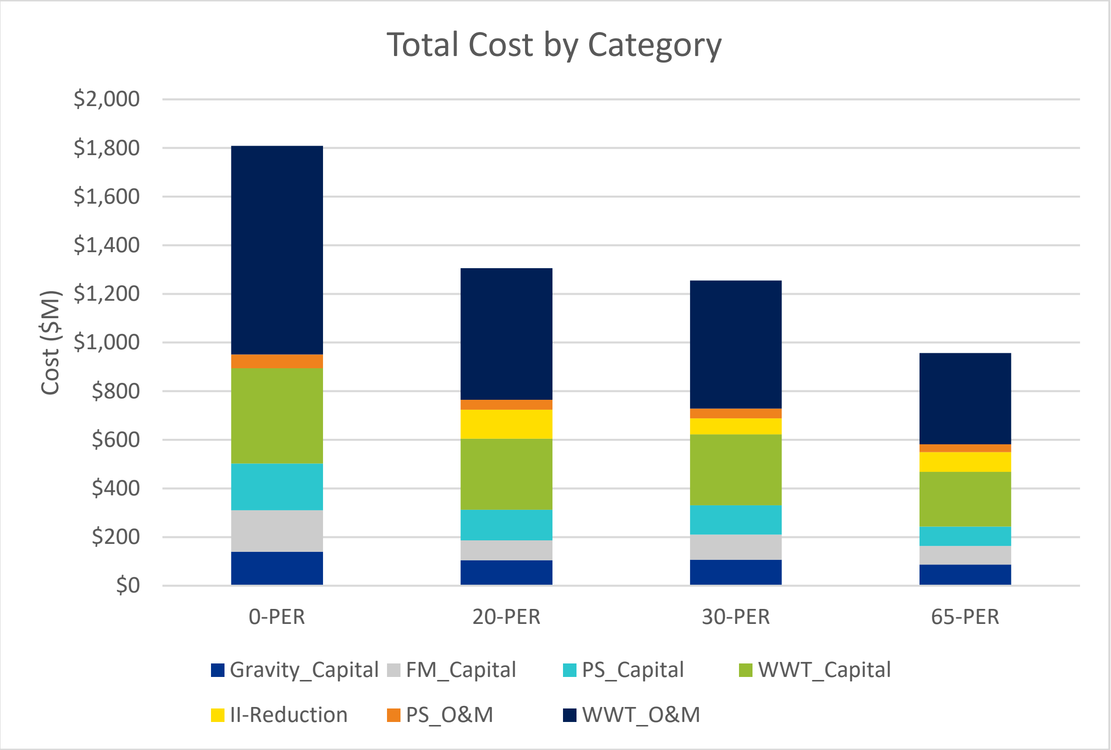


Figure 5-9b. Cost Effectiveness Curves (line-graph) and Lowest Life-Cycle Costs (bar chart), Optimal RDI/I Reduction for Buildout Target Reduction Date

Note: Percent reduction on x-axis of line graph represents system-wide total peak flow reduction when applying 0, 20, 30, or 65-percent reduction to specific subbasins. Total costs exclude Category 1 R&R Program costs and include Category 2 RDI/I Rehabilitation Program costs.

5.3.2 Recommendations for Target RDI/I Reduction Level and Date

Based on review of the cost-effectiveness evaluation and discussions with WES staff, the 65-percent reduction level was recommended by 2040 as the most cost-effective RDI/I reduction target and date. The recommendation assumes investment by cities and local jurisdictions to implement R&R Programs to extend the useful life of aging pipelines and RDI/I Rehabilitation Programs to reduce RDI/I. The recommendation is based on the following trends:

- RDI/I reduction is most cost effective for future timeframes (2040 to buildout) as local infrastructure reaches the end of its useful life and requires rehabilitation, repair, or replacement. As shown on Figure 5-10, the systemwide, life-cycle cost savings by 2040 are estimated at $110 million dollars for 65-percent targeted subbasin reduction compared to the conveyance and treatment alternative with 0-percent reduction. The costs include operations and maintenance, RDI/I rehabilitation, treatment expansion, pump station expansion, force main upsizing, and gravity conveyance upsizing. This savings is roughly two times the cost savings of 20-percent targeted reduction and three times the cost savings of 30-percent targeted reduction.
- Capital investments including improvements to the Tri-City WRRF and Intertie 2 Pump Station are required for peak flow estimates between 2020 and 2035 to accommodate growth. By 2040, RDI/I degradation is significantly more impactful than growth.
- A date of 2040 for targeted 65-percent reduction provides time for RDI/I Rehabilitation Program implementation and monitoring. RDI/I reductions prior to 2040 are recommended to reduce existing system overflow risks and provide flexibility in phasing of required capital projects.
- RDI/I degradation without reduction by 2040 requires substantial improvement to the Tri-City WRRF beyond planned capacity upgrades. As shown on Figures 5-11 and 5-12, investment in targeted RDI/I reduction will minimize capacity upgrades at the WRRF to a total peak flow capacity less than 108 mgd when compared to 176 mgd without reduction. The WRRF capital cost savings is estimated at $95 million.
- 19 subbasins were identified for 65-percent reduction by 2040 as shown on Figure 5-8a and listed in Table 5-3. These subbasins are estimated to exceed an RDI/I rate threshold of 15,000 gpad on a net acreage basis.
- RDI/I reduction is recommended at the 65-percent level beyond 2040 in 14 additional subbasins, for a total of 33 subbasins by buildout (2087), as shown on Figure 5-9 and listed in Table 5-3. These subbasins are estimated to exceed an RDI/I rate of 26,000 gpad on a net acreage basis.
- Flow estimates for the future conditions at each WRRF for 2040 and buildout with targeted 65-percent RDI/I reduction are presented in Table 5-4 including a summary of Intertie 2 Pump Station diversion upgrades assuming a maximum capacity at the Kellogg WRRF of 25 mgd. These flow rates are carried forward as the design flow rates for the alternatives evaluation presented in Section 8.
- RDI/I reduction in the Milwaukie subbasin is identified as critical to maintain Kellogg WRRF peak flow rates below the planned capacity of 25 mgd. The Intertie 2 Pump Station provides substantial relief to the Kellogg WRRF; however, the maximum available flow diversion at the pump station is limited by 2040. To further minimize impacts at the Kellogg WRRF, RDI/I reduction is required in adjacent subbasins. Reduction in the Milwaukie subbasin was selected based on a high metered RDI/I rate. Milwaukie reduction would eliminate an estimated 13 mgd of excess flow at Kellogg. Alternately, an equivalent reduction may be achieved in a combination of the Milwaukie, Harmony, and Lower Kellogg subbasins.
- Gravity conveyance and pump station improvement projects are minimized with targeted 65-percent RDI/I reduction. The benefits to the system include limiting capital project extents, sizing, and costs as summarized in Tables 5-5 and 5-6. Preliminary capital cost savings for conveyance upsizing and pump station improvements are estimated at $29 million.

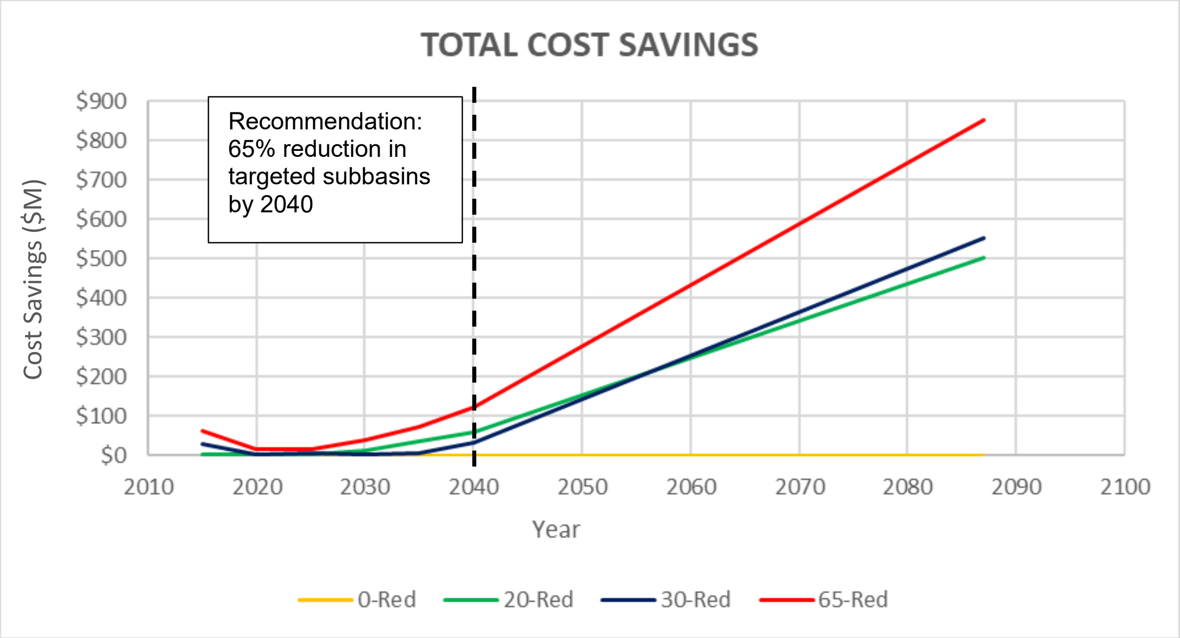


Figure 5-10. Total Life Cycle Cost Savings by Reduction Target and Date (cost savings compared to 0-percent reduction)

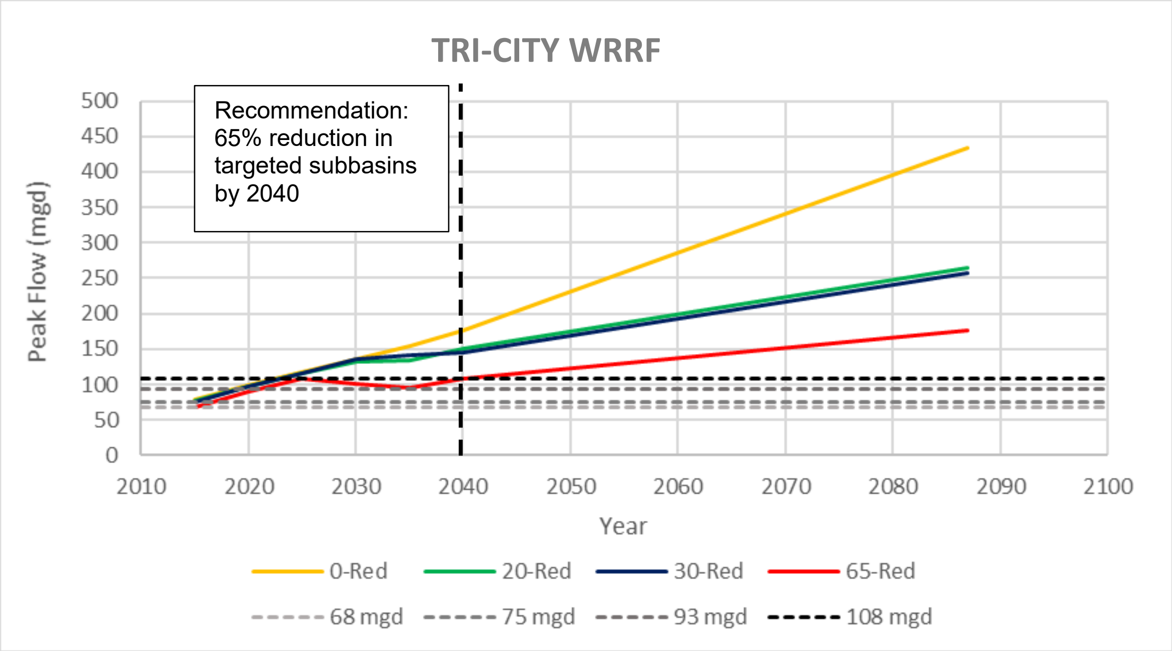


Figure 5-11. Peak Flow to the Tri-City WRRF by Reduction Target and Date

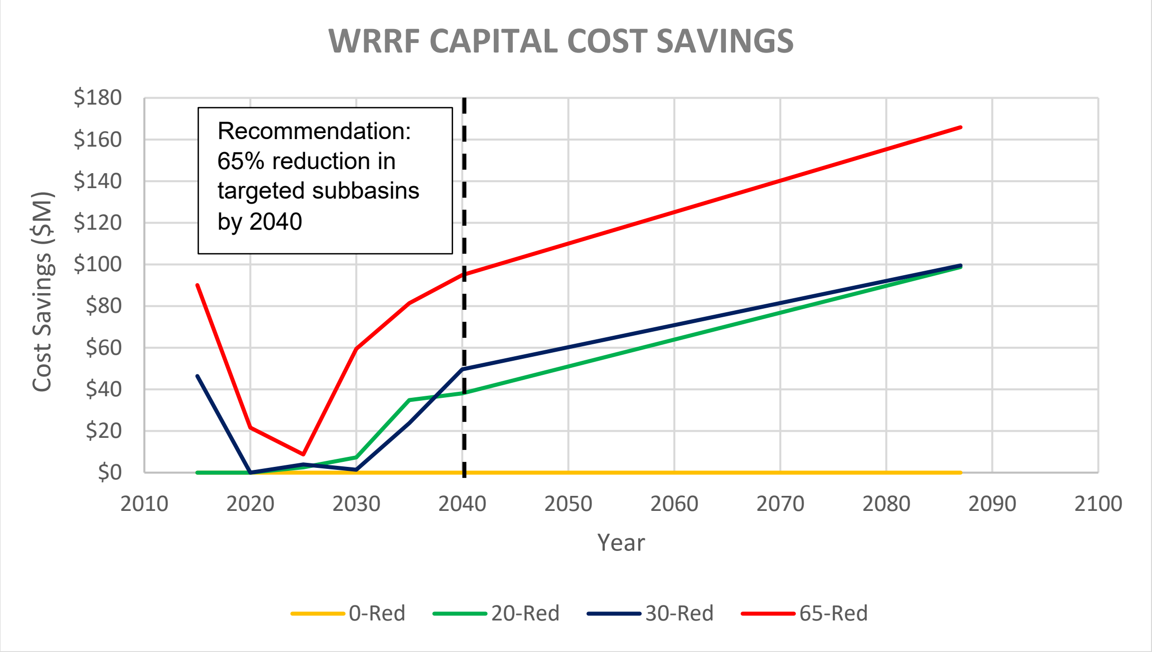


Figure 5-12. Tri-City WRRF Capital Cost Savings by Reduction Target and Date (cost savings compared to 0-percent reduction)

Table 5-3. Subbasins Targeted for RDI/I Reduction by 2040 and Buildout

Priority	MAP ID	Subbasin	Basin	Jurisdiction	Acres	RDI/I Reduction Target Timeframe[a]	RDI/I Rate at Timeframe of Reduction Target	Estimated CIPP Rehab Length (miles)	Estimated Lateral Services	Category 1, Percentage (R&R Program)[b]	Category 2, Percentage (RDI/I Rehab Program)[c]
1	25	OC_M08	WI-40	Oregon City	107	2040	54,600	9.7	300	100%	0%
2	26	OC_M10	WI-40	Oregon City	70	2040	47,600	4.2	210	100%	0%
3	37	WL_2	Mill_Street	West Linn	148	2040	31,500	8.0	1,410	87%	13%
4	32	Hwy_43	Holly	West Linn	354	2040	28,000	20.2	1,570	79%	21%
5	18	US_1_10100&DS_2_20400	Gladstone_PS	Gladstone	0.2	2040	28,000	0.3	10	79%	21%
6	40	Buck_Street_2A-19	Holly	West Linn	106	2040	27,600	3.6	290	78%	22%
7	8	1_10100	Gladstone_PS	Gladstone	191	2040	25,400	7.3	1,320	73%	27%
8	41	Holly	Holly	West Linn	94	2040	24,500	3.4	540	71%	29%
9	27	OC_M12	WI-40	Oregon City	522	2040	24,500	30.9	1,920	71%	29%
10	9	2_20400	Gladstone_PS	Gladstone	201	2040	23,700	9.5	1,020	69%	31%
11	34	River_Street	River_Str_PS	West Linn	64	2040	23,200	2.1	490	68%	32%
12	43	WL_1_2B-1-0	Bolton_PS	West Linn	89	2040	21,500	3.2	260	64%	36%
13	36	Willamette_9C-3	Willamette_PS	West Linn	113	2040	20,600	10.2	670	62%	38%
14	42	Mill_Street	Willamette_PS	West Linn	287	2040	19,700	19.7	990	60%	40%
15	24	OC_M05	Agnes_Main	Oregon City	509	2040	19,300	42.7	2,180	59%	41%
16	5	Mount_Talbert	Mount_Talbert	Clackamas Co	1603	2040	18,900	93.7	6,800	58%	42%
17	39	Bolton_3A-8	Bolton_PS	West Linn	284	2040	18,000	21.1	1,450	56%	44%
18	19	Milwaukie	Milwaukie	Milwaukie	1087	2040	17,100	41.9	5,850	54%	46%
19	2	Clackamas_PS	Clackamas_PS	Clackamas Co	466	2040	15,000	12.9	2,130	53%	47%
20	38	9A-14	Willamette_PS	West Linn	269	Buildout	37,200	18.0	1,010	100%	0%

Table 5-3. Subbasins Targeted for RDI/I Reduction by 2040 and Buildout

Priority	MAP ID	Subbasin	Basin	Jurisdiction	Acres	RDI/I Reduction Target Timeframe[a]	RDI/I Rate at Timeframe of Reduction Target	Estimated CIPP Rehab Length (miles)	Estimated Lateral Services	Category 1, Percentage (R&R Program)[b]	Category 2, Percentage (RDI/I Rehab Program)[c]
21	33	Mapleton	Bolton_PS	West Linn	155	Buildout	36,300	7.5	880	98%	2%
22	21	OC_M02	Agnes_Main	Oregon City	125	Buildout	35,800	7.3	290	97%	3%
23	11	2_20940	Gladstone_PS	Gladstone	10	Buildout	35,800	0.3	50	97%	3%
24	7	Unified Grocers	Unified Grocer	Clackamas Co	501	Buildout	35,400	13.7	2,160	96%	4%
25	20	OC_M01	Agnes	Oregon City	410	Buildout	35,000	11.9	940	95%	5%
26	31	OC_M16	Agnes_Main	Oregon City	300	Buildout	34,500	16.5	1,380	94%	6%
27	4	Lower Kellogg	Lower Kellogg	Clackamas Co	1508	Buildout	34,500	68.4	3,470	94%	6%
28	3	Harmony	Harmony	Clackamas Co	744	Buildout	34,500	30.2	3,500	94%	6%
29	16	82ND DR PS	Gladstone_PS	Gladstone	39	Buildout	34,100	2.2	100	93%	7%
30	35	West_Willamette	Willamette_PS	West Linn	228	Buildout	32,800	18.6	1,250	90%	10%
31	6	Phillips_Int	Phillips_Int	Clackamas Co	1422	Buildout	30,600	59.1	8,690	85%	15%
32	12	2_22800	Gladstone_PS	Gladstone	115	Buildout	30,200	6.0	510	84%	16%
33	17	UNMETERED	Gladstone_PS	Gladstone	23	Buildout	26,700	0.9	90	76%	24%

[a] Reduction target timeframe indicates a maximum date. For example, reduction with a 2040 timeframe is best implemented between the existing timeframe and prior to 2040. Buildout timeframe is best implemented between 2040 and estimated buildout date of 2087.

[b] Category 1, R&R Program: Percentage of piping/laterals within the subbasin excluded from the cost effectiveness analysis and attributed to local pipe repair and replacement.

[c] Category 2, RDI/I Program: Percentage of piping/laterals within the subbasin included in the cost effectiveness analysis and attributed RDI/I reduction.

Table 5-4. Future Flow Estimates with Targeted 65-percent RDI/I Reduction

Time	Flow Rate (mgd)	Kellogg WRRF	Intertie 2 PS	Tri-City IPS	Tri-City WRRF[a]
Existing	Average DWF	5.5	3.2	5.2	8.8
	Peak DWF	6.6	5.1	6.4	12.0
	Peak DWF + GWI	9.9	5.9	11.0	17.8
	Peak DWF + GWI + RDI/I[b]	25.0	14.5	62.3	78.3
	Peak Degraded DWF + GWI + RDI/I[c]	25.0	14.5	62.3	78.3
2040	Average DWF	7.2	5.5	6.6	12.6
	Peak DWF	9.2	6.6	9.2	16.2
	Peak DWF + GWI	14.2	7.4	14.1	22.3
	Peak DWF + GWI + RDI/I[b]	25.0	22.0	66.0	90.8
	Peak DWF + GWI + degraded RDI/I[c]	25.0	70.3	99.5	175.7
	Peak DWF + GWI + degraded & reduced RDI/I[d]	25.0	31.8	70.6	104.4
Buildout	Average DWF	11.0	7.1	9.7	17.7
	Peak DWF	13.9	7.9	13.8	22.6
	Peak DWF + GWI	21.2	8.9	20.1	30.5
	Peak DWF + GWI + RDI/I[b]	25.0	29.1	74.4	108.0
	Peak DWF + GWI + degraded RDI/I[c]	25.0	230.7	187.8	433.7
	Peak DWF + GWI + degraded and reduced RDI/I[d]	25.0	82.8	75.5	162.8

[a] Includes diversion flow rates from the Clackamas Pump Station and Intertie 2 Pump Station.

[b] Peak RDI/I during 11/2011 design storm, nondegraded flow rate.

[c] Peak RDI/I during 11/2011 design storm, degraded flow rate, no RDI/I reduction. Degraded flow rates by buildout are theoretical assuming no investment in replacement and repair of the system.

[d] Peak RDI/I during 11/2011 design storm, degraded flow rate, targeted 65-percent RDI/I reduction.

Note: 2040 Peak DWF + GWI + degraded & reduced RDI/I used for alternatives evaluation including pump station and force main improvement sizing. Buildout Peak DWF + GWI + degraded & reduced RDI/I additionally used for gravity conveyance oversizing.

Table 5-5. WES Gravity Conveyance Improvement Savings Resulting from Targeted RDI/I Reduction by 2040

Gravity Conveyance Improvements	0-Reduction			65-Percent Reduction			Cost Savings ($Million)[a]
	Improved Length (feet)	Max Diameter (inch)	Cost Estimate ($Million)[a]	Improved Length (feet)	Max Diameter (inch)	Cost Estimate ($Million)[a]	
Upper Phillips Interceptor	2,600	30	1.2	2,600	30	1.2	0.0
Upper Phillips Tributaries	2,000	12	0.8	1,300	10	0.6	0.2
Lower Phillips Interceptor	8,300	18	3.7	8,300	18	3.7	0.0
Lower Phillips Tributaries	700	10	0.3	700	10	0.3	0.0
Mount Scott Interceptor	5,600	48	4.2	3,100	36	1.7	2.5
Mount Scott Tributaries	4,000	12	1.5	600	10	0.2	1.3
Mount Talbert Interceptor	9,300	36	5.3	2,900	15	1.4	3.9
Mount Talbert Tributaries	2,700	18	1.2	1,800	12	0.7	0.4
Happy Valley Interceptor	12,600	36	6.9	6,400	30	3.2	3.8
Happy Valley Tributaries	1,000	15	0.4	0	0	0.0	0.4
Clackamas Interceptor	24,100	36	13.3	24,100	36	13.3	0.1
Clackamas Interceptor Tributaries	3,000	12	1.3	1,200	12	0.6	0.7
Rock Creek Interceptor	200	36	0.4	200	36	0.4	0.0
Rock Creek Damascus Trunk	800	30	0.5	800	30	0.5	0.0
Rock Creek Tributaries	300	12	0.1	300	12	0.1	0.0
Jennifer Main	6,100	18	2.6	6,100	10	2.3	0.3
CIA Gravity	1,900	12	0.7	500	10	0.2	0.5
Sieben Gravity	100	24	0.1	100	24	0.1	0.0
UK Gravity	3,000	27	1.4	2,700	27	1.3	0.2
Willamette Interceptor	7,800	84	7.2	6,800	84	5.0	2.2
West Linn Interceptor	2,700	42	1.4	2,200	42	1.1	0.3
Abernathy Interceptor	1,500	36	0.8	1,400	36	0.7	0.1
Newell Creek Interceptor	4,600	18	1.6	4,600	18	1.6	0.0
Total Gravity			**57.1**			**40.2**	**16.8**

[a] Preliminary Class 5 cost estimates based on infrastructure upsizing for RDI/I cost effectiveness evaluation and prior to alternatives refinement.

Table 5-6. WES Pump Station and Force Main Improvements Savings Resulting from Targeted RDI/I Reduction by 2040

Pump Station and Force main Improvements	0-Reduction					65-Percent Reduction					Cost Savings ($Million) [a]
	Pump Station Peak Flow (mgd)	Pump Station Cost Estimate ($Million)[a]	Force Main Improved Length (feet)	Force Main Diameter (inch)	Force main Cost Estimate ($Million) [a]	Pump Station Peak Flow (mgd)	Pump Station Cost Estimate ($Million) [a]	Force main Improved Length (feet)	Force Main Diameter (inch)	Force main Cost Estimate ($Million) [a]	
Clackamas	6.8	6.2	13,700	18	4.7	3.1	3.6	400	12	0.1	7.2
Intertie2	70.3	23.3	21,700	36+	38.8	31.8	14.3	21,700	18	19.6	28.2
Gladstone	10.1	8.1	100	12	0.0	4.6	0.0	0	0	0.0	8.1
Willamette	14.4	10.3	6,200	30	4.0	14.3	10.3	6,200	30	4.0	0.0
Lower Phillips	2.0	2.6	300	8	0.1	2.0	2.6	300	8	0.1	0.0
CIA	2.6	3.1	0	0	0.0	0.9	0.0	0	0	0.0	3.1
Tri-City IPS	99.5	19.6	0	0	0.0	70.6	5.0	0	0	0.0	14.6
Total Pump Station and Force Main		**73.1**			**47.6**		**35.7**			**23.8**	**11.9**

[a] Preliminary Class 5 cost estimates based on infrastructure upsizing for RDI/I cost effectiveness evaluation and prior to alternatives refinement.

5.3.3 Flow Monitoring Program and Flow Trigger Estimates to Achieve Targeted RDI/I Reduction Recommendations for Target RDI/I Reduction Level and Timeframe

Flow monitoring may be used for refinement of an RDI/I Rehabilitation Program and to identify timing of downstream capacity improvements. Existing WES flow monitoring captures RDI/I rates for relatively large basins within the sanitary sewer service area. In the future, flow isolation monitoring and closed-circuit television (CCTV) inspection in cities' and county subbasins are recommended to better define localized RDI/I contributions and prioritize local piping and laterals for rehabilitation. Post-rehabilitation monitoring and hydraulic modeling are recommended to determine the impact and effectiveness of RDI/I reduction projects.

To track the effectiveness of the RDI/I reduction, it is recommended that WES expand the large-scale basin flow monitoring program. Additionally, flowmeter data can be used to make decisions on acceleration or delay of capacity-related improvement projects. Recommended and existing flow monitoring locations are shown on Figure 5-13. Representative flow triggers and flow targets are identified for each meter location in Table 5-7. Definitions of flow triggers/targets and an explanation of how to utilize the flow data to effectively monitor RDI/I reduction and project timing are provided below.

1. Permanent flowmeter locations are identified as "existing" or "recommended," as shown on Figure 5-13. Data are currently being collected at "existing" meter locations. "Recommended" locations are new and require additional investment to install metering equipment. Permanent meter locations were selected to track long-term effectiveness of RDI/I reduction and to monitor timing of capacity improvements.

2. In addition to "existing" and "recommended" meter locations, WES may choose to invest in mobile meters. Mobile meters are used to identify specific RDI/I sources and are moved to locations of temporary interest for project implementation. Temporary metering sites are not currently defined and require development as part of an on-going RDI/I Rehabilitation Program.

3. A metering objective is identified for each permanent meter location. Objectives include:

   Improvement Flow Trigger – Meter locations are tied to a maximum available capacity within the system or a flow trigger. If the monitored peak flow rates exceed the flow trigger, the system is reaching its capacity limitation and improvements are required. Specific improvements associated with each meter location and associated flow trigger are provided in Table 5-7.

   Flow triggers are identified for both wet weather (design storm RDI/I) and dry weather conditions. The estimated RDI/I flow trigger is based on surcharge allowance with minimum 2 feet freeboard for gravity sewers and firm capacity for pump stations. If measured flow is greater than trigger flow during winter months, associated capital improvements are recommended.

   The estimated dry weather flow trigger is based on the wet weather flow trigger divided by a location specific RDI/I to DWF peaking factor. Peaking factors range from 4 to 10 throughout the system. Because the wet weather flow trigger may only occur during infrequent large storm events, the dry weather flow trigger is a better measurement of required improvement timing. If measured flow is greater than trigger flow during summer months, associated capital improvements are recommended.

   RDI/I Metering – Meter locations are tied to a targeted maximum flow rate by 2040. The targeted flow rates were developed from the cost effectiveness analysis which identified 65-percent reduction in 19 subbasins. WES capital projects for conveyance and pumping have been planned to the targeted flow rates, but may be inadequate for flows exceeding the flow targets. Flow targets are specific to each meter location and can be used to refine local RDI/I Rehabilitation Programs.

Table 5-7. Flow Target and Flow Trigger Recommendations

Meter/Pump Station	Meter Status	Basin	Target 2040 Peak Flow with 65-percent RDI/I Reduction (mgd)[a]	Metering Objective	Improvement Trigger Description	RDI/I Capacity Flow Trigger (mgd)[b]	DWF Capacity Flow Trigger (mgd)[c]
CL63	Recommended	Clackamas Int	10.1	Improvement flow trigger	Upper Clackamas Interceptor Capacity	4.4	0.9
CL51	Recommended	Clackamas Int	13.2	Improvement flow trigger	Upper Clackamas Interceptor Capacity, Jennifer Diversion	7.2	1.4
CL11	Recommended	Clackamas Int	15.0	Improvement flow trigger	Middle Clackamas Interceptor Capacity, Jennifer Diversion	8.1	1.6
Clackamas Int	Existing	Clackamas Int	16.3	Improvement flow trigger, Targeted flow may vary for alternatives where Clackamas Interceptor is rerouted to Jennifer Main & Clackamas PS	Lower Clackamas Interceptor Capacity	12.2	2.4
Clackamas PS	Existing (Pump Station)	Clackamas PS	2.0	Improvement flow trigger, Targeted flow may vary for alternatives where Clackamas Interceptor is rerouted to Jennifer Main & Clackamas PS	Jennifer Main and Clackamas Pump Station Capacity,	0.6 (Jennifer Main), 2.5 mgd (Clackamas PS)	0.1 (Jennifer Main), 0.5 mgd (Clackamas PS)
HV67	Recommended	Happy Valley	0.8	Improvement flow trigger, RDI/I meter	RDI/I Source Investigation, RDI/I Reduction, Happy Valley/Mount Talbert Capacity	1.2	0.2
HV44	Recommended	Happy Valley	2.6	Improvement flow trigger, RDI/I meter	RDI/I Source Investigation, RDI/I Reduction, Happy Valley/Mount Talbert Capacity	2.9	0.4
HV29	Recommended	Happy Valley	3.0	Improvement flow trigger, RDI/I meter	RDI/I Source Investigation, RDI/I Reduction, Happy Valley/Mount Talbert Capacity	4.8	0.7
Mount Talbert	Existing	Mount Talbert	8.7	Improvement flow trigger, RDI/I meter	RDI/I Source Investigation, RDI/I Reduction, Happy Valley/Mount Talbert Capacity	15.8	3.2
LP8-4	Recommended	Lower Phillips	2.5	Improvement flow trigger	Upper and Lower Phillips Interceptor Capacity	2.2	0.4

Table 5-7. Flow Target and Flow Trigger Recommendations

Meter/Pump Station	Meter Status	Basin	Target 2040 Peak Flow with 65-percent RDI/I Reduction (mgd)[a]	Metering Objective	Improvement Trigger Description	RDI/I Capacity Flow Trigger (mgd)[b]	DWF Capacity Flow Trigger (mgd)[c]
LP256	Recommended	Upper Phillips	4.2	Improvement flow trigger, monitored upstream of deficient piping	Upper and Lower Phillips Interceptor Capacity	5.0	1.0
Phillips Int	Existing	Phillips Int	8.7	Improvement flow trigger, monitored downstream of deficient piping	Lower Phillips Interceptor Capacity	12.0	2.4
Harmony	Existing	Harmony	5.9	RDI/I meter	RDI/I Reduction	-	-
Milwaukie	Existing	Milwaukie	7.0	RDI/I meter	RDI/I Reduction	-	-
Lower Kellogg	Existing	Lower Kellogg	18.1	RDI/I meter, includes contributions from all basins downstream of Intertie 2 PS with the exception of Milwaukie	RDI/I Reduction	-	-
Unified Grocery	Existing	Unified Grocery	10.4	RDI/I meter	RDI/I Reduction	-	-
Tri-City WRRF	Existing (Pump Station)	Tri-City IPS	70.6	Improvement flow trigger, RDI/I meter	Tri-City IPS Capacity, Tri-City WRRF Capacity, RDI/I Reduction	67.7	-
Tri-City WRRF	Existing	Combination of Intertie 2 PS and Clackamas PS	33.8	Improvement flow trigger, RDI/I meter	Tri-City WRRF Capacity, RDI/I Reduction	12.5	-
Intertie 2 M35A	Existing	Intertie 2 M35A	31.8	Improvement flow trigger, RDI/I meter, Targeted flow may vary for alternatives where Clackamas Interceptor is rerouted to Jennifer Main & Clackamas PS	Intertie 2 Pump Station Capacity	10.0	-
Intertie 2 PS	Existing (Pump Station)	Intertie 2 PS	31.8	Improvement flow trigger, RDI/I meter, Targeted flow may vary for alternatives where Clackamas Interceptor is rerouted to	Intertie 2 Pump Station Capacity	10.0	-

Table 5-7. Flow Target and Flow Trigger Recommendations

Meter/Pump Station	Meter Status	Basin	Target 2040 Peak Flow with 65-percent RDI/I Reduction (mgd)[a]	Metering Objective	Improvement Trigger Description	RDI/I Capacity Flow Trigger (mgd)[b]	DWF Capacity Flow Trigger (mgd)[c]
				Jennifer Main & Clackamas PS			
Kellogg IPS	Existing (Pump Station)	Kellogg IPS	25.0	Improvement flow trigger, RDI/I meter	RDI/I Reduction, Intertie 2 Pump Station Capacity	18.0 (current), 25.0 (expanded)	-
WI-22	Existing	WI-22	41.5	Improvement flow trigger, RDI/I meter, Targeted flow may vary for alternatives where Willamette PS is rerouted to Upper Willamette Interceptor	RDI/I Reduction, Willamette Interceptor Capacity	38.0	4.8
WI-40	Existing	WI-40	7.6	Improvement flow trigger, RDI/I meter, Targeted flow may vary for alternatives where Willamette PS is rerouted to Upper Willamette Interceptor	RDI/I Reduction, Willamette Interceptor Capacity	5.8	0.7
Willamette PS	Existing (Pump Station)	Willamette PS	9.6	Improvement flow trigger, RDI/I meter	RDI/I Reduction, Willamette PS and Force Main Capacity	4.4	0.9
CV-7	Recommended	Country Village	1.2	Improvement flow trigger	Country Village Capacity	1.0	0.2
NC-11	Recommended	Newell Creek	9.0	Improvement flow trigger	Newell Creek Capacity	7.9	1.6
Agnes	Existing	Agnes	1.7	RDI/I meter	RDI/I Reduction	-	-
Agnes Main	Existing	Agnes Main	50.4	RDI/I meter	RDI/I Reduction	-	-
Holly	Existing	Holly	<1.0	RDI/I meter, Target assumes significant reroute of flows via diversion structures to River Street PS and/or Bolton PS; ideal RDI/I contribution with diversion reroutes is ~0 mgd	RDI/I Reduction	-	-

Table 5-7. Flow Target and Flow Trigger Recommendations

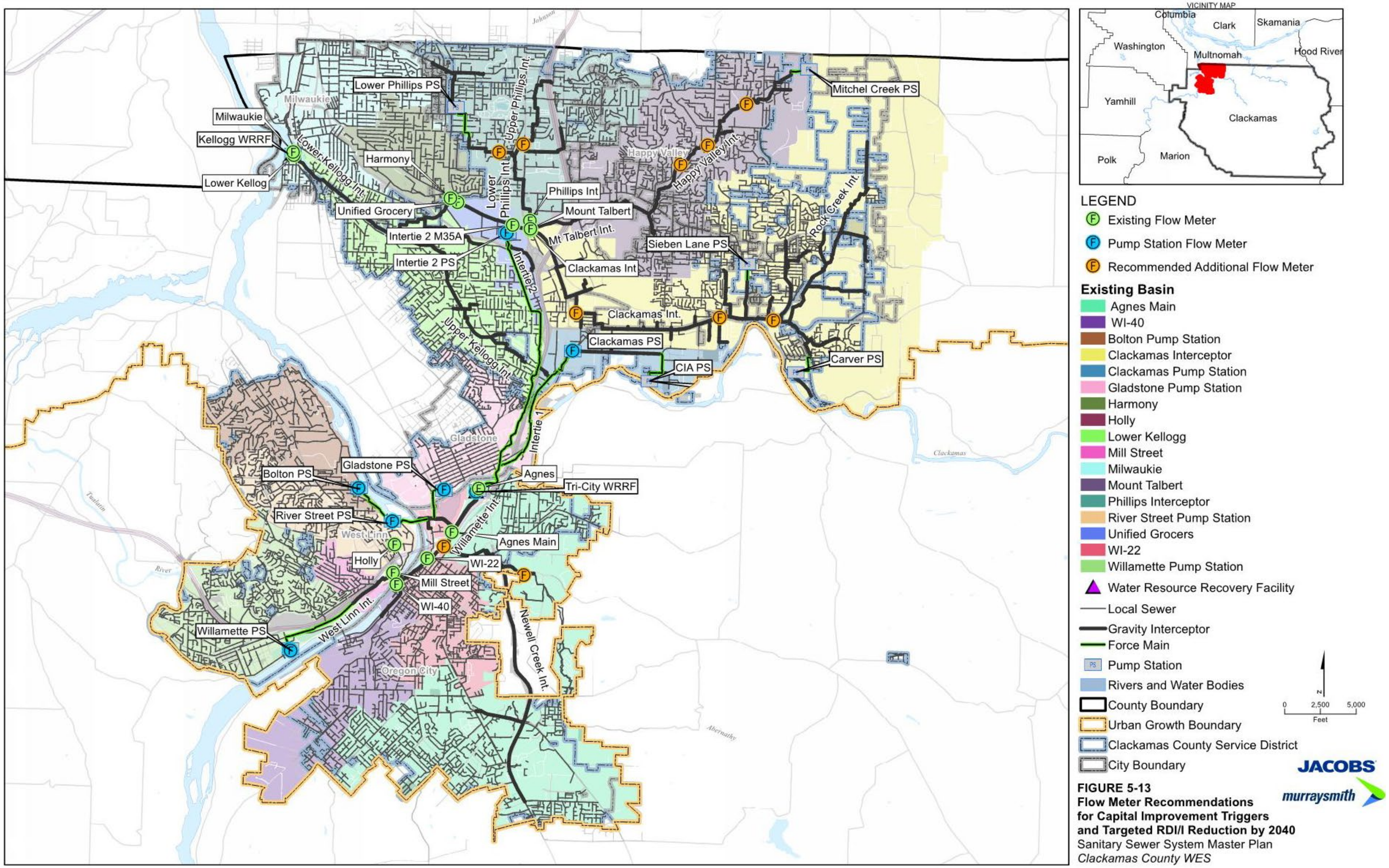
Meter/Pump Station	Meter Status	Basin	Target 2040 Peak Flow with 65-percent RDI/I Reduction (mgd)[a]	Metering Objective	Improvement Trigger Description	RDI/I Capacity Flow Trigger (mgd)[b]	DWF Capacity Flow Trigger (mgd)[c]
Mill Street	Existing	Mill Street	12.2	RDI/I meter, Targeted flow may vary for alternatives where Willamette PS is rerouted to Upper Willamette Interceptor	RDI/I Reduction	-	-
River Street PS	Existing (Pump Station)	River Street PS	0.7	RDI/I meter	RDI/I Reduction	-	-
Bolton PS	Existing (Pump Station)	Bolton PS	4.0	RDI/I meter	RDI/I Reduction	-	-
Gladstone PS	Existing (Pump Station)	Gladstone PS	4.1	RDI/I meter	RDI/I Reduction	-	-
AB-A1	Recommended	Oregon City (DS end)	12.8	RDI/I meter	RDI/I Reduction	-	-

[a] The flow target indicates peak flow estimate by 2040 with 65-percent RDI/I reduction in select subbasins. The flow estimates are intended to be used in measuring effectiveness of RDI/I reduction. Targets are established from modeling of the WES design storm.

[b] Estimated RDI/I flow trigger is based on surcharge allowance with minimum 2 feet freeboard for gravity sewers and firm capacity for pump stations. Trigger is intended for measurement during wet weather flow conditions such as the WES design storm. If measured flow is greater than trigger flow during winter months, associated capital improvements are recommended.

[c] Estimated dry weather flow trigger is based on the wet weather flow trigger divided by a location specific RDI/I to DWF peaking factor. Peaking factors range from 4 to 10 throughout the system. Because the wet weather flow trigger may only occur during infrequent large storm events, the dry weather flow trigger is a better measurement of required improvement timing. If measured flow is greater than trigger flow during summer months, associated capital improvements are recommended.

Note: Flow targets and flow triggers are preliminary. Refinement of flow estimates is recommended as additional flow monitoring data are collected or capacity limitations are observed in the system.



<ACP>UNK G:\PDX_Projects\16\1801 - CH2M Hill Engineers TCSD & CCSD#1 Sanitary Sewer Master Plan Project\GIS\MXD\Flow_meter_locations_10_02_2018.mxd sam 10/2/2018 5:22:27 PM</ACP>

Figure 5-13. Flowmeter Recommendations for Capital Improvement Triggers and Targeted RDI/I Reduction by 2040

6. Collection System Condition Assessment

This section describes the collection system condition assessment performed on a selection of WES pump stations, gravity interceptors, and force main assets. The assessment was completed through collaboration between Jacobs and WES in-house staff. This section is organized into three major subsections. Within each subsection, objectives, methodology and analysis, and findings are summarized. Under "Findings," recommendations for capital improvement projects or operational changes are presented. These recommendations have been incorporated into the identification and prioritization of capital improvement projects presented in Section 9, Project Recommendations and Prioritization.

6.1 Pump Stations

This section summarizes the pump station condition assessment completed by Jacobs for WES in 2016 - 2017. The technical memorandum in Appendix B provides supporting details.

6.1.1 Objectives

The primary objective of the pump station assessment was to evaluate the condition of five WES pump stations and their components. WES selected the pump stations to be assessed. The pump stations not selected were either relatively new or had previously been assessed by WES. The results of this condition assessment will highlight which pump station components require attention to reduce the overall risk of an asset failure. Measures to reduce risk have been incorporated into recommendations for capital improvement projects or as operational changes.

6.1.2 Methodology and Analysis

The methodology used to conduct the pump station condition assessment was designed to be repeatable for each pump station so that results would be comparable. This section describes the steps taken to facilitate repeatability.

6.1.2.1 Methodology

The condition assessment approach was designed for application by multiple individuals, including those beyond the consultant team, to achieve analogous results. The same approach, assessment "questions" for specific assets, and definitions for the rating criteria were applied to each inspection. The approach consisted of the following steps:

1) The assessment team used the Jacobs Asset Condition Evaluation System (ACES)[1] database to collect information about assets and their assessment. ACES is based on the *International Infrastructure Management Manual* (New Zealand Asset Management Support, 2006) and was set up during a 2008 condition assessment conducted as part of a study of CCSD (now WES)[1]. ACES combines information collected in the field with plant performance and maintenance history to prioritize future changes that will most efficiently improve the reliability of a facility.

2) WES provided basic information about the major assets to be inspected, and the base data were loaded into the ACES database. The condition assessment team developed a series of weighted questions for the two new asset types to assess their current condition.

---

[1] ACES is an asset management reporting and data collection software application for storing and analyzing asset condition and risk assessment information on all types of assets. It facilitates assessments through predefined or user-defined conditions stored on desktops and through risk criteria, as well as sorting and reporting options. Data collection can be accomplished on portable computers and data servers.

3) In total, 208 assets were identified at the five WES pump stations. These assets were categorized by type and entered into ACES. In addition, WES requested that two CCSD 1 pump stations previously assessed in 2008 be reassessed in this evaluation. Sixty-four assets in these two pump stations were identified to be reassessed.

4) The field condition assessment information and photographs of the assets were gathered and uploaded to a server to provide condition assessment personnel access to the same information. The field team reviewed the information for quality assurance/quality control.

Table 6-1 lists the pump stations assessed and their ID numbers.

Table 6-1. WES Pump Stations Assessed

(Formerly) Tri-City Pump Station	(Formerly) CCSD 1 Pump Station
58 – Bolton	51 – Clackamas
59 – Willamette	55 – Sieben Lane
63 – River ST	
70 – Gladstone	
80 – 82nd*	

*This pump station is maintained by WES but not owned by WES.

6.1.2.2 Evaluation Criteria

Each component of the pump station (e.g., electrical, mechanical, structural) was assessed and given a score on a scale of 1 to 5. The total score for all the assets that comprise the station is the pump station "condition rating." Condition ratings are established according to the ranges shown in Table 6-2. A complete description of the condition criteria, their weights, and ranges of answers is shown for all pump station asset types in Appendix B.

The condition ratings provide insight into changes in maintenance strategy that may be necessary. Table 6-2 explains each rating, describes the associated condition, and estimates the percent of useful service life remaining.

Table 6-2. Asset Condition Rating Guide

Score	Condition Rating	Rating	Description of Condition	% Remaining Service Life*
1.00 to 1.49	1	Very Good	New or nearly new. Only normal maintenance required.	95
1.50 to 2.48	2	Good	Minor defects; minimal corrective maintenance required. Approximately 5 percent needs maintenance.	75
2.50 to 3.49	3	Fair	Backlog corrective maintenance is necessary, likely requiring outside assistance. Approximately 10 to 20 percent needs maintenance.	50
3.50 to 4.49	4	Poor	Significant backlog maintenance or partial rehabilitation required. Outside assistance needed. Approximately 20 to 50 percent needs maintenance.	30
4.50 to 5.00	5	Very Poor	Asset may be unserviceable; over 50 percent of the asset requires maintenance or rehabilitation; asset may need to be replaced.	5

* Source: New Zealand Asset Management Support, 2006.

6.1.2.3 Analysis

WES staff uploaded the list of pump station assets into ACES for the Jacobs field team to use in the field. Asset information for the CCSD (now WES) one pump station was already in the ACES database from the 2008 work. The project team consisted of two certified maintenance and reliability professionals accompanied by WES personnel available to address questions, provide access to facilities, and operate equipment.

In total, 272 asset components were identified to be assessed. The condition of asset components was scored using the questions and answers developed for each asset type. The detailed evaluation provides a snapshot-in-time of the current condition of these assets and allows WES to compare the results of future evaluations. The average condition score for each pump station was rolled up to give equal weighting to each asset within the station. This approach provides the clearest picture of the overall condition of each station.

Obsolescence is a factor in the overall condition assessment and is covered as one of the questions for specific asset types in the assessment procedure. However, obsolescence is not a major factor in determining operating condition because an asset can be obsolete, in good condition, and still be performing its intended function well. Consequently, obsolescence, by itself, does not contribute materially to the likelihood of an asset’s failure.

6.1.3 Findings

The data collected in the field condition assessment were summarized by asset. This section presents the results. The pump station assets were found to be generally in very good condition with 78 percent of the assets in asset condition rating 1. The high percentage of assets in good and very good condition indicates that the maintenance program has serviced the assets effectively.

6.1.3.1 Asset Condition

Figure 6-1 shows the number of assets at the pump stations in each asset condition rating. This assessment found 93 percent of the assets in the pump stations to be in very good (condition rating 1) or good (condition rating 2) overall condition.

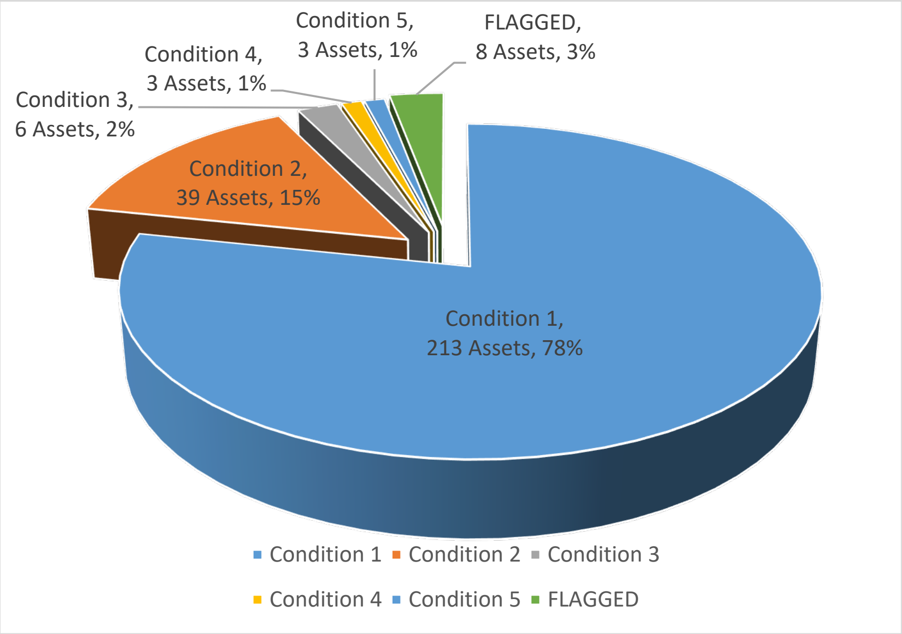


Figure 6-1. Pump Station Asset Condition Rating Distribution

Of the 272 asset components identified to be assessed, eight assets, or 3 percent of the total, could not be assessed for the following three reasons:

- Four of the assets could not be accessed. These were two valves each located at the 55-Sieben Lane and 63-River Street pump stations.
- Three assets were determined not to exist, two located at pump station 59-Willamette and one located at pump station 70-Gladstone.
- One asset at pump station 59-Willamette could not be found.

Figure 6-1 indicates these unassessed assets as "flagged."

The average condition score of assets at each station was calculated to rank the pump stations by relative condition. Figure 6-2 contains a bar graph showing the results. For some assets, this presentation of the data helps to show if one pump station is significantly more deficient than the others. In this case, the chart shows relatively little variance. A detailed list of the overall asset score for each asset in the pump stations arranged by pump station can be found in Appendix B. A query of this appendix would reveal specific assets that scored poorly and have been incorporated into later recommended improvements.

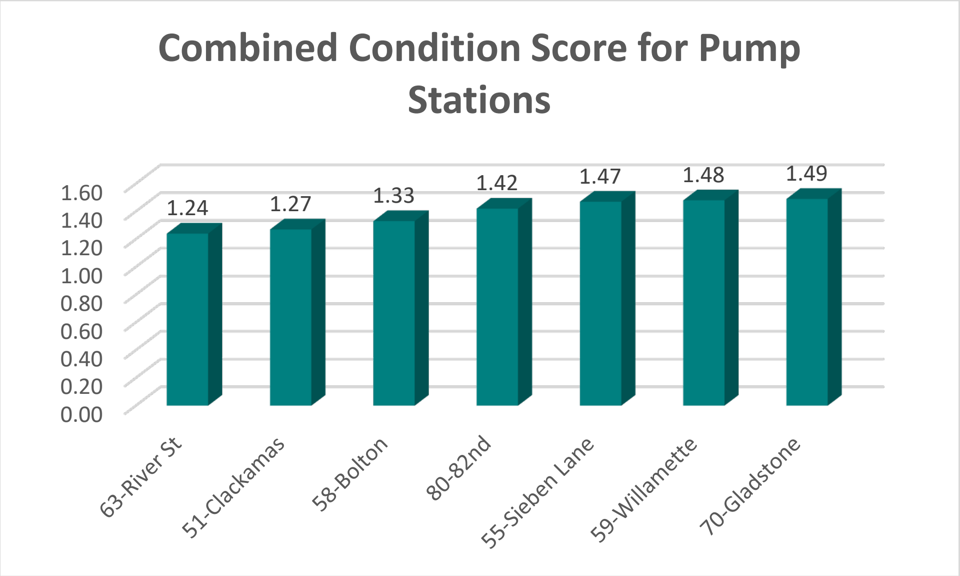


Figure 6-2. Pump Station Average Asset Condition Ranking

6.1.3.2 Recommendations

Four percent of the assets have a condition rating of 3, 4, or 5 and will most likely require some immediate maintenance.

While the majority of the assets are in very good to good condition, there may still be issues to address to keep their condition from deteriorating. Of the 272 assets, 73 had one or more measures with a score of 3 and greater. This result does not indicate that the asset was in poor condition, but rather that the assessment team noted an issue which may require attention. Appendix B contain a detailed list of the asset findings.

Ten assets were found to be not current, but supported, and four assets were found to be obsolete and not supported. Tables 6-3 and 6-4 list the assets assigned a not current or obsolete score. All are electrical controls. Based on WES staff input, many (if not all) of the variable frequency drives in West Linn are obsolete except for Pump 2 at the Willamette Pump Station. Although these assets were functioning properly at the time of inspection, a future replacement program with modern equipment may be prudent. Replacement of the assets listed in these tables should be considered when developing the list of planned capital improvements.

Table 6-3. WES Pump Station Assets That Are Not Current or Obsolete

Pump Station	Asset	Score	Description
58-Bolton	Generator Transfer Switch	5	Obsolete – Not Supported
58-Bolton	Level Control Panel	3	Not Current – Supported
59-Willamette	Level Control Panel	3	Not Current – Supported
59-Willamette	Pump Control Panel	3	Not Current – Supported
59-Willamette	Generator Transfer Switch	5	Obsolete – Not Supported
63-River St.	Generator Transfer Switch	5	Obsolete – Not Supported
63-River St.	Level Control Panel	3	Not Current – Supported
63-River St.	Pump Control Panel	3	Not Current – Supported
70-Gladstone	Pump Control Panel	3	Not Current – Supported
70-Gladstone	Generator Transfer Switch	5	Obsolete – Not Supported
80-82nd Drive	Pump Control Panel	3	Not Current – Supported

Table 6-4. (Formerly) CCSD 1 Pump Station Assets That Are Not Current or Obsolete

Pump Station	Asset	Score	Description
55-Sieben Lane	Pump Control Panel	3	Not Current – Supported
55-Sieben Lane	Pump 2 MCC	3	Not Current – Supported
55-Sieben Lane	Pump 3 MCC	3	Not Current – Supported

6.2 Gravity Interceptors

This section summarizes the gravity interceptor pipe condition assessment completed by Jacobs for WES in 2016 - 2017. The technical memorandum in Appendix C provides supporting details.

6.2.1 Objectives

The objectives of the gravity interceptor condition assessment were to assess the condition of a selection of large-diameter (18-inch and greater) sewer interceptors following a tiered investigation, characterize the likelihood of failure (LOF), and identify recommended improvements and preventive maintenance alternatives.

6.2.2 Methodology and Analysis

The gravity interceptor condition assessment consisted of progressive, tiered levels of inspection. This section summarizes the methodology and analysis.

6.2.3 Methodology

Owing to the large size of the collection system, and the inherent difficulty in assessing the condition of buried linear infrastructure (versus exposed vertical infrastructure, like pump stations), a tiered approach was followed to investigate the gravity interceptors and their associated appurtenances. The tiers are Tier 0 desktop studies, Tier 1 inspections from manholes, Tier 2 inspections using CCTV, and Tier 3 inspections using multi-sensor inspection equipment, test pits, and coupon analyses. Tier 3 inspections were not recommended or conducted for this assessment.

The assessment was conducted in a progressive, step-by-step manner to assess a large study area cost-effectively. The steps are summarized as follows and described in greater detail

1) 21 gravity interceptors (totaling 39 miles in length) were prioritized from highest to lowest risk during a “Tier 0” desktop analysis in order to select which interceptors would be inspected.

2) 11 gravity interceptors (totaling 17 miles in length) then received a “Tier 1” pole-camera inspection by WES crews in order to identify suspected areas with the most deterioration.

3) 7 gravity interceptors (totaling 24,000 linear feet) then received “Tier 2” closed-circuit television (CCTV) inspection by Jacobs crews to characterize the pipelines and develop recommendations for repairs and maintenance.

4) Upon completion of the base work, WES identified an additional three interceptors with a total length of 10,670 linear feet for condition assessment.

Figure 6-3 shows a map of the study area with the inspected portions of the interceptors identified. Figure 6-4 illustrates the progressive, tiered levels of inspection targeting increasingly concentrated study areas. Additional description of each tier follows the figures.

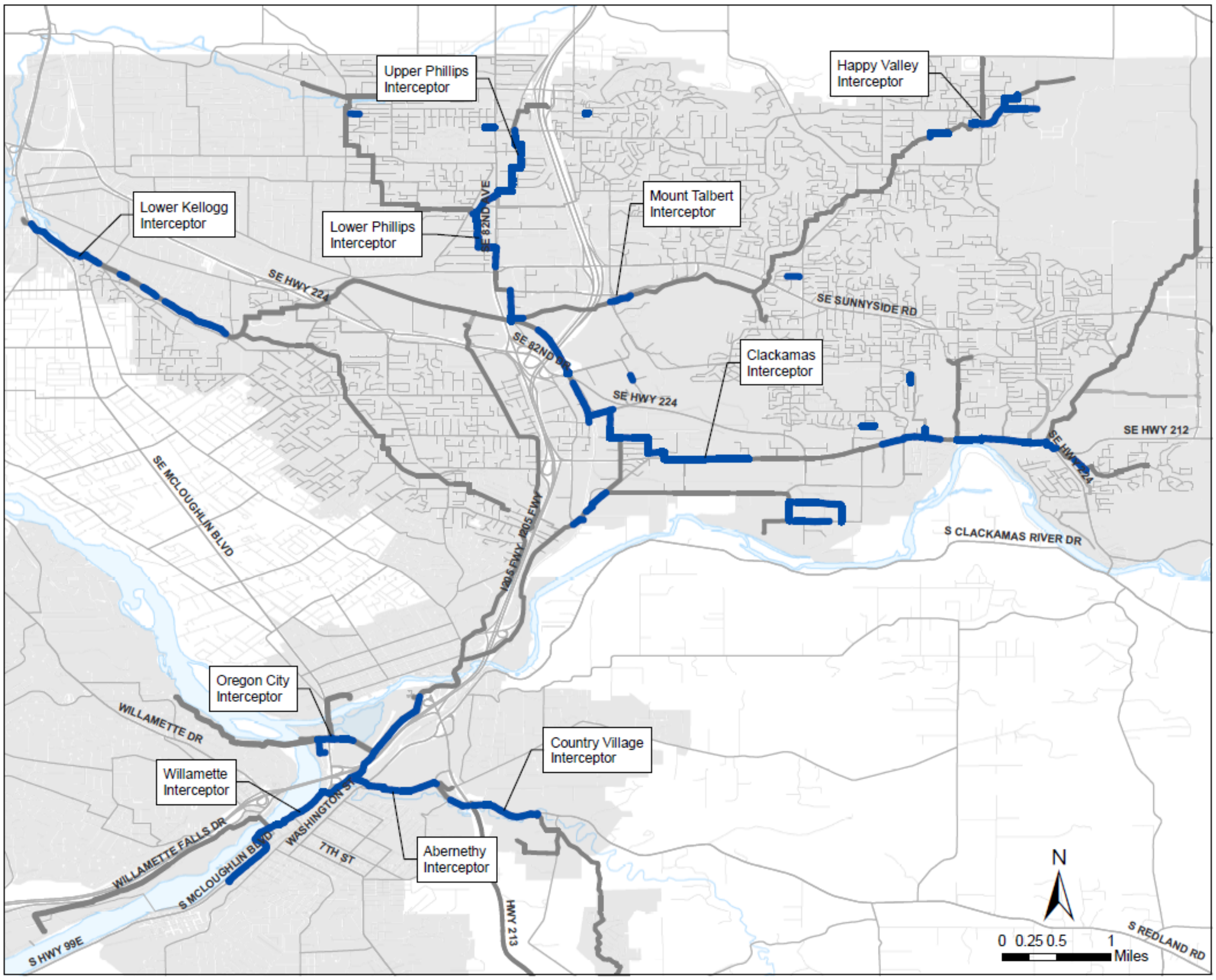


Figure 6-3. Pipe Segments Receiving Tier 1 or Tier 2 Inspection (Shown in Blue)

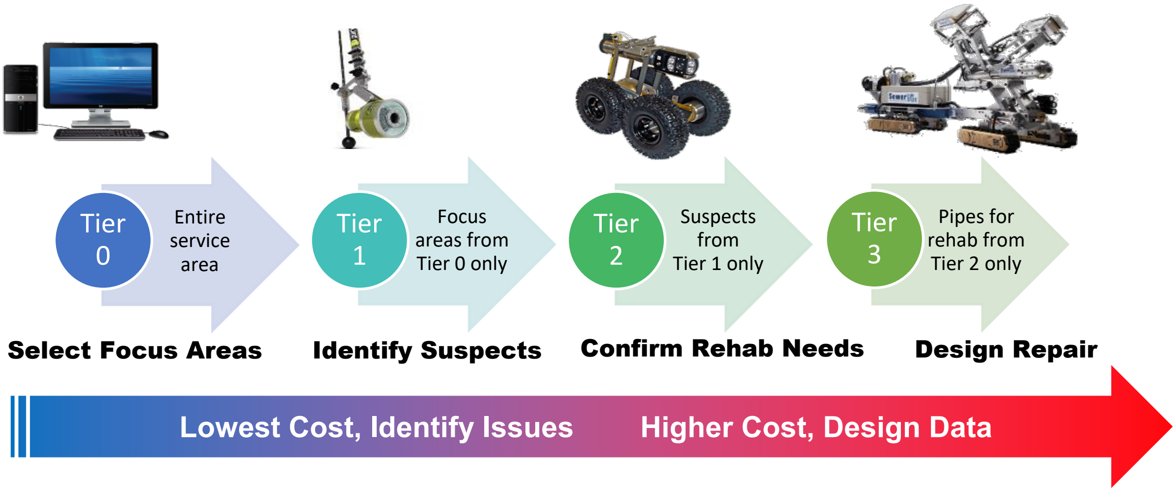


Figure 6-4. Tiered Condition Assessment Approach

The tiered approach is based on an assessment of the known common modes of failure, and on data available at the time of assessment. This approach balances risk with inspection costs and cannot guarantee that all potential failures are accounted for in the assessment. Continued forecasting and maintenance plans and budgets should still include provisions for responding to intangible events such as damage by third parties and for implementing needed repairs.

Tier 0. Tier 0 included a desktop analysis of the collection system and a collaborative workshop with Jacobs and WES staff held on June 7, 2016. An asset hierarchy was constructed that represented the major collection system elements (interceptors, force mains, collection basins), and institutional knowledge from workshop participants was used to assign LOF and consequence of failure (COF) ratings to the assets following a prescribed set of criteria and variables. Selected gravity interceptors from the asset hierarchy were then scheduled for inspection.

Tier 1. Tier 1 inspections included topside inspections of the gravity interceptors, performed by WES staff using pole-mounted zoom-camera equipment. The results of the inspections were delivered to Jacobs in the form of a NASSCO Pipeline Assessment Certification Program (PACP) Standard Exchange Database, which Jacobs analyzed and used to identify locations for further investigation during Tier 2 investigations.

Tier 2. Tier 2 investigations included CCTV inspection of pipes that exhibited higher defect scores based on the Tier 1 results. Visual observations were recorded during the inspection and cataloged in an electronic database in accordance with the NASSCO PACP standards. The data were later analyzed, and condition assessment scores were calculated based on the type, frequency, and severity of defects observed. The results were then used to evaluate the LOF of specific reaches of the pipe. A completed NASSCO PACP Standard Exchange Database and associated media (photos, video) from the Tier 2 inspections are included as an electronic deliverable component of Appendix C.

Tier 3. Tier 3 inspections for gravity interceptors typically include multi-sensor inline inspection (laser, sonar, radar), destructive testing of pipe coupons, or test pits. The objective of the Tier 3 inspections is to collect detailed information on the deteriorated interceptors (identified in Tier 1 and Tier 2) that can be used to select an appropriate rehabilitation method—only if the results of Tier 1 and Tier 2 are insufficient to make this determination. No additional Tier 3 investigations were recommended as part of the Sanitary Sewer System Master Plan, but recommendations are made to conduct Tier 3 investigation as part of selected rehabilitation projects.

6.2.3.1 Analysis

The data collected from the Tier 1 and 2 inspections were used to refine the LOF ratings for each of the assets. The same general criteria that were used in the Tier 0 workshop were used to evaluate the assets, with modifications made to accommodate quantitative data from the inspections in lieu of anecdotal data from institutional knowledge collected during the Tier 0 workshop. The LOF ratings were also used in the asset risk assessment discussed in Section 7.

LOF Rating Categories. As identified in the workshop, the four categories and their associated overall category ratings that determine LOF were:

- Physical Condition (35 percent)
- Hydraulic Performance (30 percent)
- Operations and Maintenance (O&M) Protocols/Maintenance (15 percent)
- External and Internal Factors Affecting the Asset (20 percent)

Consistent with the asset hierarchy established at the risk workshop, each gravity interceptor was discretized into individual assets consisting of a single manhole-to-manhole pipe segment. A complete description of the condition criteria, weights, and range of possible scores is included in Appendix C.

Total Asset LOF Rating Method. The total rating for each segment is a product of the score and weight for each criterion. The following equations explains how the LOF ratings are calculated:

$$LOF\ Score = \sum Category\ Scores \times Category\ Weight\ Percentage$$

Condition ratings are used to describe asset conditions and are determined according to the condition score ranges shown in Table 6-5.

Table 6-5. Asset LOF Rating

RScore	Rating		Description of LOF
1.00 to 1.49	1	Very Good	New or nearly new. Only normal maintenance required.
1.50 to 2.49	2	Good	Good. Minor defects; minimal corrective maintenance required.
2.50 to 3.49	3	Fair	Backlog corrective maintenance is necessary, likely requiring outside assistance.
3.50 to 4.49	4	Poor	Significant backlog maintenance or partial rehabilitation required. Outside assistance needed.
4.50 to 5.00	5	Very Poor	Asset may be unserviceable; requires maintenance or rehabilitation; asset may need to be replaced.

6.2.4 Findings

Jacobs reviewed the data for each interceptor to provide a qualitative characterization of the asset against each LOF criterion. This section summarizes the major findings by interceptor (Section 6.2.3.1), followed by LOF rating results (Section 6.2.3.2) and recommendations (Section 6.2.3.3). Hydraulic performance is discussed in Section 4 (Future System Flow Projections and Capacity Evaluations). Detailed descriptions of the interceptor defects are included in Appendix C.

6.2.4.1 Summary of Major Findings by Interceptor

Willamette Interceptor.

- Physical Condition: Intermediate corrosion at the upstream extents along McLoughlin Boulevard and the seawall, worsening to more consistent advanced corrosion downstream towards the WRRF.
- Operations and Maintenance: No major debris issues.
- External and Internal Factors: The segment near the interchange between McLoughlin Boulevard and Interstate 205) is at an elevated risk of inundation likely due to a depression in the topography.

Oregon City Interceptor.

- Physical Condition: Intermediate corrosion but without wide-spread exposure of the reinforcing steel.
- Operations and Maintenance: No major debris issues.
- External and Internal Factors: Portions along Main Street and into Clackamette Park at an elevated risk of inundation from the Willamette River and are susceptible to shifting soils in the event of a geological disturbance (like earthquakes, erosion, or settling). Inadvertent impacts from the Cove Development construction nearby moderately increase the potential for inadvertent damage.

Country Village Interceptor.

- Physical Condition: Intermediate corrosion near the downstream end but without wide-spread exposure of the reinforcing steel.
- Operations and Maintenance: Large amounts of grease and deposits.

- External and Internal Factors: Entire alignment is at an elevated risk of inundation and susceptible to shifting soils in the event of a geological disturbance (like earthquakes, erosion, or settling).

Clackamas Interceptor.

- Physical Condition: Intermediate corrosion in the northern portion along Camp Withycombe, and the Union Pacific Railroad, but without wide-spread exposure of the reinforcing steel.
- Operations and Maintenance: Isolated areas of root intrusion, deposits, and manufacturing defects.
- External and Internal Factors: Isolated portions of the interceptor near the railroad are at an elevated risk of inundation, and the majority of the alignment (with isolated exceptions along the ODOT corridor) is susceptible to shifting soils in the event of a geological disturbance (like earthquakes, erosion, or settling).

Lower Philips Interceptor.

- Physical Condition: Isolated areas of intermediate corrosion.
- Operations and Maintenance: Minor grease accumulation.
- External and Internal Factors: Only the downstream portions (near the railroad) are at an elevated risk of inundation, but the entire alignment is susceptible to shifting soils in the event of a geological disturbance (like earthquakes, erosion, or settling).

Upper Philips Interceptor.

- Physical Condition: Isolated areas of early, minor corrosion.
- Operations and Maintenance: Minor grease accumulation.
- External and Internal Factors: The entire alignment is susceptible to shifting soils in the event of a geological disturbance (like earthquakes, erosion, or settling).

Mount Talbert Interceptor. A limited portion of the Mount Talbert interceptor could be inspected due to the limited access. Approximately 80 percent of the interceptor is not accessible without major tree clearing and grubbing along the north edge of the Mount Talbert Nature Park and possible mobilization of additional specialty equipment. The remaining 20 percent was accessible with conventional large diameter CCTV inspection equipment.

- Physical Condition: Isolated areas of early, minor corrosion.
- Operations and Maintenance: No major debris issues, but no formalized maintenance plan.
- External and Internal Factors: The entire alignment is susceptible to shifting soils in the event of a geological disturbance (like earthquakes, erosion, or settling).

Lower Kellogg Interceptor.

- Physical Condition: Isolated areas of early, minor corrosion, as well as infiltration.
- Operations and Maintenance: No major debris issues.
- External and Internal Factors: The majority of the interceptor is at an elevated risk of inundation from the Willamette River, in large part due to its proximity to the tributary creek bed. The entire alignment is susceptible to shifting soils in the event of a geological disturbance (like earthquakes, erosion, or settling).

Abernethy Interceptor. After review of the Tier 1 investigations, the Abernethy interceptor scored relatively lower than the other interceptors and was therefore not scheduled for further Tier 2 inspection. The following assessment is based on review of the Tier 1 data collected by WES.

- Physical Condition: Only minor defects including attached deposits (grease), isolated surface roughness, and infiltration staining/weepers were observed.

- Operations and Maintenance: No major debris issues.
- External and Internal Factors: The east and west extents are at an elevated risk of inundation while the middle third is less exposed. The entire alignment is susceptible to shifting soils in the event of a geological disturbance (like earthquakes, erosion, or settling).

Happy Valley Interceptor. Although not on the original list of interceptors identified for inspection during the Tier 0 workshop, early findings from a separate flow monitoring task of the Sanitary Sewer Master Plan identified Happy Valley as a potential source of high infiltration and inflow. As a result, Jacobs was requested to inspect portions of the alignment to investigate if the interceptors could be the likely cause.

- Physical Condition: The inspected portions of the interceptor consisted of PVC pipe, which was in good condition without any major defects.
- Operations and Maintenance: No major debris issues.
- External and Internal Factors: The alignment is susceptible to shifting soils in the event of a geological disturbance (like earthquakes, erosion, or settling).

Uninspected Interceptors. As a part of the Tier 0 workshop, a prioritized list of interceptors was identified for Tier 1 inspection by WES crews. However, during execution of the field work, not all the identified interceptors were able to be inspected. The following paragraphs summarize the circumstances that surround these uninspected pipelines.

West Linn Interceptor. After further research, the West Linn Interceptor along Willamette Drive and down to the westerly end of the Oregon City bridge was installed in 1986 with PVC pipe and the manholes were rehabilitated in 2016 with epoxy coating. Furthermore, the portion that crosses over the bridge was not practical to inspect due to very high flows. As a result of these circumstances, the interceptor was not inspected.

Newell Creek Interceptor. Data for the Newell Creek Interceptor were not provided with the Tier 1 results. Additional information regarding the findings of additional research or field circumstances was not available at the time of this writing.

Willamette Outfall. Data for the Willamette Outfall Interceptor were not provided with the Tier 1 results. Additional information regarding the findings of additional research or field circumstances were not available at the time of this writing.

Other WES-Performed Tier 1 Inspections. During the Tier 1 inspections performed by WES, data were collected from other isolated locations within the collection system that were outside the areas targeted for Tier 1 inspection during the Tier 0 workshop. These data were provided to Jacobs at the completion of the Tier 1 field effort and were briefly reviewed, as summarized below. Although these conclusions are not comprehensive, the data were included in the register of each asset; their individual ratings are provided in Appendix C.

Fischers Forest Basin. No major defects were observed in the limited Tier 1 pole-camera data for this interceptor.

Boring Basin. Only minor defects including defective taps and offset joints were observed in the limited Tier 1 pole-camera data for this interceptor.

Rock Creek Interceptor. Only minor defects including attached deposits (grease) and roots were observed in the limited Tier 1 pole-camera data for this interceptor.

Johnson Creek Interceptor. No major defects were observed in the limited Tier 1 pole-camera data for this interceptor.

6.2.4.2 LOF Rating Results

The LOF ratings were compiled separately for the individual interceptor pipe segments, and then all asset components were rolled-up into a LOF rating for each interceptor. The LOF ratings are a combination of the total category ratings and the associated weighting of each category in the overall LOF.

Category Ratings. To better understand the types and extent of deficiencies in the system, the data for all of the interceptors may be presented in terms of which percentage of the inspected assets falls into which rating category. Figure 6-5 shows a summary of the asset ratings broken down by LOF category and rating range. By observation, the key findings are as follows:

- Performance deficiencies are the most significant contributor to LOF in the system
- Relatively few inspected assets (approximately 3 percent) have a "Poor" physical condition rating of 4 or higher
- O&M issues do not appear to be deleterious
- None of the inspected assets have an overall rating more severe than "Fair" (rating 3)

A complete register of the assets and their individual ratings is provided in Appendix C.

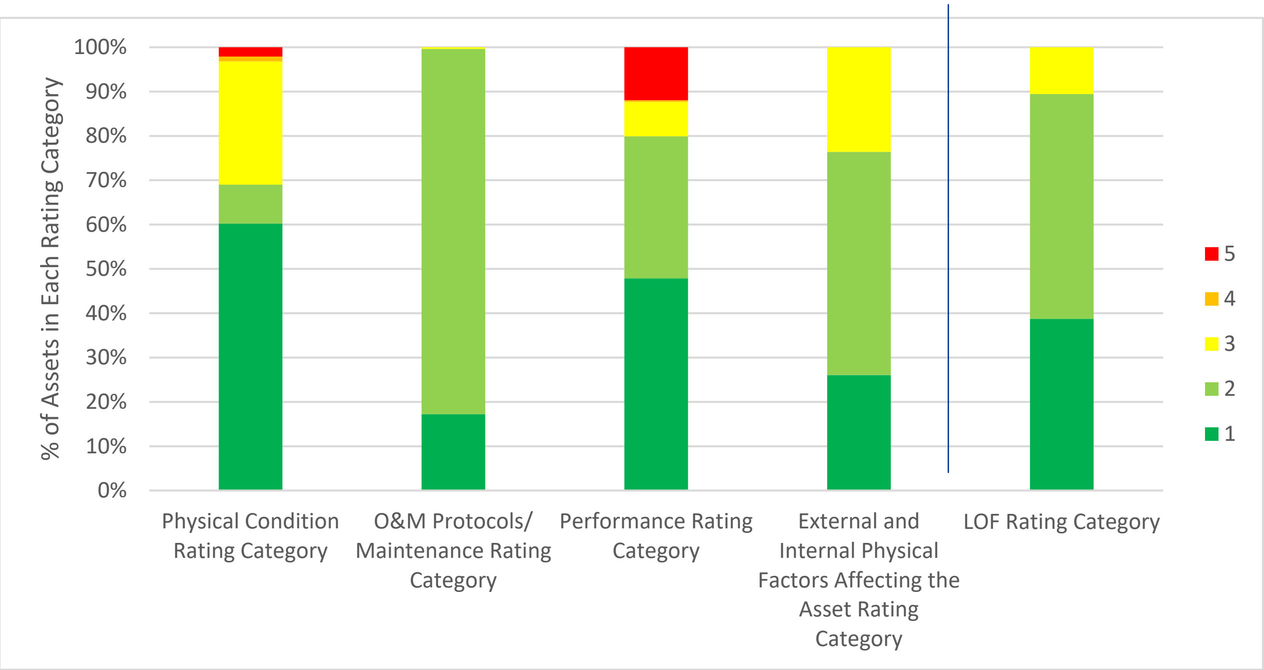


Figure 6-5. Asset Rating Summary by LOF Category

Interceptor Ratings. To further understand which interceptors are more deteriorated in comparison to one another, the data for all of the interceptors may be presented in terms of what total footage, per interceptor, falls in which LOF rating category. Figure 6-6 shows a summary of the overall LOF ratings broken down by total footage per interceptor. This chart does not include the small amount of data from the "Other System Portions" described above.

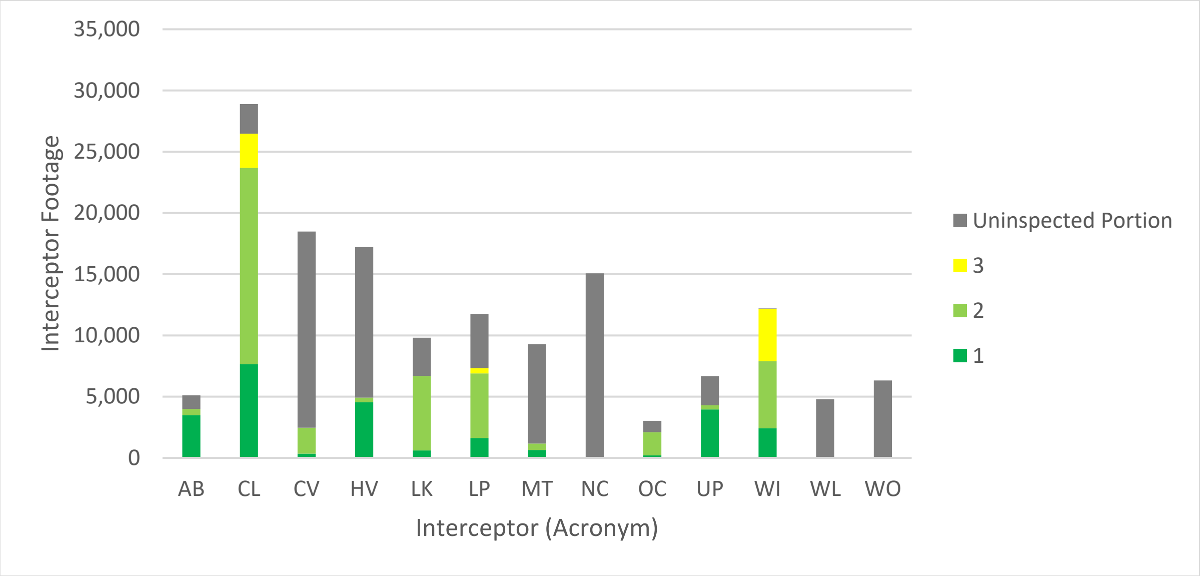


Figure 6-6. Summary of Footage LOF Ratings by Interceptor

AB = Abernethy Interceptor; CL = Clackamas Interceptor; CV = Country Village Interceptor; HV = Happy Valley Interceptor; LK = Lower Kellogg Interceptor; LP = Lower Philips Interceptor; MT = Mount Talbert Interceptor; NC= Newell Creek Interceptor; OC = Oregon City Interceptor; UP = Upper Philips Interceptor; WI = Willamette Interceptor; WL = West Linn Interceptor; WO = Willamette Outfall

By observation, the key findings are summarized as follows:

- Willamette Interceptor has the highest total footage of pipes with a “Fair” rating of 3, followed by Clackamas Interceptor.
- Data from Newell Creek, West Linn, and Willamette Outfall interceptors were not available for the study.

Figure 6-7 displays a map of the inspected interceptor assets with a summary of the overall LOF ratings per pipe segment. Appendix C contains the condition scores of all inspected assets for each interceptor that were combined to arrive at the total (inspected) interceptor condition score. The condition scores will be used in the risk assessment of all assets in the system. From that analysis, guidance will be provided on whether additional maintenance, capital improvements, or other actions will be most effective in reducing risk of asset failure.

6.2.4.3 Recommendations

The recommendations for gravity interceptors are organized into the following categories:

- **Maintain**—Regular inspection and maintenance on a schedule commensurate with the risk rating.
- **Special Monitoring**—Regular inspection and maintenance with special attention to particular defects (such as corrosion, infiltration, or debris).
- **Phased Rehabilitation (Near Term)**—Structural rehabilitation of the interceptor is advised for the next reasonable capital planning window (1 to 5 years).
- **Phased Rehabilitation (Far Term)**—Structural rehabilitation of the interceptor is advised for the future capital planning window (5 to 10 years).
- **Rehabilitation**—Structural rehabilitation of the interceptor is advised as soon as funding and resources are available.

- **General Preventive Maintenance**—No formal preventive maintenance plan currently exists for the gravity interceptors. Overall, it is recommended that the interceptors be placed on a regular maintenance cycle that includes the following activities:
  - Inspect pipe and manhole assets at a frequency based on their overall risk rating (see Section 7), as shown in Table 6-6. The methods of inspection should mirror those used in the tiered approach followed during this study.
  - For the interceptors that were not inspected as part of this study, proceed with inspection on a schedule prioritized by their current risk rating until more detailed condition assessment data can be collected to supplant the institutional knowledge ratings (similar to the process followed in this study).
- **Tier 3 Inspections**—Large-diameter rehabilitation projects can be more effectively designed and constructed if Tier 3, high-resolution, multisensor information data are available. Multisensor inspection may include laser profiling, sonar, and pipe-penetrating radar. For the rehabilitation projects identified in this report, it is recommended that Tier 3 inspection be performed prior to detailed design or construction.

These recommendations were incorporated into the identification and prioritization of capital improvement projects presented in Section 9, Project Recommendations and Prioritization. Figure 6-8 displays a map of the inspected interceptor assets with a summary of the overall recommendations. Appendix C contains a complete register of asset-specific recommendations.

Table 6-6. O&M Recommendations Based on Likelihood and Consequence Scoring

High	5	4-yr cycle	2-yr cycle	2-yr cycle	2-yr cycle	2-yr cycle
	4	6-yr cycle	6-yr cycle	4-yr cycle	2-yr cycle	2-yr cycle
Likelihood	3	8-yr cycle	6-yr cycle	6-yr cycle	4-yr cycle	2-yr cycle
	2	10-yr cycle	8-yr cycle	6-yr cycle	6-yr cycle	4-yr cycle
Low	1	10-yr cycle	10-yr cycle	8-yr cycle	8-yr cycle	6-yr cycle
		1	2	3	4	5
		Low		**Consequence**		High

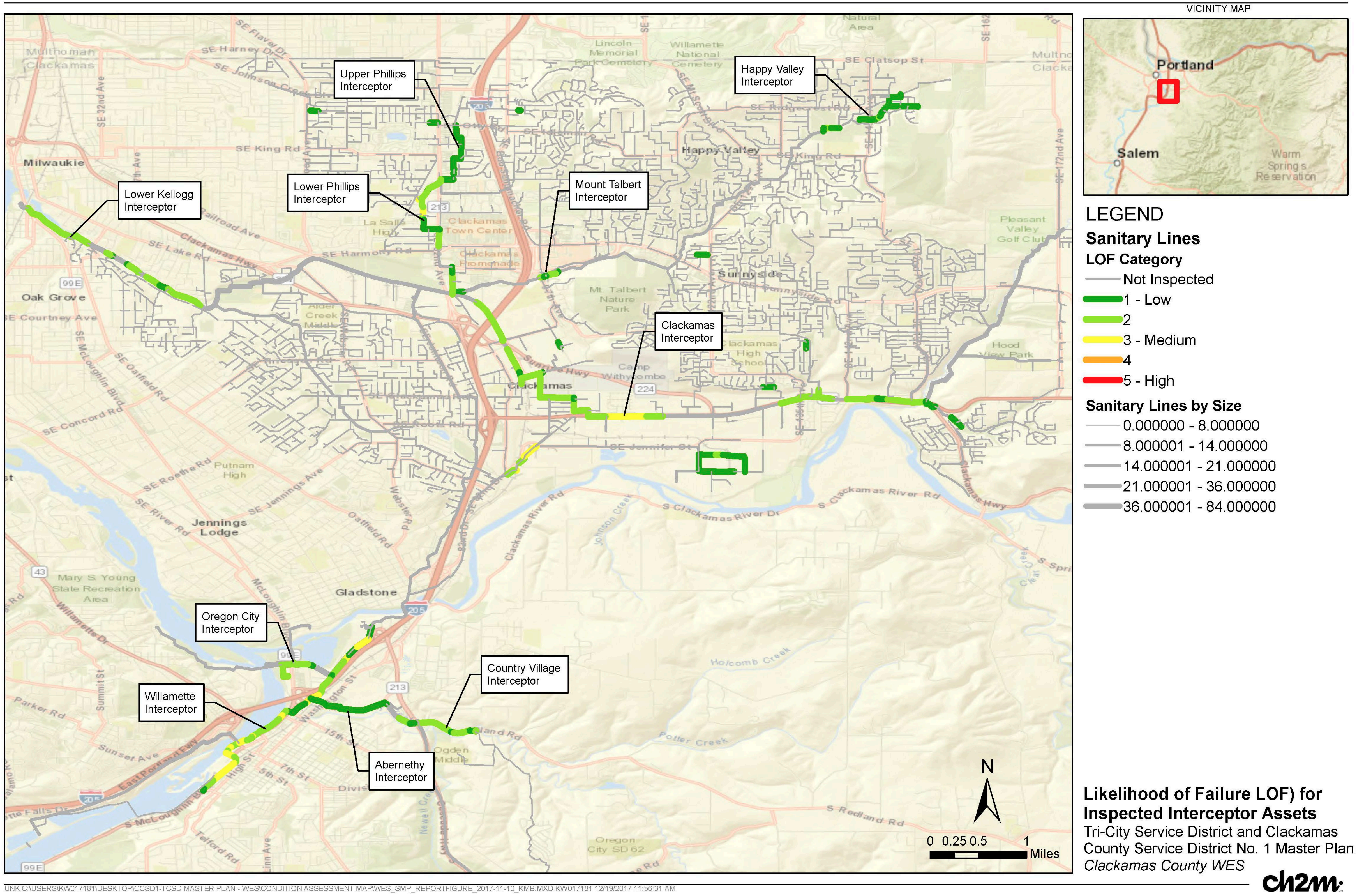


Figure 6-7. Likelihood of Failure (LOF) for Inspected Interceptor Assets

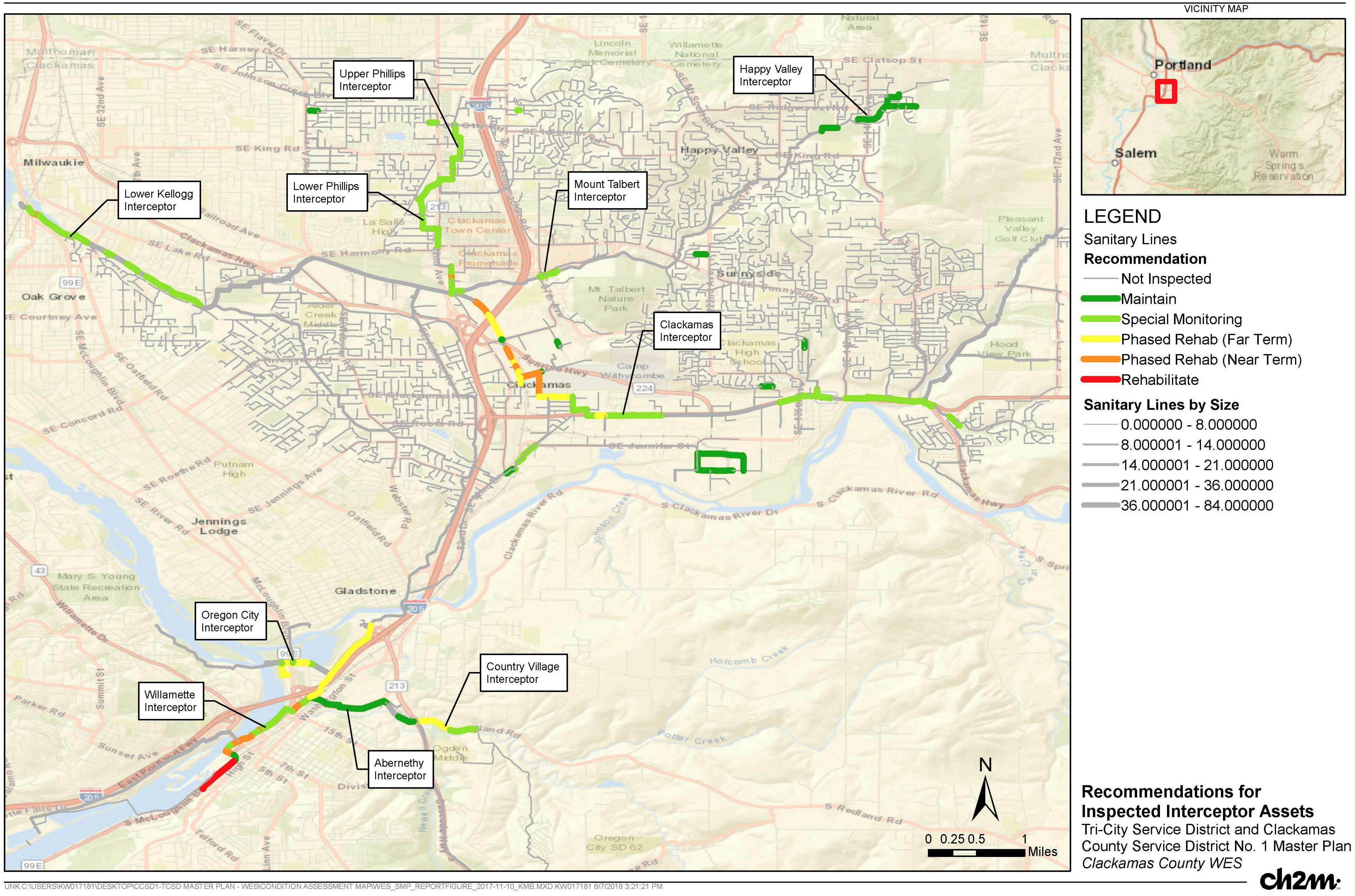


Figure 6-8. Recommendations for Inspected Interceptor Assets

6.3 Force Mains

This section summarizes the force main condition assessment completed by Jacobs for WES in 2016 - 2017. The technical memorandum in Appendix D provides supporting details.

6.3.1 Objectives

The objectives of the work were to provide a condition assessment of four preselected force mains, characterize the LOF, and identify recommended improvements and preventive maintenance alternatives.

6.3.2 Methodology and Analysis

WES selected four force mains for condition assessment based on their age, material, and prior history. The selected force mains were as follows:

- West Linn Force Main: 6,200 feet of 18-inch ductile iron pipe (DIP) from Willamette Pump Station, installed in 1986
- Bolton Street Force Main: 6,300 feet of 16-inch DIP from Bolton Pump Station, installed in 1985
- River Street Force Main: 2,600 feet of 12-inch DIP from River Street Pump Station, installed in 1985
- Gladstone Force Main: 2,800 feet of 20-inch concrete cylinder pipe (CCP) from Gladstone Pump Station, installed in 1985

This section presents the findings of the tiered investigation. This assessment, combined with the evaluation of other LOF and COF criteria, will lead to a determination of which force mains require attention to reduce the overall risk of a failure. Measures to reduce risk were incorporated into the identification and prioritization of capital improvement projects or as operational changes.

6.3.2.1 Methodology

A tiered approach was utilized to inspect the force mains and their associated appurtenances as described in this subsection.

Tier 0. Tier 0 included a desktop analysis of the collection system and a collaborative workshop with Jacobs and WES staff held on June 7, 2016 to confirm selected force mains for inspection.

Tier 1. Tier 1 inspections included topside inspections of the force main valves, vaults, and other associated appurtenances as well as soil corrosivity measurements along the alignment. The results were used to assess the condition of the appurtenances, evaluate their LOF, and identify locations for further investigation of the buried portions of the pipelines. A compilation of observations, photos, and measurements from the Tier 1 field inspection work is included as an electronic file in Appendix D.

Tier 2. Tier 2 inspections included test pits along the alignment where there was potential for corrosion or other deterioration of the pipeline or the buried connections and fittings. Visual observations as well as pit depth measurements and ultrasonic wall thickness tests were conducted on the exposed pipelines. The results were used to evaluate the LOF of distinct reaches of the pipe.

A compilation of observations, photos, and measurements from the Tier 2 field inspection work is included as an electronic file in Appendix D.

Tier 3. Tier 3 inspections included confined space entry of selected vaults along the alignment of the force mains in order to inspect the exposed portion of the pipe within. Inspections also included an additional pipe coupon from the Willamette Force Main. Visual observations as well as pit depth measurements and ultrasonic wall thickness tests were conducted on the exposed pipelines. The results were used to evaluate the LOF of the pipe within. This assessment was distinct from that of the attached appurtenances (e.g., valves and meters). These investigations are considered a Tier 3 assessment technique within the scope of work, but were performed during the Tier 2 assessment because the inspectors and equipment were already onsite.

Based on the findings of the prior tiers, additional Tier 3 methods including acoustic surveying, in-line inspection tools, and dewatered CCTV were evaluated for some of the force mains. As of the time of this writing, no additional Tier 3 investigation were conducted as part of the Sanitary Sewer Master Plan, but recommendations are made to conduct additional future Tier 3 investigation for select force mains.

A compilation of observations, photos, and measurements from the Tier 3 field inspection work is included as Appendix D.

6.3.2.2 Analysis

The same methodology used to quantitatively score the gravity interceptors was also applied to the force mains, including the use of the four categories that determine LOF:

- Physical Condition
- Hydraulic Performance
- O&M Protocols/Maintenance
- External and Internal Factors Affecting the Asset

A complete description of the condition criteria, weights, and range of possible scores is included in Appendix D.

As a refinement to the asset hierarchy established at the risk workshop, each force main was organized into the following additional individual assets:

- Distinct pipe reaches from one given station to another
- Different appurtenances (e.g., relief valve and vault, control valve and can)

6.3.3 Findings

Jacobs reviewed the data for each force main to provide a qualitative characterization of the asset against each LOF criterion. This section summarizes the major findings by force main (Section 6.3.3.1), followed by LOF rating results (Section 6.3.3.2) and recommendations (Section 6.3.3.3). Hydraulic performance is discussed in Section 4 (Future System Flow Projections and Capacity Evaluations). Detailed descriptions of each force main are documented in Appendix D.

6.3.3.1 Summary of Major Findings by Force Main

Bolton Street Force Main.

- Physical Condition: The buried pipe was in generally fair to good condition with limited pitting or surface corrosion on the DIP. The exposed force main pipe within the vaults was in very poor to poor condition primarily due to the severity of external corrosion by entrapped sewer gasses released by the relief valves.
- Operations and Maintenance: No record of reactive maintenance issues, however prior complaints have been made due to foul odors near the relief valves at STA 32+25.
- External and Internal Factors: Downstream portions (after the alignment exists Burnside Park) are at an elevated risk of inundation from the Willamette River, and the entire alignment is susceptible to shifting soils if the event of a geological disturbance (like earthquakes, erosion, or settling).

In May of 2017, the force main experienced a failure near STA 37+00 in Maddax Woods. Forensic investigation during the repair revealed that the invert of the pipe had corroded in an isolated area where the pipe had not been bedded in granular backfill, but was instead adjacent to clayey soils. Soil resistivities of a sample of the clayey embedment measured 1,150 ohm-cm, indicating corrosive conditions. Just a few feet upstream and downstream of the failure location, the pipe wall was in good condition with no signs of corrosion or wall loss. Further analysis concluded that the corrosion had consumed the entire pipe wall thickness at the hole before the leak manifested at the surface, and that the failure had not occurred earlier because the cement mortar lining had remained intact and “bridged” the hole. Once the hole had reached a critical size where the cement mortar lining could no longer “bridge” the gap, the lining ruptured and the leak reached the surface. The phenomenon of isolated, discrete corrosion cells occurring where the pipe was improperly bedded (as was the case in the May 2017 failure, where the small portion of the pipe was bedded on clay) is the most difficult to determine by Tier 1 or Tier 2 methods. Prior history of this type of failure is often the most significant indicator of the future likelihood, and Tier 3 methods are commonly needed to measure the location and extent of precursor defects.

Multiple Tier 3 inspection tools were evaluated as potential candidates for detecting similar weaknesses along the pipe alignment. Many technologies were precluded because of the challenges associated with launching the tools (e.g. the need to construct pig launching/retrieval stations), flow rates that could not be reduced and exceeded the tools operational threshold, and ability of the tools to detect the failure mode of concern. Specialty “smart pigging” technology providers presented potential solutions, but additional risk mitigation measures to address scenarios where the pig may be arrested in the pipe during deployment are needed before the inspection would be further considered.

River Street Force Main.

As described in the *Force Main Condition Assessment Tier 2 and 3 Investigation Plan (Revised)* (CH2M, 2017) the results of the investigations on the parallel Bolton Street Force Main were extrapolated to the River Street Force Main. This implies that the buried portions of the River Street force main are in a similar state of generally fair to good condition with limited pitting or surface corrosion on the DIP, and no endemic joint defects. However, the exposed force main pipe within the vaults was in very poor to poor condition primarily due to the severity of external corrosion by entrapped sewer gasses released by the relief valves.

Gladstone Force Main.

- Physical Condition: The buried pipe was in generally good condition with little to no observed corrosion on the CCP or steel pipe sections. The installation appeared to utilize proper embedment techniques for the pipe, and no significant joint defects were observed.
- Operations and Maintenance: No record of reactive maintenance issues.
- External and Internal Factors: Recent construction activity related to commercial development near the upstream portion of the force main could pose a threat.

Willamette Force Main.

- Physical Condition: The buried pipe was in generally good condition with little to know external pitting or surface corrosion on the DIP. The installation appeared to utilize proper embedment techniques for the pipe, and no significant joint defects were observed. However, analysis of the coupons indicated that the cement mortar lining is no longer adhered to the pipe or has a depleted pH that no longer pacifies the underlying DIP. The appurtenances and vaults ranged widely from poor to good condition. The worst-rated appurtenance was the abandoned air injection station apparatus.
- Operations and Maintenance: The relief valves were recently replaced with plastic valve bodies to avoid issues from the trapped corrosive gasses. The air injection stations have been abandoned but not capped/demolished. WES staff responded to an instance where a leader line from one of the valves was broken and required repair. The other appurtenances have not historically been a source of reactive or corrective maintenance work orders, nor is there a history of prior failures. There is a record of prior complaints due to foul odors near the relief valves at STA 32+25.
- External and Internal Factors: The upstream portion (prior to ascending the ridge to Willamette Falls Drive) is at an elevated risk of inundation from the Willamette River, and the entire alignment is

susceptible to shifting soils if the event of a geological disturbance (like earthquakes, erosion, or settling).

6.3.3.2 LOF Rating Results

The LOF ratings were compiled separately for the individual force main pipe reaches and appurtenances, and then all asset components were rolled-up into a LOF rating for each force main. The LOF ratings are a combination of the total category ratings and the associated weighting of each category in the overall LOF.

Component Ratings. Figure 6-9 shows the asset ratings broken down by LOF category and rating range. A complete register of each asset and their individual ratings is provided in Appendix D.

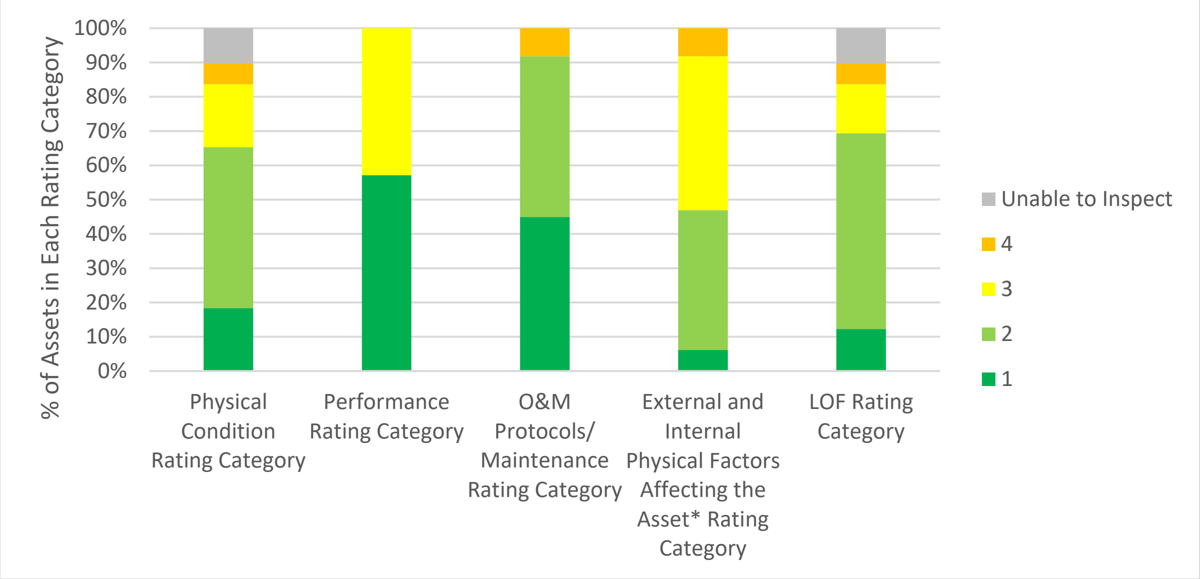


Figure 6-9. Asset Rating Summary by LOF Category

Force Main Ratings. Figure 6-10 shows the overall LOF asset ratings broken down by force main. Appendix D contains the condition scores of all assets in each force main that are combined to arrive at the total force main condition score. The condition scores will be used in the risk assessment of all assets in the system. From that analysis, guidance will be provided on whether additional maintenance, capital improvement, or other actions will be most effective in reducing risk of asset failure.

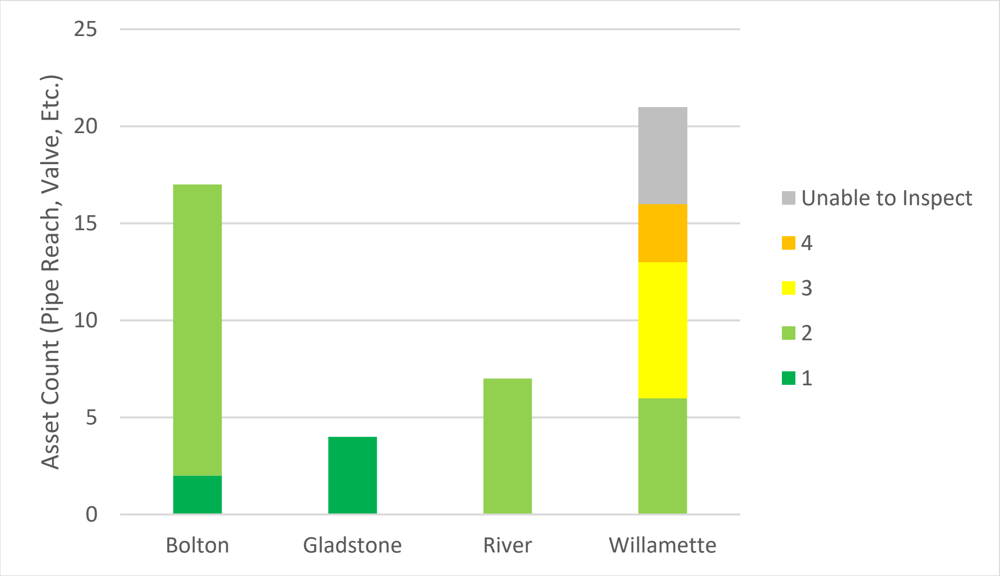


Figure 6-10. Summary of Asset LOF Ratings by Force Main

6.3.3.3 Recommendations

This section contains general recommendations for each force main. These recommendations were incorporated into the identification and prioritization of capital improvement projects presented in Section 9, Project Recommendations and Prioritization. A complete register of asset-specific recommendations is included in Appendix D.

Bolton Street Force Main. Although the buried force main pipe itself appears to be in acceptable condition, the appurtenances and pipe spools that are exposed in the vaults present the highest contributing factor the LOF. These exposed pipes should be rehabilitated with corrosion-resistant epoxy paint, or replaced. For pipes that are at risk of structural failure, they should be replaced with new pipe spools or rehabilitated with a structural technology such as carbon fiber wrap. After replacement or rehabilitation, the pipe seal where there the pipes penetrate into the vault walls must also be repaired. The pipe seal should be chipped out, the pipe spool cleaned to bright metal, and an epoxy paint coating applied. Afterwards, the pipe seal may be rebuilt with trowelable mortar and a bead of seal caulk.

The valves in the aforementioned vaults should also be protected with a corrosion-resistant point coating. Corroded fittings should be replaced with stainless fasteners, or sand-blasted clean and wrapped with wax tape. In all instances, a proper ventilation device should be installed on the vaults to prevent the accumulation of further corrosive gasses.

Despite the measurements that indicated relatively little wall loss from the buried force main pipe, it has been observed in other force mains of similar construction and time period that the interior cement mortar lining (CML) may be depleted and not provide adequate protection relatively early on in the assets life. Subsequent inspections should track the rate of measured wall loss and whether it appears to be a result of external or internal corrosion. If identified early on, the force main may be rehabilitated with a corrosion protection lining before it becomes structurally compromised.

Lastly, the May 2017 failure of the force main has raised concerns about the possibility of additional, isolated areas of discrete corrosion cells caused by improper installation. While the overall pipe itself is in acceptable condition, and has significant remaining service life, the potential for similar leaks and failures in the future cannot be disregarded. In addition to the measures described above, further Tier 3 investigation (that appropriately accounts for the sensitive location and importance of the pipeline, and includes robust risk mitigation measures) is recommended to identify these defects and implement proactive remedial repairs.

Examples of Tier 3 risk mitigation measures may include construction of dedicated pig launching/retrieval stations at intermittent locations along the pipeline, and construction of fully redundant bypass operations. In the meantime, preparation of an emergency response plan is recommended to address future potential failures that may occur as a result of similar circumstances of isolated corrosion cells.

River Street Force Main. Similar to the parallel Bolton Street Force Main, the buried pipes appeared to be in acceptable condition but the appurtenance and pipe spools that are exposed in the vaults present elevated LOF and should be rehabilitated in the manner described above.

In addition, future inspection should include measurements to evaluate the potential for CML depletion and the onset of internal corrosion, as well as Tier 3 investigation to identify potential areas of installation-related deterioration.

Gladstone Force Main. Minor preventive maintenance measures such as touchups on the paint of the steel pipe bridge crossing, and monitoring of the construction activity in the vicinity of the pipeline should be sufficient to prolong the asset’s remaining useful life.

Willamette Force Main. Although the force main pipe appears to be currently in acceptable condition, the pipe coupons collected at both the upstream and downstream locations confirmed that the cement mortar lining has a depleted pH, is no longer adhered to the pipe, and is not protecting the interior of the pipe from corrosion. While the extent of the corrosion is currently relatively minor, it may be expected to continue unabated without the protection of an interior lining. Careful future monitoring of the pipeline wall thickness (via ultrasonic testing like that used during this assessment) is recommended for early detection of a more severe corrosion case.

In addition, it is recommended that, in the future, this pipe be considered for rehabilitation by means of a nonstructural polymer or epoxy internal lining before the corrosion consumes the pipe wall thickness to the point that structural rehabilitation is required.

A unique aspect of the Willamette Force Main is the presence of air injection stations. During the course of this assessment it was apparent that the air injection stations were not functional and were therefore abandoned. Even with the 2-inch isolation valve along the leader pipe closed, these stations still present a direct connection to the force main and are frequently damaged by road and ditch maintenance equipment (such as tractor-mounter brush cutters). If left abandoned, an errant brush cutting blade could strike the valve, piping, or leader pipe and cause a spillage. For this reason, it is recommended that these stations be properly demolished with the leader line capped and buried out of harm’s way.

General Preventive Maintenance Recommendations. No formal maintenance plan exists for the force mains. However, an ad hoc program is in place to remove, inspect, clean, and reinstall the valves periodically. Overall, it is recommended that the force mains be placed on a regular maintenance cycle which includes the following activities:

- Air relief valves should be flushed at least every year. In addition, they should be disassembled, cleaned, and rebuilt every 2 to 3 years.
- Control valves should be exercised every 1 to 2 years.
- Pipe and vault assets should be inspected on a frequency based on their overall risk rating, as shown in Table 6-6. The methods of inspection should mirror those used in the tiered approach followed during this study.

7. Risk-based Asset Evaluation

Section 7 describes the risk evaluation of assets based on consequence of failure and likelihood of failure. The asset hierarchy from previous master plans was expanded and revised based on condition assessment and hydraulic modeling results to provide overall risk scores for all assets.

7.1 Objectives

The objectives of the risk-based asset evaluation are:

- Expand the existing asset management framework current used by WES to include assets that are not currently in the asset hierarchy.
- Prioritize and progress through the Tiered and Adaptive Plan approach for condition assessment.
- Evaluate the relative risk of asset failure using consequence of failure and likelihood of failure to identify and prioritize risk-reduction measures.

7.2 Methodology and Analysis

The risk assessment included reviewing the framework and risk-measurement factors with WES, expanding the hierarchy with additional assets, reviewing initial scoring with WES staff, using preliminary results to select assets for condition assessments, revising condition and capacity scoring, and calculating final risk scores for all assets.

The risk assessment used the risk-based asset management framework that was creating and used in the 2009 CCSD #1 Master Plan and the 2017 Hoodland Master Plan. The framework calculates a risk score by multiplying the consequence of failure by the likelihood of failure. The consequence and likelihood of failure scores are computed from a set of level of service category scores and weights. The consequence and likelihood categories and definitions of ratings from the 2017 Hoodland Master Plan were reviewed and used with an expanded definition for performance.

The consequence of failure is evaluated by the impact on levels of service, which fall into the categories of health and safety of the public and employees, financial impact on the utility, public confidence, environmental compliance, and system reliability. The consequence of failure categories, weights, and scoring guidance are outlined in Table 7-1. A level of service category score of 1, 4, 7, or 10 is assigned to each asset based on data from desktop studies and knowledge of the system.

Table 7-1. Consequence of Failure Scoring

Risk-Based Asset Management Framework

Level of Service Category	Wt.	1 (Negligible)	4 (Low)	7 (Moderate)	10 (Severe)
Health & safety of public and employees	26%	Routine work. Does not involve confined space entry. No potential human contact.	Involves exposure to increased hazards, such as raw sewage in the street, or one of the following: • Confined space • Biohazard • >20 feet above ground • Energized power >240v but <600v • Trench >10 ft. deep • Pipe adjacent to, or crossing arterial/major road, or bridge/ river/stream crossing	Involves exposure to increased hazards such as raw sewage backup into dwellings or residential property, or two or more of the following: • Confined space • Biohazard • >20 feet above ground • Energized power >240v but <600v • Trench >10 ft. deep • Pipe adjacent to, or crossing arterial/major road, or bridge/ river/stream crossing	Involves exposure to extreme adverse conditions or hazards requiring significant challenges, such as: • Energized power ≥600v • Gases such as C–l2, NH3, HF, or explosive atmosphere • Very high concentrations of H2S resulting in significant O2 deficiency • Gas main within trench
Financial impact on Utility	15%	Able to be absorbed in O&M budget's applicable cost center. Does not affect other O&M activities	Requires Director approval	Requires Board approval	May require new borrowing or impact rates
Public confidence	15%	No odor complaints. Minor disruption (e.g., traffic, dust, noise). No adverse media coverage. Minor service interruption, service restored without public reaction.	Localized odor complaints. Minor disruption (e.g., traffic, dust, noise). No adverse media coverage. Minor service interruption, service restored without public reaction.	Substantial increase in odor complaints. Substantial but short-term disruption. Adverse media coverage due to public impact.	Long-term impact. Area-wide disruption. Widespread adverse media coverage. Public outcry of dissatisfaction with utility services.
Environmental compliance	18%	Full compliance with NPDES and State permits	Some regulatory enforcement but no fines. (e.g. NOVs, formal notification to State). No environmental impact.	Probable enforcement action with fines. Short-term environmental impact that can be mitigated quickly.	Enforcement action with directed change in program(s) and redirection of priorities. Long-term environmental impact that cannot easily be mitigated.

Table 7-1. Consequence of Failure Scoring

Risk-Based Asset Management Framework

Level of Service Category	Wt.	1 (Negligible)	4 (Low)	7 (Moderate)	10 (Severe)
System reliability	26%	No loss of treatment or system effectiveness. No loss of capacity. No SSOs. No flows to surface waters. Effluent/reuse and biosolids meet contractual requirements.	Potentially result in loss of treatment or system effectiveness if action is not taken quickly. Loss of <20% of system capacity but can still meet current flow conditions. SSO, but not to stormwater infrastructure or surface waters. Effluent/reuse and biosolids meet contractual requirements.	Will immediately result in loss of treatment or system effectiveness, but with possible mitigation. Loss of ≥20% but <40% of system capacity impacting ability to meet peak flows SSO confined to stormwater infrastructure Effluent/reuse and biosolids does not meet contractual requirements.	Will immediately result in loss of treatment or system effectiveness, which cannot be easily reversed or mitigated. Loss of >40% system capacity impacting ability to meet average day flows. SSO to waters of the State Effluent/reuse and biosolids cannot be disposed of by normal processes.

The likelihood of failure is the possibility that the asset will fail and is evaluated based on the physical condition of the asset, performance, external and internal physical factors affecting the asset, O&M protocols, and reliability history. The likelihood of failure and is computed based on the categories, weights, and scores provided in Table 7-2. A score of 1, 2, 4, 7 or 10 is applied to each asset based on data from condition assessments, system modeling, GIS data, and operations and maintenance experience. After condition assessments were performed, the scoring described in Section 6 was mapped to match the ratings in Table 7-2 and the scores were updated. In the absence of current condition assessment data or hydraulic modeling, institutional knowledge from staff or past data can be used to inform the scoring. Interviews and visual observation are recommended to make educated assumptions.

Table 7-2. Likelihood of Failure Scoring

Risk-Based Asset Management Framework

Level of Service Category	Wt.	1 (Negligible)	2 (Unlikely)	4 (Possible)	7 (Likely)	10 (Very Likely)
Physical Condition (General)	35%	Very good (Condition Grade 1). No deficiencies Needs no corrective maintenance Presently not a safety hazard	Good (Condition Grade 2). Few minor deficiencies Needs minimal amount of corrective maintenance Presently not a safety hazard	Fair (Condition Grade 3). Several minor deficiencies. Needs moderate amount of corrective maintenance. Presently not a safety hazard.	Poor (Condition Grade 4). Major deficiencies. Needs substantial amount of corrective maintenance or partial rehabilitation. Presently a potential safety hazard.	Very poor (Condition Grade 5). Asset may be unserviceable. Needs replacement or major rehabilitation. Presently a safety hazard.

Table 7-2. Likelihood of Failure Scoring

Risk-Based Asset Management Framework

Level of Service Category	Wt.	1 (Negligible)	2 (Unlikely)	4 (Possible)	7 (Likely)	10 (Very Likely)
Physical Condition (Mechanical/ Electrical Equipment)		No apparent damage or deterioration except for possible surface staining or discoloration Instrumentation is periodically calibrated with data documented and trended	Showing some wear and tear; some minimal damage or deterioration (e.g., a minor leak) although protective coatings are intact Instrumentation is periodically calibrated with data documented but not trended	Obvious damage or deterioration (e.g., moderate leak, abnormal vibration, some surface corrosion). Instrumentation is periodically calibrated but data not documented nor trended.	Considerable damage or deterioration (e.g., major leak, excessive vibration, corrosion affecting more than the surface, perforations). Instrumentation is periodically calibrated but data not documented nor trended.	Significant damage or deterioration; severe corrosion Frequent breakdowns Instrumentation is rarely calibrated, and data not documented nor trended
Physical Condition (Structures)		Sound structure with no apparent damage nor deterioration except for possible surface staining or discoloration Building are secure and weatherproof Appears well-maintained	Sound structure but showing minor wear and tear with some minimal damage or deterioration (e.g., minor spalling but no corrosion staining) Building is secure and weatherproof Needs some minor corrective maintenance	Sound structure but showing some obvious damage or deterioration (e.g., minor cracking, peeling coatings, moderate spalling with some corrosion staining, minor leak). Building has a minor leaks but otherwise secure. Needs corrective maintenance.	Structure is functioning but showing considerable damage or deterioration (e.g., significant cracking, spalling, major corrosion affecting a structural member, major leak, missing components, loss of stability, marked deformation). Building has several minor leaks or a major leak, but otherwise secure. Needs substantial corrective maintenance or partial rehabilitation.	Serious structural problems. Buildings are not secure nor weatherproof. Needs major rehabilitation or replacement.
Physical Condition (Gravity Sewers)		No damage or deterioration with no evidence of internal or external degradation and no structural defects.	Slight deterioration such as circumferential cracking or minor joint defects.	Some minor defects (both O&M and structural) over not more than 25% of the length; structural defects ≤5% of the length. Exposed aggregate on concrete pipe; several misaligned joints; root intrusion. Deformation 0 to 5%.	Some moderate defects (both O&M and structural) over not more than 25% of the length; structural defects (including missing or collapsed liner) >5%, ≤10% of the length. Numerous misaligned joints; cracks, leaking, significant root intrusion. Visible I/I. Deformation 5% to 10%.	Significant defects (both structural and O&M) for over 25% of the length; structural defects (including missing or collapsed liner) >10% of the length; missing or collapsed liner. Deformation >10%.

Table 7-2. Likelihood of Failure Scoring

Risk-Based Asset Management Framework

Level of Service Category	Wt.	1 (Negligible)	2 (Unlikely)	4 (Possible)	7 (Likely)	10 (Very Likely)
Physical Condition (Manholes)		Sound structure well maintained with no problems with the structure, cover, frame, shelf, and invert pipe entries No sediment or clogging	Structure showing minor wear and tear and minor deterioration, such as some surface damage but no corrosion staining, cracking, or loss of stability Minor wear and tear of cover or frame, but good alignment. Sediment occasionally found, but no clogging	Structure showing some obvious damage or deterioration, such as minor cracking, peeling coatings, moderate spalling with some corrosion staining, minor leak, significant sedimentation, signs of vegetation. Obvious wear and tear of cover or frame, and/or some minor misalignment Sediment frequently found, and/or occasional clogging	Structure is functioning but showing considerable damage or deterioration, such as infiltration, loss of stability or deformation Cover, frame, or steps showing signs of corrosion and/or significant misalignment Frequent clogging	Serious structural problems with structure, cover, frame, and/or significant misalignment.
Physical Condition (Force Mains)		No damage or deterioration, and no evidence of internal or external degradation No history of pipe wall nor joint failures/breaks	No damage but evidence of slight external or internal degradation No history of pipe wall nor joint failures/breaks	Some damage or moderate external or internal degradation 1-2 pipe wall or joint failures/breaks in past 10 years (per 1,000± feet of pipe)	Significant pipe wall or joint failures or evidence of significant external or internal degradation. More than 2 pipe wall or joint failures/breaks in past 10 years (per 1,000± feet of pipe).	Extensive external or internal degradation Frequent pipe wall or joint failures/breaks in the past 10 years

Table 7-2. Likelihood of Failure Scoring

Risk-Based Asset Management Framework

Level of Service Category	Wt.	1 (Negligible)	2 (Unlikely)	4 (Possible)	7 (Likely)	10 (Very Likely)
Performance	30%	Meets all functional requirements with normal O&M procedures under all demand conditions (e.g., average and maximum day flow and peak design flow). Appropriate utilization and function. No surcharge in collection system. DWF peak d/D < 0.8, WWF peak q/Q < 1.0 for interceptors. WWF peak velocity < 8 fps for force mains.	Meets all functional requirements under all demand conditions (e.g., average and maximum day flow and peak design flow) but occasionally requires increased attention from O&M staff during extreme conditions. Inefficient due additional resource requirements (e.g. energy, labor, chemicals). No surcharge in collection system. DWF peak d/D < 0.8, WWF peak q/Q < 1.0 for interceptors. WWF peak velocity ≥ 8 fps for force mains.	Meets functional requirements under most conditions (e.g., average and maximum day but not peak design flow). Occasionally unstable or difficult to operate without increased attention from O&M staff. Some components are obsolete with spare parts difficult to obtain. During peak design flow event, hydraulic grade line (water surface elevation) greater than 8 feet from ground but pipes are surcharged (pressurized). Force main may have insufficient capacity or must operate at significantly high pressures. DWF peak d/D < 0.8, WWF peak q/Q > 1.0 for interceptors. WWF peak velocity ≥ 10 fps for force mains.	Meets functional requirements only under normal conditions (e.g., average day but not maximum day or peak design flow). Frequently unstable or difficult to operate without increased attention from O&M staff. Most or all components are obsolete with spare parts difficult to obtain. During peak design flow event, hydraulic grade line (water surface elevation) 2 feet to 8 feet below ground or basement elevations for 1 hour or greater. Pipes surcharged (pressurized). DWF peak d/D ≥ 0.8, WWF peak q/Q > 1.0 for interceptors. WWF peak velocity ≥ 12.5 fps for force mains.	Unable to meet current average capacity requirements. Does not meet functional requirements under normal conditions. Very unstable or difficult to operate even with increased attention from O&M staff. Water surface elevation within 2 feet of ground occurs for the peak design flow event. WWF peak q/Q > 1.0 for interceptors. WWF peak velocity ≥ 15 fps for force mains.
External and Internal Physical Factors Affecting the Asset	15%	Stable foundation and support. Appropriate installation and construction. Noncorrosive soils and flows.	N/A	Sewer crosses creek or river below grade with potential for undermining or washout; or Susceptible to flooding; or Suspended pipeline or soils or flows somewhat corrosive to asset.	Unstable foundation and/or support; historical landslide; questionable construction Highly corrosive flows or highly corrosive soils	Unstable foundation, poor support, and questionable construction Located within defined channel migration zone

Table 7-2. Likelihood of Failure Scoring
Risk-Based Asset Management Framework

Level of Service Category	Wt.	1 (Negligible)	2 (Unlikely)	4 (Possible)	7 (Likely)	10 (Very Likely)
O&M Protocols/ Maintenance	20%	Complete, up-to-date, written/ online, easily accessible. Appropriate maintenance over life. Ratio of planned maintenance hours to total maintenance hours is ≥ 70%. Planned maintenance activities rarely find needed corrective maintenance. Mean time between failure (MTBF) is acceptable and steady or trending higher.	Complete, written/ online, up-to-date, but not easily accessible. Ratio of planned maintenance hours to total maintenance hours is <70% but ≥60%. Planned maintenance activities rarely find needed corrective maintenance. MTBF is acceptable but trending lower.	Written/online but not complete or not up-to-date. General or broad written protocols. Recent or inadequate appropriate maintenance over life. Ratio of planned maintenance hours to total maintenance hours is <60% but ≥40%. Planned maintenance activities frequently find needed corrective maintenance. MTBF is unacceptable but trending higher.	Written/online but outdated or location unknown. Ratio of planned maintenance hours to total maintenance hours is <40% but ≥30%. Planned maintenance activities frequently find needed corrective maintenance. MTBF is unacceptable but steady.	No written or online protocols. No appropriate maintenance over life. Ratio of planned maintenance hours to total maintenance hours is <30%. Planned maintenance activities always find needed corrective maintenance. MTBF is unacceptable and trending lower.

Starting with the asset hierarchy created for CCSD #1 for the previous master plan in 2009, the scores were reviewed and updated, and the hierarchy was expanded to include assets in the Tri-City service WES. For the assets in the CCSD #1 service WES, the 2009 scores for both consequence and likelihood of failure were updated based on the refined scoring guidance and information from GIS and knowledge of the system. Assets in the Tri-City service WES were added to the hierarchy and consequence ratings were assigned based on a desktop GIS study.

In a workshop with WES staff from operations, engineering, and management in June 2016, scoring of all interceptors was performed and reviewed as part of the Tier 0 evaluation in the Tiered Assessment Plan in order to select interceptors for the Tier 1 assessment. During the workshop, consequence of failure and likelihood of failure scores for the CCSD #1 interceptors were reviewed and confirmed with input from operations staff. The consequence of failure scores initially assigned by Jacobs staff for the Tri-City interceptors were also reviewed and revised. The likelihood of failure scoring for Tri-City assets was completed during the workshop based on WES staff knowledge. Based on the scoring and knowledge of WES staff, eleven interceptors or sections of interceptors were selected for Tier 1 condition assessment (as described in Section 6).

Condition assessments of various levels were performed on selected pump stations, force mains, and interceptors, and the results were incorporated into the risk scoring. The condition, external and internal physical factors affecting the asset, and O&M protocol categories were updated based on the data gathered during the condition assessment and scoring described in Section 6. The performance category scores were updated based on hydraulic modeling, where available.

7.3 Findings

The updated scores from the condition assessment and hydraulic modeling were compiled, and final asset risk scores were calculated for all WES conveyance assets. The final consequence of failure scores, likelihood of failure scores, and overall risk scores are provided in Appendix E.

The risk assessment resulted in the development of risk scores for locations in the system based on likelihood and consequence of failure. Likelihood of failure is mostly driven by either capacity or condition deficiencies. Those likelihood of failure elements of the risk analysis become a significant driver in creating and prioritizing projects given that overflows due to a capacity exceedance or structural failure create high risk and the timing of those potential overflows due to the deficiency significantly influences priority of recommended project improvements. While the risk scores generated were not used explicitly in the prioritization of projects, they can be considered in decisions regarding priority as more detailed capital improvement implementation plans are developed. Table 7-3 provides the overall risk scores for the existing assets that the projects and alternatives address.

Table 7-3. Risk Scores for Assets Addressed by Project Alternatives

Asset	Risk Score
Willamette Interceptor	69
West Linn Interceptor	66
Newell Creek Interceptor	43
Happy Valley Interceptor	42
Clackamas Interceptor	40
Mount Talbert Interceptor	37
Mount Scott Interceptor	32
Lower Phillips Interceptor	31
Country Village Interceptor	28
Intertie 2 Diversion Force Main	25
Oregon City Interceptor	21
Willamette Pump Station	21
Upper Phillips Interceptor	17
Willamette Force Main	17
Clackamas Force Main	17
Sieben Lane Pump Station	16
Lower Phillips Pump Station	12
Intertie 2 Pump Station	10
Intertie 1 Force Main	10
Clackamas Pump Station	9

Overall risk scores for the remaining WES assets are provided in Appendix E. Other assets that have high risk scores, but are not addressed by master plan projects, should be monitored.

During project development, capacity and condition issues were found to be the main drivers of projects. As a result, WES may consider revising the existing likelihood of failure criteria weighting to better reflect the actual drivers. Refining the risk score with higher weights on performance and physical condition is suggested for consideration to enhance the risk scoring process.

8. Alternatives Development and Evaluation

Section 8 describes the alternatives development and evaluation process for selecting master plan projects. Alternatives and projects were developed based on the results of the capacity, condition, and I/I reduction analyses and initially were evaluated against a set of screening criteria to eliminate and refine alternatives. The refined alternatives were further developed to provide sizing and cost estimates and the advantages and disadvantages of the alternatives were compared to support the selection of a preferred alternative(s).

8.1 Objectives

The objectives of the alternatives development and evaluation process are summarized as follows:

- Identify alternatives to mitigate unacceptable levels of risk, including correcting capacity and condition deficiencies through replacement, rehabilitation, and/or I/I reduction.
- Identify planning level sewer extension alignments.
- Refine alternatives to determine sizing and flow regimes.
- Provide capital and operations and maintenance cost estimates for alternatives.
- Evaluate alternatives, taking into account multiple risk attributes, to select operational and capital improvement projects for correcting deficiencies and reducing risk.

8.2 Methodology and Analysis

Based on the results of the capacity analysis, condition assessment, and cost-effective I/I reduction analysis, project alternatives were developed to address the deficiencies in the system. The alternatives initially were evaluated using a set of screening criteria and presented to WES, where some alternatives were eliminated. The remaining alternatives were refined to incorporate feedback from WES and include sizing and cost estimates.

8.2.1 Approach to Defining Improvements

Projects and alternatives were developed based on condition and capacity deficiencies. As documented in Section 5, the I/I analysis concluded that the cost-effective solution involves targeted 65 percent reduction of I/I by 2040 and discounts the cost of the age-based improvements required to maintain the system. The capacity analysis, as described in Section 4, assumes degradation of the I/I rate over time. The capacity assessment identified deficiencies in the following assets (as shown n Figure 4-4):

- Clackamas Interceptor
- Intertie 2 Pump Station
- Intertie 2 Force Main
- Jennifer Main
- Clackamas (Intertie 1) Pump Station
- Intertie 1 Force Main
- Willamette Pump Station
- Willamette Force Main
- West Linn Interceptor
- Willamette Interceptor
- Country Village Interceptor
- Newell Creek Interceptor
- Mount Scott Interceptor
- Happy Valley Interceptor
- Mount Talbert Interceptor
- Lower Phillips Pump Station

- Lower Phillips Interceptor
- Upper Phillips Interceptor
- Gladstone Pump Station

Additional projects were identified based on the results of the condition assessment. The condition assessment identified the following assets as requiring rehabilitation in either the far-term (5 to 10 years), near-term (1 to 5 years), or currently:

- Willamette Interceptor
- Oregon City Interceptor
- Country Village Interceptor
- Clackamas Interceptor

In addition to capacity and condition deficiencies, projects and alternatives were developed based on anticipated growth. The alternatives and projects were also compared against potential regulatory changes and ideas developed in previous analyses, such as work performed for Intertie 2, earlier master plans, and input from WES to ensure relevant projects or alternatives were not missed.

Capacity improvements are triggered by deficiencies identified for the 2040 land use conditions associated with peak wet weather flows based on the design storms, as documented in Section 3. Sizing of gravity infrastructure was identified for buildout capacity requirements as the gravity pipelines can have a life cycle of 80 to 100-years. Pump station and force main improvements were sized for 2040 peak wet weather flows.

8.2.2 Basis of Cost Estimates

Cost estimates were developed for the projects alternatives to compare alternatives and for planning. The cost estimates are AACEI Class 5 estimates with an accuracy range of +100% and -50%. Initially, costs were developed for the I/I cost-effective analysis, as discussed in Section 5 and in the *Cost Basis and Assumptions Technical Memorandum* in Appendix A, and were later refined for specific project alternatives. When the costs were revised for the refined project alternatives, a cost for rehabilitation of the Willamette Lagoon for storage was developed, with details provided in the Rehabilitation of Willamette Lagoon for Storage of Raw Sewage Technical Memorandum in Appendix A. The refined project alternatives cost estimates are provided in Appendix F.

Preliminary costs for additional treatment capacity and associated capital improvements were developed by WES for a peak wet weather flow of up to 108 mgd. All but one of the conveyance alternatives assume an estimated 2040 peak wet weather flow of 104.4 mgd at the Tri-City plant, which accounts for growth, I/I increases through degradation, and 65 percent I/I reduction resulting from rehabilitation in targeted basins. The capital cost of the treatment plant expansion for 104.4 mgd is $112 million and the O&M cost is $196 million. This treatment cost is not included in the cost estimates for alternatives because the cost is the same across all but one alternative. The West Linn/Willamette Alternative 2 includes storage that reduces the peak flow to the plant by 11 mgd, which results in a capital treatment plant cost of $90 million and an O&M cost of $178 million. In order to compare this alternative to the others, a credit has been shown for the reduced treatment costs. Treatment cost details are provided in Appendix A.

8.2.3 Alternatives Evaluation

Alternatives evaluation was conducted in a two-step process with an initial screening evaluation that was presented to WES in a workshop, followed by a revised comparison that incorporated feedback. The initial alternatives and projects that were developed were evaluated against a set of screening criteria, different from the risk scoring criteria in Section 7, to narrow down and refine the alternatives. The screening evaluation used the criteria from the 2009 CCSD #1 Master Plan and 2017 Hoodland Master Plan with a few minor modifications. The screening criteria and weighting is outlined in Table 8-1 with the modifications from the previous criteria noted.

Table 8-1. Alternatives Evaluation Screening Criteria and Weights

Criteria	Weight	Performance Measure Definition by Score		
		5	3	1
1. Financial - Effect on O&M	50	Reduces O&M Costs	No Change in O&M Costs	Increases O&M Costs
2. Financial - Source of Capital Funding	25	100% funded from nonrate revenues (outside sources or SDC funded)	Partial funding (25%-50%) from nonrate revenues and requires use of planned operating capital	All funded by rates
3. Human Resources	25	Internal expertise and staff are available, staff development and training are products of the project, opportunity to mentor junior staff, eliminates safety concerns	Combination of internal and external expertise required, partial availability of staff, minimal staff development opportunity, minor improvement in safety	Expertise must be obtained externally, staff are not available, no improvement in safety
4. Environmental	50	Significantly improves ability to comply with regulatory requirements, advances other efforts to protect natural environment or systems, routine permitting requirements, enhances resource protection	Slight improvement in ability to comply with regulatory requirements, no permanent damage to natural environment or some mitigation required, routine permitting requirements, minimal resource protection	No improvement in compliance with regulatory requirements, mitigation required for effects on natural environment, difficult permitting requirements, no additional resource protection
5. Implementation	25	Well-proven technology, simple application of technology and few components, good understanding of implementation conditions (e.g., geotechnical, public, community), operational certainty, little construction risk*	Moderately-proven technology, complex application of technology or many components, incomplete understanding of implementation conditions (e.g., geotechnical, public, community), uncertain operational results, some construction risk*	Unproven technology, complex application of technology and many components, poor understanding of implementation conditions (e.g., geotechnical, public, community), uncertain operational results, high construction risk*
6. Synergies	25	Meshes with other investments, results in partnering with other agencies,	No benefit from other investments, no partnering with other agencies, requires some construction on ODOT right-of-way*	Conflicts with other investments, discourages partnering with other agencies, requires major construction on ODOT right-of-way*
7. System Integrity	75	Increases system capacity, eliminates service disruptions, improves operational flexibility, 20+ years of usefulness, wide benefit to customers/ watersheds, provides information to fill gaps	No capacity improvement, reduces service disruptions, improves operational flexibility, 10-20 years of usefulness, small customer population/partial watersheds benefitted, no new information for data gaps	No capacity improvement, no impact on service disruptions or operational flexibility, 5 years or less of usefulness, few customers/partial watersheds benefitted, no new information for data gaps
8. Public/Social	50	High support from the community, supports economic development, no long-term community impacts, provides opportunity for public education, eliminates public health risks, minor or no traffic impacts*	Community neutral to the project, supports economic development, acceptable long-term community impacts, public education opportunity, reduces public health risks, some traffic impacts*	Community opposition to the project, does not support economic development, long-term community impacts, no public education opportunity, no effect on public health risks, major traffic impacts*

Table 8-1. Alternatives Evaluation Screening Criteria and Weights

Criteria	Weight	Performance Measure Definition by Score		
		5	3	1
9. **Risk Reduction Relative to Asset Failure**	50	For an asset with risk score greater than action level, project reduces risk below action level	Reduces risk for an asset but not below action level	Project does not reduce risk of existing asset OR addresses an asset with an acceptable risk

*Denotes phrase added to the criteria description used in the 2009 CCSD #1 Master Plan and 2017 Hoodland Master Plan

The scoring for each alternative is provided in Appendix G.

Based on the feedback and input from WES, alternatives were removed, added, and refined. The refined alternatives and projects were developed in more detail to provide sizing and cost estimates. For project areas with multiple alternatives remaining, a comparison of project components and advantages and disadvantages was prepared to aid in selecting a preferred alternative(s).

Pipe data, pump station system curves, pipeline profiles used in the development and review of the alternatives, as well as specific cost estimates, are provided in Appendix F.

8.2.3.1 Clackamas/Intertie 1/Intertie 2

Clackamas/Intertie 1/Intertie 2 Initial Alternatives. The Clackamas/Intertie 1/Intertie 2 alternatives address the Clackamas interceptor deficiencies, and the needed capacity increases for Intertie pumping and conveyance from the intertie pump station(s) to the Tri-City WRRF. Specifically, the alternatives address capacity deficiencies and condition issues in the Clackamas Interceptor, a short segment of the Mount Scott Interceptor from the Clackamas Interceptor to the Intertie 2 Pump Station, Intertie 2 Pump Station, Intertie 2 Force Main, Jennifer Main, Clackamas (Intertie 1) Pump Station, and Intertie 1 Force Main.

Initially, three alternatives for this area were developed, as shown on Figure 8-1:

- Alternative 1 maintains the existing flow pattern by upsizing the entire length of the Clackamas Interceptor, improves Intertie 2 Pump Station and Intertie 2 Force Main, upsizes Jennifer Main, and improves Clackamas Pump Station.
- Alternative 2 diverts all the flow from upper and middle Clackamas Interceptor to the Clackamas Pump Station with a gravity lines near SE Evelyn Street. This involves upsizing the upper and middle Clackamas Interceptor, lining the lower Clackamas Interceptor based on condition issues, installing a new gravity main at SE Evelyn Street, replacing Clackamas Pump Station, upsizing Intertie 1 Force Main, improving Intertie 2 Pump Station and Intertie 2 Force Main, and upsizing Jennifer Main to the Clackamas Pump Station.
- Alternative 3 diverts all the flow from the upper Clackamas Interceptor to Jennifer Main with a new gravity line near SE 130th Avenue. Alternative 3 upsizes the upper Clackamas, lines the lower Clackamas Interceptor, installs a new gravity line from the Clackamas Interceptor to Jennifer Main, replaces the Clackamas Pump Station, upsizes Intertie 1 Force Main, improves Intertie 2 Pump Station and Intertie 2 Force Main, and upsizes Jennifer Main to the Clackamas Pump Station.

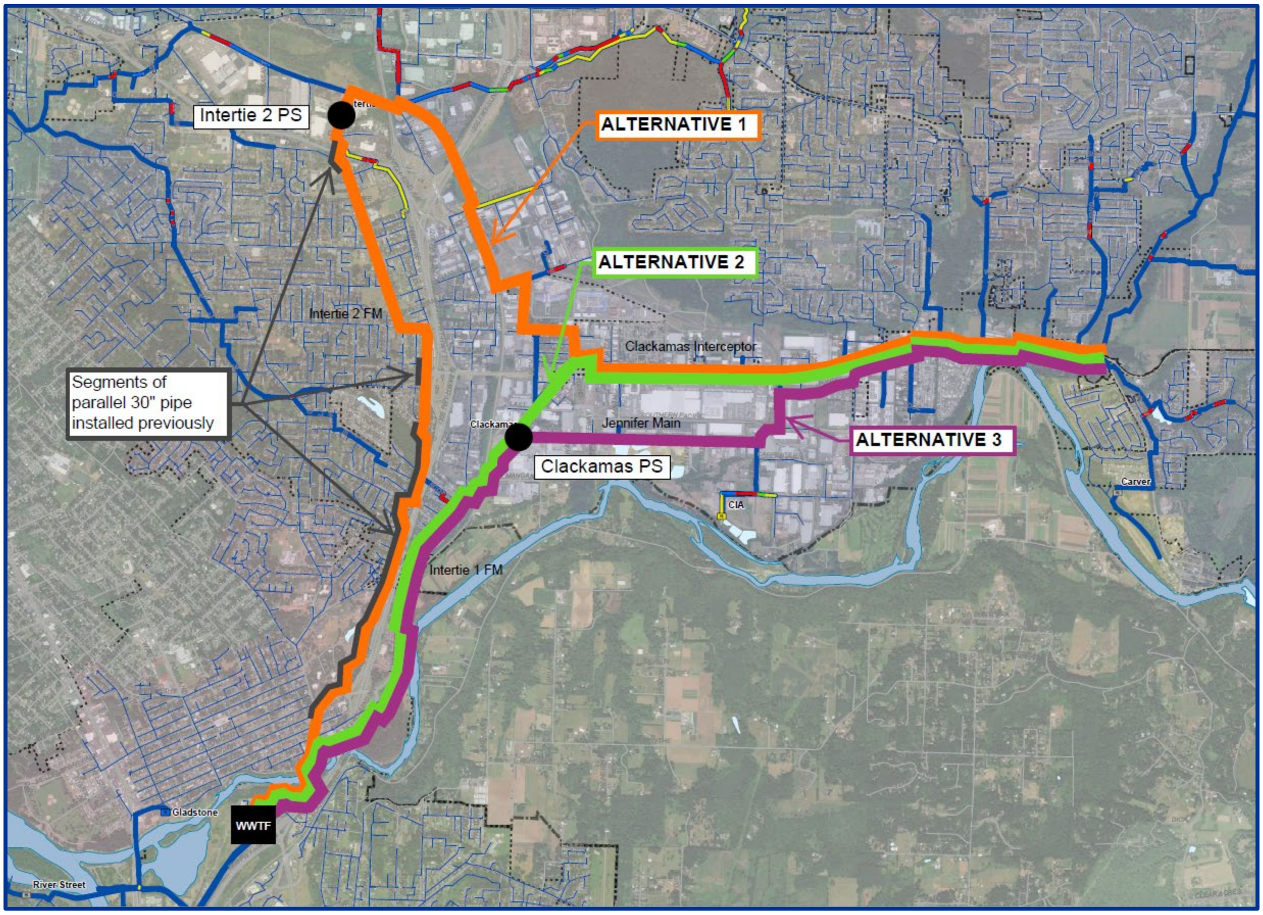


Figure 8-1. Clackamas/Intertie 1/Intertie 2 Initial Alternatives

The three alternatives were evaluated against the screening criteria. Alternative 1 received the lowest score of 57 primarily due to the environmental impacts of constructing in the wetland area for the lower Clackamas Interceptor and more work in the ODOT ROW that requires coordination. Alternative 2 scored 60 due to the larger pump stations that require more maintenance; more construction risk and complexity due to the new pump stations and new force main, work in busy roads, and the lining of the lower Clackamas Interceptor; and more work in the ODOT ROW; however, Alternative 2 would increase flexibility with the potential to divert flow back to Intertie 2 instead of Clackamas Pump Station. Alternative 3 received the highest score of 68 due to increased flexibility with potential to divert flow back to Intertie 2 and fewer public and social impacts due to traffic, although, similar to Alternative 2, Alternative 3 has larger pump stations and more construction risk and complexity due to the new pump stations and new force main, work in busy roads, and the lining of the lower Clackamas Interceptor. In an initial cost comparison evaluation, it was determined that Alternatives 1 and 2 would be similar in cost and Alternative 3 would have a lower cost due to combining the Clackamas Interceptor flow with Jennifer Main. Additional details of the screening evaluation and scoring can be found in Appendix G.

The alternatives and screening evaluation were reviewed with WES in a workshop in April 2018. WES staff agreed that the differences between Alternatives 2 and 3 were more of a routing decision and Alternative 3 was preferred because it would relieve the surcharge of the CIA Pump Station. Therefore, Alternative 2 was eliminated. During the workshop, an additional alternative, Alternative 4, was created that diverts flow from the upper Clackamas Interceptor to Jennifer Main, then at the Clackamas Pump Station, a new force main would cross I-205 and connect to the Intertie 2 Force Main to use more of the secondary Intertie 2 Force Main pipe that has already been installed. Alternatives 1, 3, and 4 were carried forward for additional analysis.

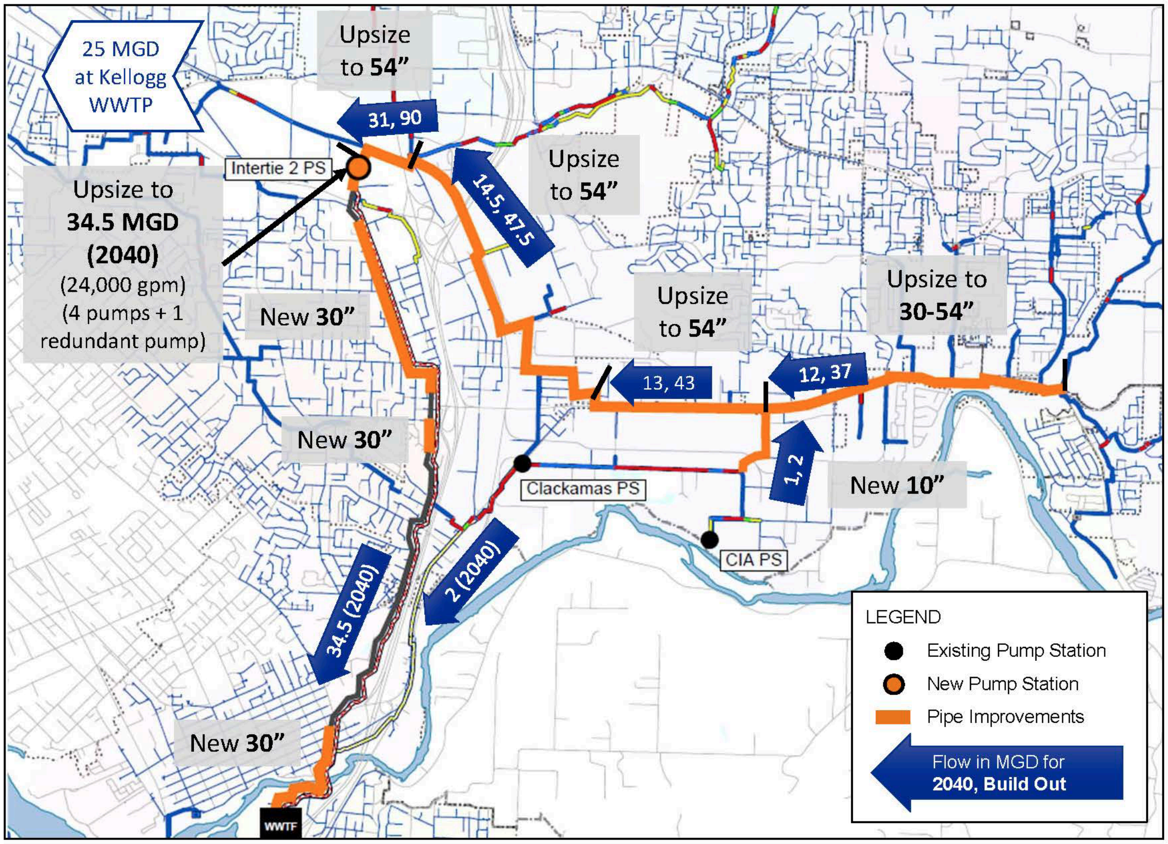
Clackamas/Intertie 1/Intertie 2 Refined Alternatives. Alternatives 1, 3, and 4 were further developed to identify sizing of improvements, timing, and cost estimates. The alternatives all assume that flow would be diverted or I/I reduced to limit peak flow at the Kellogg plant to 25 mgd. Improvements are triggered by deficiencies identified for 2040 and gravity pipeline improvements are based on buildout flows, while pump station and force main sizing is based on the 2040 peak wet weather flows.

Alternative 1 – Clackamas to Intertie 2. Alternative 1 conveys most of the flow through the Clackamas Interceptor and Intertie 2 Force Mains and consists of the components listed on Figure 8-2. The costs for each component of Alternative 1 are provided in Table 8-2.

Table 8-2. Costs for Alternative 1 – Clackamas to Intertie 2

Infrastructure	Capital ($M)	O&M ($M)
Clackamas Interceptor, Upper	$10.4	$0
Clackamas Interceptor, Middle	$11.6	$0
Clackamas Interceptor, Lower and Mount Scott	$12.6	$0
Jennifer Main	$0	$0
CIA FM Extension	$0.4	$0
Clackamas Diversion, Gravity Clackamas to Jennifer	$0	$0
Clackamas (Intertie 1) Pump Station	$0	$2.3
Intertie 2 Pump Station	$10.8	$9.7
Intertie 1 Force Main	$0	$0
Intertie 2 Force Main	$9.4	$0
Three Creeks Hydraulic Modification	$0.3	$0
SUBTOTAL	**$55.4**	**$12.0**
TOTAL PRESENT WORTH	***$67.4***	

Alternative 1 is considered the simplest for operation and addresses both required condition and capacity improvements in the lower Clackamas Interceptor. Alternative 1 also allows for the greatest flexibility in construction phasing because construction of the middle and lower sections of the Interceptor can be delayed beyond the 2020 timeframe. However, this alternative has less system redundancy, the least overall force main capacity, and construction requires open-cut trenching through the wetland area for Clackamas Interceptor. This alternative also involves upsizing the existing 36-inch casing to a 72-inch casing under the Union Pacific Railroad (UPRR) for the new 54-inch Lower Clackamas Interceptor pipe, which requires a hydraulic analysis to confirm capacity due to the flat slope.



Alternative 1 – *Clackamas to Intertie 2*

PROJECT COMPONENTS

- Upsize Upper Clackamas Interceptor to 30-54"
- Upsize Middle Clackamas Interceptor to 54"
- Upsize Lower Clackamas Interceptor to 54" (including new 72" casing bored under UPRR)
- Upsize Mt. Scott Interceptor to 54"
- Increase Intertie 2 PS to 34.5 MGD at 185 feet TDH
- Complete and use 30" Intertie 2 FM segments
- Use existing 20" Intertie 2 FM
- Divert CIA PS to Clackamas Interceptor by extending 10" CIA FM
- Use existing Jennifer Trunk
- Use existing Clackamas (Intertie 1) PS
- Use existing Intertie 1 FM
- Three Creeks hydraulic modifications

COST ESTIMATE

Infrastructure	Capital ($M)	O&M ($M)
Alternative 1 Improvements	$55.4	$12.0
Total Present Worth	**$67.4**	

Figure 8-2. Clackamas/Intertie 1/Intertie 2 Alternative 1

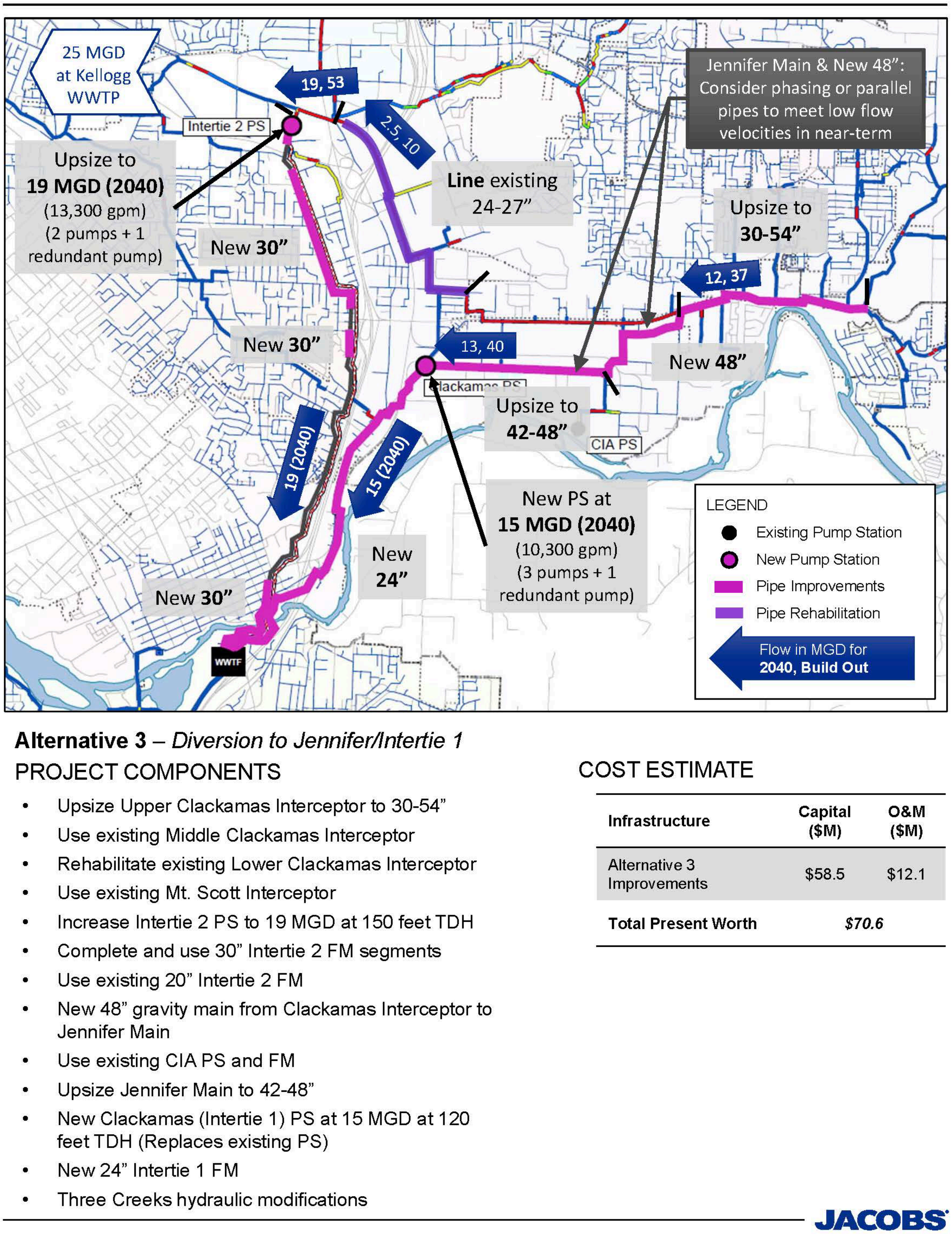
Alternative 3 – Full Diversion to Jennifer Main and Intertie 1. Alternative 3 diverts all flow from the upper Clackamas Interceptor through an upsized Jennifer Main and Intertie 1 Force Main, and includes the components listed on Figure 8-3. The costs for each component of Alternative 3 are provided in Table 8-3.

Table 8-3. Costs for Alternative 3 – Full Diversion to Jennifer Main and Intertie 1

Infrastructure	Capital ($M)	O&M ($M)
Clackamas Interceptor, Upper	$7.5	$0
Clackamas Interceptor, Middle	$0	$0
Clackamas Interceptor, Lower (Rehab)	$5.9	$0
Jennifer Main	$6.6	$0
CIA Force Main Extension	$0	$0
Clackamas Diversion, Gravity Clackamas to Jennifer	$5.3	$0
Clackamas (Intertie 1) Pump Station	$10.3	$4.9
Intertie 2 Pump Station	$4.9	$7.2
Intertie 1 Force Main	$7.7	$0
Existing 12” Intertie 1 Force Main (Convert segment to gravity)	$0.6	$0
Intertie 2 Force Main	$9.4	$0
Three Creeks Hydraulic Modification	$0.3	$0
SUBTOTAL	**$58.5**	**$12.1**
TOTAL PRESENT WORTH	***$70.6***	

Alternative 3 has greater system redundancy, reduces the Intertie 2 Pump Station improvements long-term, and has flexibility for shifting flows post-2040 with the larger third force main. Alternative 3 also has less transient risk and allows a section of the existing 12-inch Intertie 1 Force Main to be converted to gravity to honor the agreement with Edgewater. This alternative has the most force main capacity, however, there are potential space and bridge loading constraints on the pedestrian bridge and has permitting challenges if HDD is required under the Clackamas River instead of using the pedestrian bridge. Alternative 3 also has less opportunity for phasing of improvements and requires operation of two large pump stations.

A modification to Alternative 3 is for the new Intertie 1 force main to be upsized to 30 inches and cross over to connect to the existing 20-inch Intertie 2 force main using the existing I-205 crossing north of the I-205 bridge over the Clackamas River (about 3,000-3,500 feet upstream from the Tri-City WRRF). This modification reduces the number of pipes across the Clackamas River pedestrian bridge to just the 20-inch and 30-inch Intertie 2 force mains.



Alternative 3 – *Diversion to Jennifer/Intertie 1*

PROJECT COMPONENTS

- Upsize Upper Clackamas Interceptor to 30-54"
- Use existing Middle Clackamas Interceptor
- Rehabilitate existing Lower Clackamas Interceptor
- Use existing Mt. Scott Interceptor
- Increase Intertie 2 PS to 19 MGD at 150 feet TDH
- Complete and use 30" Intertie 2 FM segments
- Use existing 20" Intertie 2 FM
- New 48" gravity main from Clackamas Interceptor to Jennifer Main
- Use existing CIA PS and FM
- Upsize Jennifer Main to 42-48"
- New Clackamas (Intertie 1) PS at 15 MGD at 120 feet TDH (Replaces existing PS)
- New 24" Intertie 1 FM
- Three Creeks hydraulic modifications

COST ESTIMATE

Infrastructure	Capital ($M)	O&M ($M)
Alternative 3 Improvements	$58.5	$12.1
Total Present Worth	***$70.6***	

JACOBS

Figure 8-3. Clackamas/Intertie 1/Intertie 2 Alternative 3

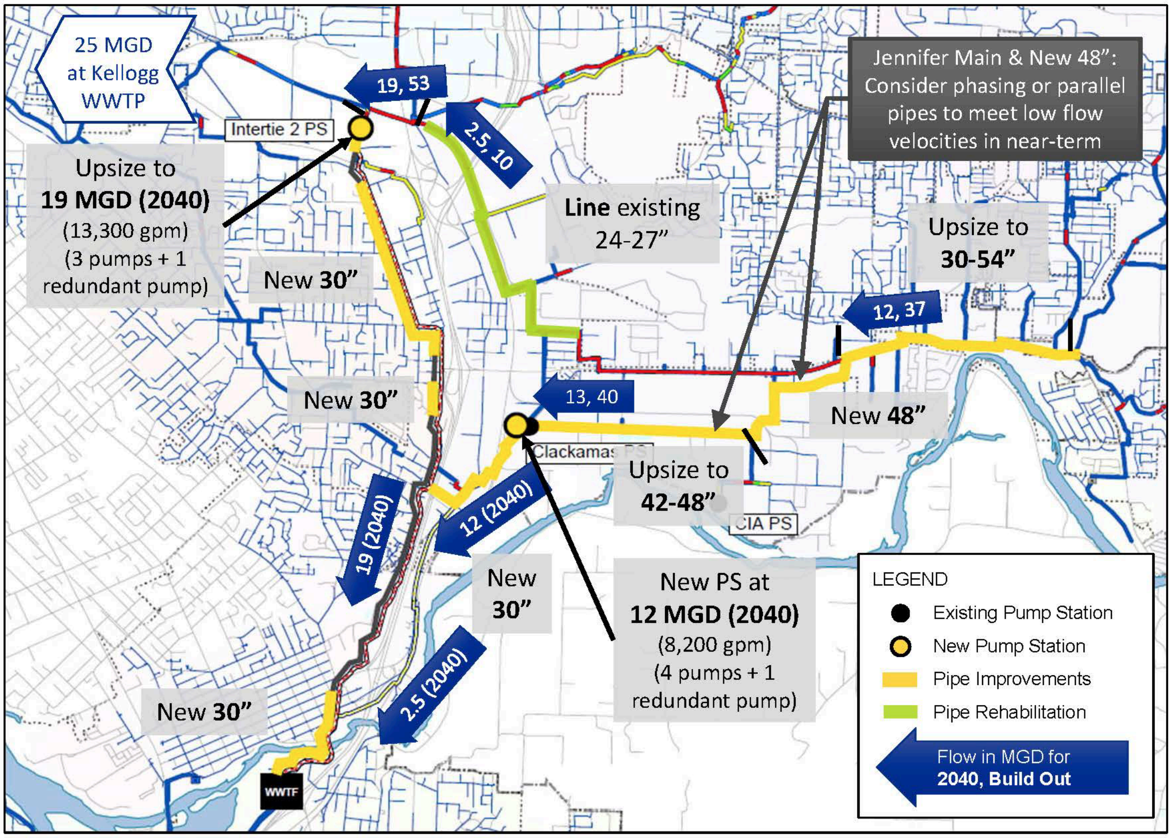
Alternative 4 – Full Diversion to Jennifer Main and Intertie 2. Alternative 4 diverts all flow from the upper Clackamas Interceptor through Jennifer Main and crosses over to connect to the 20-inch Intertie 2

Force Main. Alternative 4 includes the components listed on Figure 8-4. The costs for each component of Alternative 4 are provided in Table 8-4.

Table 8-4. Costs for Alternative 4 – Full Diversion to Jennifer Main and Intertie 2

Infrastructure	Capital ($M)	O&M ($M)
Clackamas Interceptor, Upper	$7.5	$0
Clackamas Interceptor, Middle	$0	$0
Clackamas Interceptor, Lower (Rehab)	$5.9	$0
Jennifer Main	$6.6	$0
CIA FM Extension	$0	$0
Clackamas Diversion, Gravity Clackamas to Jennifer	$5.3	$0
Clackamas (Intertie 1) Pump Station	$8.2	$7.1
Intertie 2 Pump Station	$4.9	$7.2
Intertie 1 Force Main	$8.6	$0
Intertie 2 Force Main	$9.4	$0
Three Creeks Hydraulic Modification	$0.3	$0
SUBTOTAL	**$56.7**	**$14.3**
TOTAL PRESENT WORTH	***$71.0***	

Alternative 4 has greater system redundancy, reduces the Intertie 2 Pump Station improvements over the long-term, and simpler permitting is expected. However, Alternative 4 has velocities of 8.5 fps in the 20-inch Intertie 2 Force Main, requiring a surge analysis. It also requires operation of three pump stations, including Intertie 2 Pump Station, the existing Clackamas Pump Station, and a new 12-mgd pump station on the Clackamas Pump Station site.



Alternative 4 – *Diversion to Jennifer/Intertie 2*

PROJECT COMPONENTS

- Upsize Upper Clackamas Interceptor to 30-54"
- Use existing Middle Clackamas Interceptor
- Line existing Lower Clackamas Interceptor
- Use existing Mt. Scott Interceptor
- Increase Intertie 2 PS to 19 MGD at 185 feet TDH
- Complete Intertie 2 30" FM segments
- New 48" gravity main from Clackamas Interceptor to Jennifer Main
- Use existing CIA PS and FM
- Upsize Jennifer Main to 42-48"
- Use existing Clackamas (Intertie 1) PS & FM
- New second Clackamas (Intertie 1) PS at 12 MGD at 145 feet TDH
- New 30" FM from Clackamas PS to the 20" Intertie 2 FM (using Manfield Ct) and use lower segment of 20" existing Intertie 2 FM
- Three Creeks hydraulic modifications

COST ESTIMATE

Infrastructure	Capital ($M)	O&M ($M)
Alternative 4 Improvements	$56.7	$14.3
Total Present Worth	***$71.0***	

Figure 8-4. Clackamas/Intertie 1/Intertie 2 Alternative 4

Comparison of Clackamas/Intertie 1/Intertie 2 Alternatives.

Table 8-5 outlines the proposed improvements by individual asset, a summary of assets, and other project elements for each alternative.

Table 8-5. Alternatives Components for Clackamas/Intertie 1/Intertie 2 Area

Components	Alt 1 – Clackamas Interceptor to Intertie 2	Alt 3 – Full Diversion to Jennifer and Intertie 1	Alt 4 – Full Diversion to Jennifer and Intertie 2
Individual Asset Improvements			
Upper Clackamas Interceptor	Upsize to 30-54”	Upsize to 30-54”	Upsize to 30-54”
Middle Clackamas Interceptor	Upsize to 54”	Use existing	Use existing
Lower Clackamas Interceptor	Upsize to 54”	Rehabilitate	Rehabilitate
Mount Scott Interceptor (Clackamas to Intertie 2)	Upsize to 54”	Use existing	Use existing
Intertie 2 Pump Station	Increase to 34.5 mgd	Increase to 19 mgd	Increase to 19 mgd
Intertie 2 20” Force Main	Use existing	Use existing	Use lower 10,605 LF of existing force main
Intertie 2 30” Force Main	Install 13,130 LF to complete force main	Install 13,130 LF to complete force main	Install 13,130 LF to complete force main
CIA Force Main Extension to Clackamas Interceptor	1,470 LF of 10” force main	N/A	N/A
New Gravity Main (Clackamas to Jennifer)	N/A	4,740 LF of 48” gravity main	4,740 LF of 48” gravity main
Jennifer Main	Use existing	Upsize to 42-48”	Upsize to 42-48”
Clackamas Pump Station	Use existing	Replace with new 15-mgd PS	Use existing and add a new 12-mgd PS on site
Intertie 1 Force Main	Use existing	Convert segment to gravity for Edgewater and abandon the rest	Use existing
New Intertie 1 Force Main	N/A	13,300 LF of 24” force main (Clackamas Pump Station to WRRF)	3,870 LF of 30” force main (Clackamas Pump Station to 20” Intertie 2 force main)
Three Creeks	Hydraulic modifications	Hydraulic modifications	Hydraulic modifications
Asset Summary			
Length of Gravity Main in Operation	26,245 ft – New 6,145 ft – Existing 0 ft – Rehab 32,390 ft – Total	19,450 ft – New 11,505 ft – Existing 6,180 ft – Rehab 37,135 ft – Total	19,450 ft – New 11,505 ft – Existing 6,180 ft – Rehab 37,135 ft – Total
Length of Force Main in Operation	14,595 ft – New 42,595 ft – Existing 57,190 ft – Total	26,430 ft – New 29,295 ft – Existing 55,725 ft – Total	17,000 ft – New 31,990 ft – Existing 48,990 ft – Total
Number of Pump Stations	1 Upgrade (Intertie 2) + 1 Existing (Clackamas)	1 Upgrade (Intertie 2) + 1 New (Clackamas)	1 Upgrade (Intertie 2) + 1 New (Clackamas) + 1 Existing (Clackamas

Table 8-5. Alternatives Components for Clackamas/Intertie 1/Intertie 2 Area

Components	Alt 1 – Clackamas Interceptor to Intertie 2	Alt 3 – Full Diversion to Jennifer and Intertie 1	Alt 4 – Full Diversion to Jennifer and Intertie 2
Project Details			
Permitting	Construction through wetland area and upsizing railroad crossing	Potential HDD under Clackamas River if pedestrian bridge cannot be used	Boring under I-205
Coordination with Agencies	ODOT, UPRR, EPA		ODOT
Conveyance Capital Cost ($M)	$55.4	$58.5	$56.7
Conveyance O&M PW Cost ($M)	$12.0	$12.1	$14.3
Total PW Cost ($M)	$67.4	$70.6	$71.0

Table 8-6 compares the alternatives and summarizes the advantages and disadvantages of each.

Table 8-6. Comparison of Alternative Characteristics for Clackamas/Intertie 1/Intertie 2 Area

Category	Alt 1 – Clackamas Interceptor to Intertie 2	Alt 3 – Full Diversion to Jennifer and Intertie 1	Alt 4 – Full Diversion to Jennifer and Intertie 2
Opportunities for Phasing of Improvements	More opportunities for construction phasing	Less opportunity for construction phasing	Less opportunity for construction phasing
System Redundancy	Less system redundancy due to greater reliance on Intertie 2 Pump Station	Greater system redundancy since capacity is dispersed	Greater system redundancy since capacity is dispersed
System Flexibility	Less system flexibility due to reliance on Intertie 2	More flexibility for shifting flows post-2040 with larger third force main	Moderate system flexibility
Capacity	Less force main capacity	Greatest force main capacity	Less force main capacity
Operational Simplicity	O&M staff consider this simplest for operation	Operation of two large pump stations	Operation of three pump stations
Flow Velocities	Velocities within design range	Velocities within design range	High velocities (slightly exceed design velocities) in existing 20” Intertie 2 FM
Transient Risk	Transient risk related to long force mains with high head pumps	Less transient risk due to lower head pumps	Transient risk related to long force mains with high head pumps
Stranded Assets	Strands some previously installed casings for new Intertie 1 FM	Strands existing 12” Intertie 1 FM	Strands some previously installed casings for new Intertie 1 FM and part of 20-inch Intertie 2 FM
Construction Issues	Requires upsizing of lower Clackamas Interceptor casing under UPRR and confirmation of hydraulics; access restrictions in middle Clackamas Interceptor due to proximity to ROW and 60-inch storm pipe above sewer	Access restrictions to Jennifer Main due to storm, sewer, and gas utilities	Access restrictions to Jennifer Main due to storm, sewer, and gas utilities

Table 8-6. Comparison of Alternative Characteristics for Clackamas/Intertie 1/Intertie 2 Area

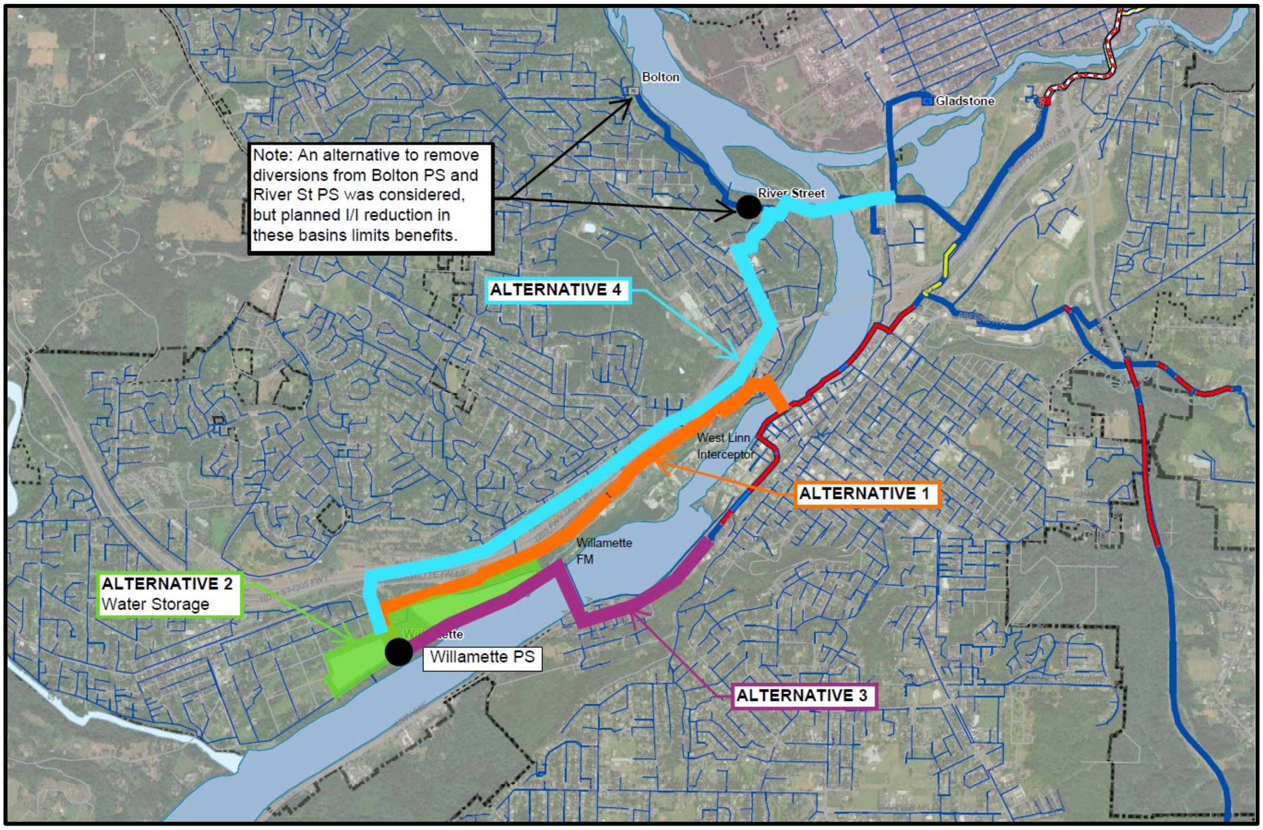
Category	Alt 1 – Clackamas Interceptor to Intertie 2	Alt 3 – Full Diversion to Jennifer and Intertie 1	Alt 4 – Full Diversion to Jennifer and Intertie 2
Permitting	Requires construction through wetland area and upsizing of casing under UPRR	Challenges if HDD is required under Clackamas River (if pedestrian bridge cannot be used)	Requires ODOT permit to bore under I-205
Bypass Pumping	Longer duration of bypass pumping required	Shorter duration of bypass pumping required	Shorter duration of bypass pumping required
Intertie 2 Pump Station Improvements	Largest increase in capacity for Intertie 2 Pump Station	Reduces Intertie 2 Pump Station improvements long-term	Reduces Intertie 2 Pump Station improvements long-term
Existing Clackamas Pump Station Site	No impact	Requires siting study for replacing the existing Clackamas Pump Station	Requires a siting study for further expansion of the existing decant facility to ensure space for additional Pump Station is available
Addressing Condition-Based Improvements	Addresses condition and capacity in the lower Clackamas Interceptor	Rehabilitation is required to address condition in lower Clackamas Interceptor	Rehabilitation is required to address condition in lower Clackamas Interceptor
Potential Spacing and Loading Constraints on Clackamas River Pedestrian Bridge	Smaller loading on bridge with addition of 30” FM to the bridge	Largest loading on bridge due to replacement of 12” FM with 24” FM and addition of 30” FM on the bridge	Smaller loading on bridge with addition of 30” FM to the bridge
Edgewater Commitment	Does not trigger Edgewater FM conversion (12” Intertie 1 FM is not abandoned)	Existing 12” Intertie 1 force main is abandoned and segment can be converted to gravity for Edgewater	Does not trigger Edgewater FM conversion (12” Intertie 1 FM is not abandoned)

8.2.3.2 West Linn/Willamette

The West Linn/Willamette alternatives initially were evaluated as two separate systems, but later combined because of the interaction between the Willamette Pump Station and the downstream gravity system.

West Linn Interceptor and Willamette Force Main Initial Alternatives. The West Linn Interceptor and Willamette Force Main alternatives address capacity deficiencies in the Willamette Pump Station, Willamette Force Main, and West Linn Interceptor. The following four alternatives were developed for the West Linn Interceptor and Willamette Force Main area, as shown on Figure 8-5:

- Alternative 1 maintains the existing flow pattern and involves upsizing the Willamette Pump Station, upsizing or installing a parallel West Linn Interceptor in the existing alignment, and upsizing the Willamette Force Main.
- Alternative 2 stores peak flow in a storage pond at the Blue Heron site. Alternative 2 includes a 4-million-gallon storage pond at the existing WES-owned pond near Willamette Pump Station, which reduces the peak flow and avoids improvements to the Willamette Pump Station, Willamette Force Main, and West Linn Interceptor.
- Alternative 3 routes flow across the river in a different alignment using the Blue Heron piping. Alternative 3 uses a new force main from Willamette Pump Station, employing the existing Blue Heron piping if possible, and connecting to the upper end of the Willamette Interceptor.
- Alternative 4 routes flow in a new alignment to River Street Pump Station. Alternative 4 upsizes the Willamette Pump Station, installs a new force main to River Street Pump Station, and crosses the river in a new force main parallel to the River Street and Bolton force mains to connect to the Oregon City Interceptor.



Note: An alternative to remove diversions from Bolton PS and River St PS was considered, but planned I/I reduction in these basins limits benefits.

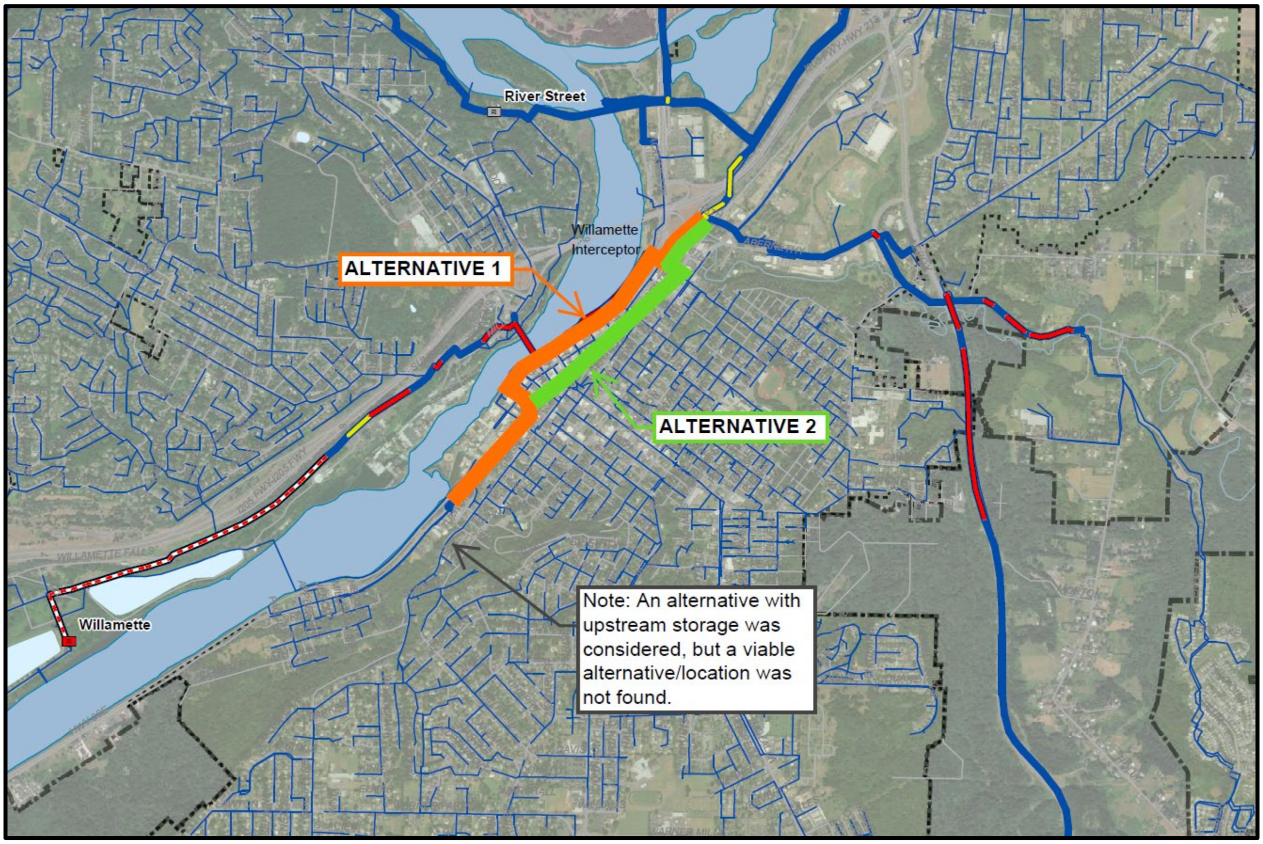
Figure 8-5. West Linn Interceptor and Willamette Force Main Initial Alternatives

When evaluated against the screening criteria, Alternative 1 scored the lowest of all alternatives with a score of 49. The primary reasons for this low score were construction risk and traffic impacts of the work required on the Oregon City bridge and the coordination required with ODOT. Alternatives 2 and 4 tied with scores of 55. Alternative 2 would require more operation and maintenance time, greater potential safety concerns, and complex environmental permitting for the storage pond. Additionally, Alternative 2 would pose some construction risk for the pond and greater potential for overflows. However, Alternative 2 would have operational flexibility with the storage pond and no traffic impacts. Alternative 4 would pose complex environmental permitting and construction risk for the river crossing and public and traffic impacts for more piping roadways along the new alignment. However, Alternative 4 would also have system flexibility with the use of existing piping. Alternative 3 received the highest score of 65 because of the system flexibility, the use of existing piping, and fewer public and traffic impacts. However, Alternative 3 would require complex environmental permitting for the river crossing and construction risk with the use of existing piping for the river crossing. Initial cost comparisons determined that Alternative 1 would cost the least and Alternatives 2, 3, and 4 would be similar in cost. Additional details of the screening evaluation and scoring can be found in Appendix G.

Following review of the alternatives with WES staff, Alternatives 2, 3, and 4 were selected for further analysis. Alternative 1 was eliminated because the construction on the Oregon City bridge was determined to be infeasible. WES staff suggested modifying Alternative 4 to pump from the Willamette Pump Station, cross the river near the I-205 crossing, and connect to the lower Willamette Interceptor, thereby creating the potential for additional redundancy with the Bolton and River Street force main crossings.

Willamette Interceptor Initial Alternatives. The Willamette Interceptor alternatives address capacity deficiencies and condition issues in the upper Willamette Interceptor. The following two alternatives were created for the Willamette Interceptor and are shown on Figure 8-6:

- Alternative 1 would upsize the Willamette Interceptor and generally following the existing alignment; however, the pipe would be moved to McLoughlin Boulevard for segments where the existing pipe is on the seawall.
- Alternative 2 would upsize the upper segment of the Willamette Interceptor, then install new piping to divert flow around the seawall section. The new pipe could follow Center Street or an alternate alignment. Alternative 2 would also involve lining or upsizing the existing Willamette Interceptor for the seawall segment depending on the flow pattern from the West Linn Interceptor.



Note: An alternative with upstream storage was considered, but a viable alternative/location was not found.

Figure 8-6. Willamette Interceptor Initial Alternatives

Using the screening criteria, Alternative 1 received the lowest score of 52 due to required coordination with ODOT and traffic impacts related to the construction in SE McLoughlin Blvd. Alternative 2 scored highest at 60 due to required coordination with Oregon City and traffic impacts; however, this alternative would have more operational flexibility. Alternative 2 was expected to cost more than Alternative 1. Additional details of the screening evaluation and scoring can be found in Appendix G.

WES staff elected to move forward with further analysis of Alternative 1 for the upper Willamette Interceptor. Because only one alternative was selected for this segment, it was integrated into the three alternatives for the West Linn Interceptor and Willamette Force Main area.

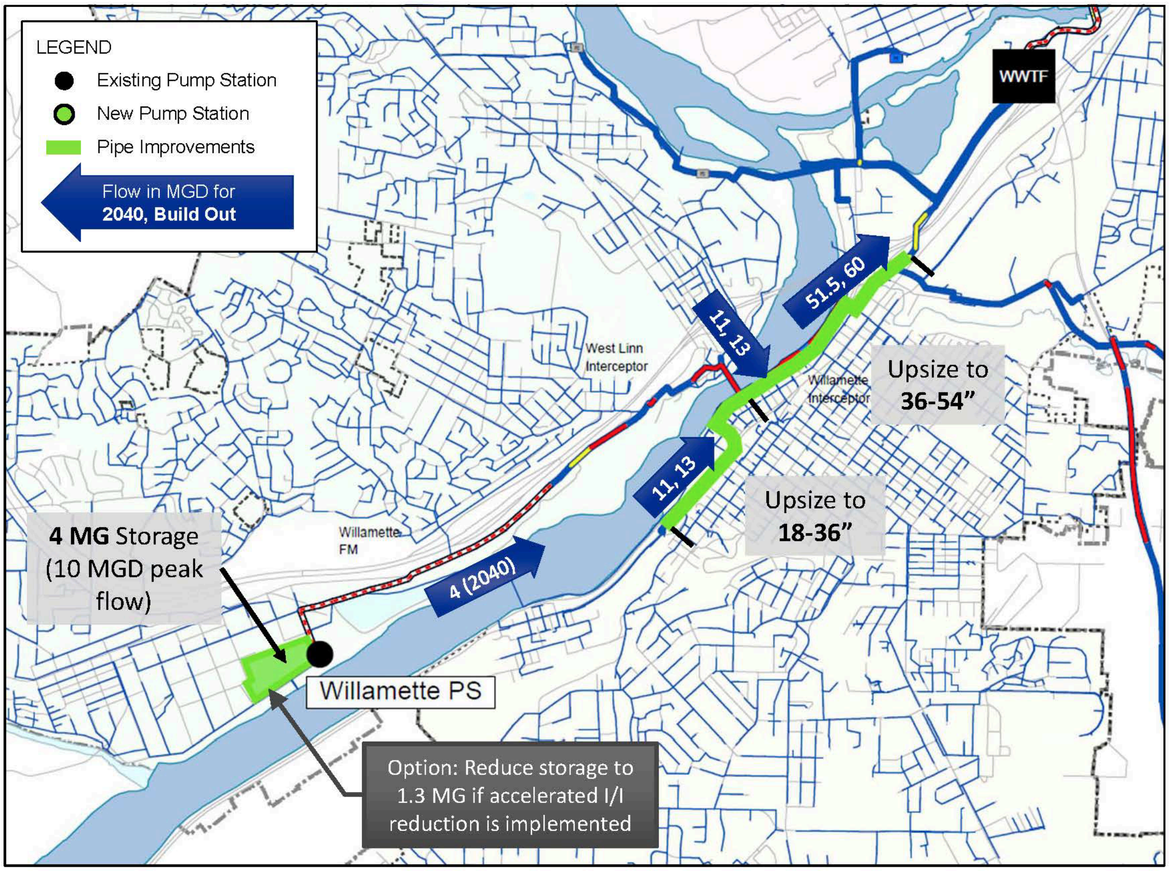
West Linn/Willamette Refined Alternatives. With the integration of the Willamette Interceptor, Alternatives 2, 3, and 4 were further developed to identify sizing of improvements, timing, and cost estimates.

Alternative 2 – Storage. In Alternative 2, during a peak flow event, water would be stored in a 4-million-gallon pond near the Willamette Pump Station to shave flow peaks and reduce the size of downstream conveyance and treatment plant improvements. Alternative 2 consists of the components listed on Figure 8-7. The costs for each component of Alternative 2 are provided in Table 8-7.

Table 8-7. Costs for Alternative 2 – Storage for West Linn/Willamette Area

Infrastructure	Capital ($M)	O&M ($M)
Existing Willamette Pump Station	$0	$2.8
New Willamette Pump Station	$0	$0
Storage Pond	$32.7	$4.3
Existing Willamette Force Main	$0	$0
Parallel Willamette Force Main	$0	$0
West Linn Interceptor	$0	$0
Willamette Interceptor, Upper	$2.3	$0
Willamette Interceptor, Middle	$2.4	$0
SUBTOTAL	**$37.3**	**$7.1**
Cost Savings for Reduced Treatment Plant Improvements	-$22	-$18
TOTAL	**$15.3**	**-$10.9**
TOTAL PRESENT WORTH	***$4.4***	

Alternative 2 reduces the peak flow to the Tri-City WRRF and therefore reduces the treatment costs, uses an existing asset, provides a buffer for variable timing of I/I reduction and effectiveness, and does not preclude implementation of other downstream solutions. However, this alternative would have permitting, , stakeholder, operations and maintenance, and odor control challenges associated with the pond. Additionally, the pond is mapped in the 100-year floodplain, which would complicate permitting.



Alternative 2 – *Storage*

PROJECT COMPONENTS

- Maintain existing Willamette PS
- Use existing Willamette FM
- Retrofit of pond for storage of 4 million gallons of raw sewage (eliminates 11 MGD peak flow) (Storage can be reduced for Build Out flows) – Includes sludge removal and rehabilitation of existing open pond
- Use existing West Linn Interceptor
- Upsize Upper Willamette Interceptor to 18-36”
- Upsize Middle Willamette Interceptor to 36-54”

COST ESTIMATE

Infrastructure	Capital ($M)	O&M ($M)
Alternative 2 Improvements	$37.3	$7.1
Cost Savings for Reduced Treatment Plant Improvements	-$22	-$18
Total Present Worth	***$4.4***	

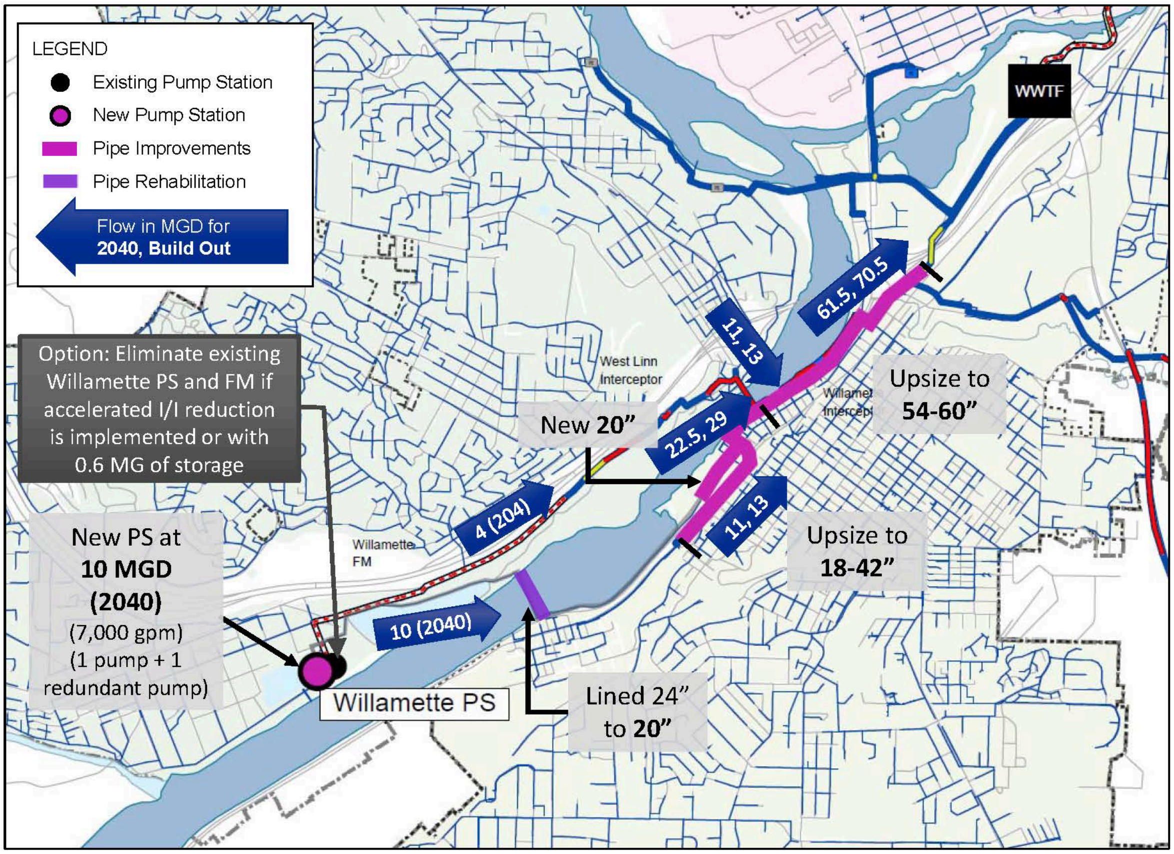
Figure 8-7. West Linn/Willamette Alternative 2

Alternative 3 – Blue Heron Alignment. Alternative 3 uses the existing Blue Heron piping as an additional force main and river crossing and includes the components listed on Figure 8-8. The costs for each component of Alternative 3 are provided in Table 8-8.

Table 8-8. Costs for Alternative 3 – Blue Heron Alignment for West Linn/ Willamette Area

Infrastructure	Capital ($M)	O&M ($M)
Existing Willamette Pump Station	$0	$2.8
New Willamette Pump Station	$8.2	$3.4
Storage	$0	$0
Existing Willamette FM	$0	$0
Blue Heron FM Lining and Extension	$2.8	$0
West Linn Interceptor	$0	$0
Willamette Interceptor, Upper	$2.2	$0
Willamette Interceptor, Middle	$8.3	$0
SUBTOTAL	**$21.5**	**$6.2**
TOTAL PRESENT WORTH	***$27.7***	

Alternative 3 would use the existing Blue Heron infrastructure, but the condition of the pipe segments upstream and downstream of the river need to be verified. Alternative 3 would have the lowest total dynamic head pumping conditions, would create a redundant river crossing, and would include the ability to eliminate the existing Willamette Pump Station and Force Main in the future. This alternative would have some risk with lining the existing Blue Heron river crossing segment and would require easement acquisition for the new length of force main connecting to the Willamette Interceptor.



Alternative 3 – *Blue Heron Alignment*

PROJECT COMPONENTS

- New Willamette PS at 10 MGD at 80 feet TDH
- Use existing 28” HDPE and 24” CCP Blue Heron piping
- Rehab existing 24” FRP river crossing
- New 20” gravity from Blue Heron piping to Willamette Interceptor
- Maintain existing Willamette PS (Required for 2040 flows only, not needed at Built Out flows)
- Use existing Willamette FM (Required for 2040 flows only, not needed at Built Out flows)
- Use existing West Linn Interceptor
- Upsize Upper Willamette Interceptor to 18-42”
- Upsize Middle Willamette Interceptor to 54-60”

COST ESTIMATE

Infrastructure	Capital ($M)	O&M ($M)
Alternative 2 Improvements	$21.5	$6.2
Total Present Worth	***$27.7***	

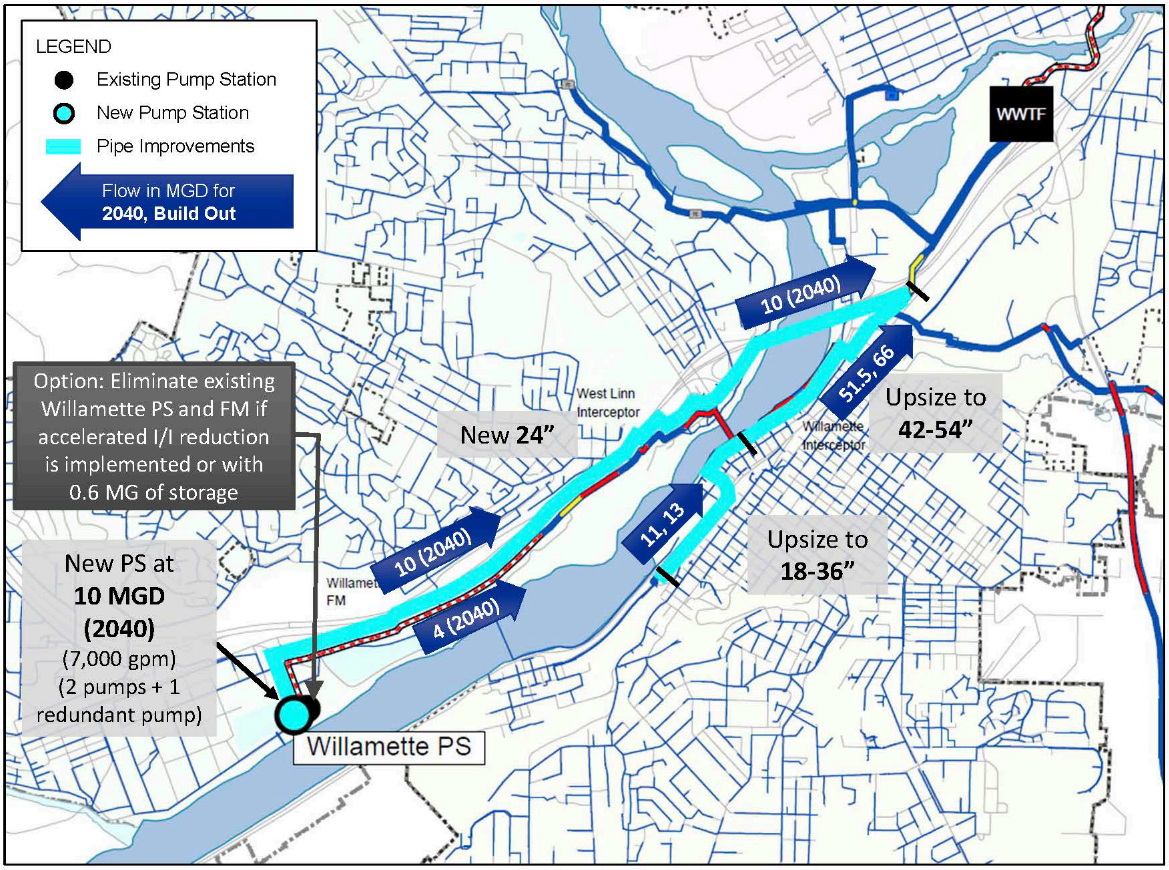
Figure 8-8. West Linn/Willamette Alternative 3

Alternative 4 – New Force Main Alignment. Alternative 4 installs an additional force main with a new alignment and includes the components listed on Figure 8-9. The costs for each component of Alternative 4 are provided in Table 8-9.

Table 8-9. Costs for Alternative 4 – New Force Main Alignment for West Linn/Willamette Area

Infrastructure	Capital ($M)	O&M ($M)
Existing Willamette Pump Station	$0	$2.8
New Willamette Pump Station	$8.2	$4.7
Storage	$0	$0
Existing Willamette Force Main	$0	$0
Parallel Willamette Force Main	$9.3	$0
West Linn Interceptor	$0	$0
Willamette Interceptor, Upper	$2.3	$0
Willamette Interceptor, Middle	$3.6	$0
SUBTOTAL	**$23.3**	**$7.5**
TOTAL PRESENT WORTH	***$30.8***	

Alternative 4 would create a redundant crossing and would have the option to eliminate the existing Willamette Pump Station and Force Main in the future. It would also reduce the diameter of the Willamette Interceptor improvements compared to the other alternatives. However, this alternative would construct a new river crossing, presents permitting challenges, would have routing challenges for the new alignment including ODOT coordination at the river crossing, and would require operation of a high head pump station.



Alternative 4 – *New Force Main Alignment*

PROJECT COMPONENTS

- New Willamette PS at 10 MGD at 185 feet TDH
- New 24" parallel Willamette FM (using I-205 crossing alignment)
- Maintain existing Willamette PS (Required for 2040 flows only, not needed at Built Out flows)
- Use existing Willamette FM (Required for 2040 flows only, not needed at Built Out flows)
- Use existing West Linn Interceptor
- Upsize Upper Willamette Interceptor to 18-36"
- Upsize Middle Willamette Interceptor to 42-54"

COST ESTIMATE

Infrastructure	Capital ($M)	O&M ($M)
Alternative 2 Improvements	$23.3	$7.5
Total Present Worth	***$30.8***	

Figure 8-9. West Linn/Willamette Alternative 4

Comparison of West Linn/Willamette Alternatives. Table 8-10 outlines the proposed improvements by individual asset, a summary of assets, and other project characteristics for each alternative.

Table 8-10. Alternatives Components for West Linn/Willamette Area

Components	Alt 2 - Storage	Alt 3 – Blue Heron Alignment	Alt 4 – New Force Main Alignment
Individual Asset Improvements			
Existing Willamette Pump Station	Use existing	Use existing	Use existing
New Willamette Pump Station	N/A	New 10 mgd PS	New 10 mgd PS
Willamette Force Main	Use existing	Use existing	Use existing
Storage Pond	Retrofit and operate a storage pond of 4 million gallons	N/A	N/A
West Linn Interceptor	Use existing	Use existing	Use existing
Blue Heron Piping	N/A	Rehabilitate 940 LF of river crossing pipe and use 9,690 LF of existing pipe	N/A
New Force Main	N/A	1,300 LF of new 20” FM (through Blue Heron to upper Willamette Int.)	14,690 LF of new 24” FM (Willamette PS to lower Willamette Int.)
Upper Willamette Interceptor	Upsize to 18-36”	Upsize to 18-42”	Upsize to 18-36”
Middle Willamette Interceptor	Upsize to 36-54”	Upsize to 54-60”	Upsize to 42-54”
Asset Summary			
Length of Gravity Main in Operation	8,005 ft – New 4,790 ft – Existing 12,795 ft – Total	8,005 ft – New 4,790 ft – Existing 12,795 ft – Total	8,005 ft – New 4,790 ft – Existing 12,795 ft – Total
Length of Force Main in Operation	0 ft – New 6,170 ft – Existing 0 ft – Rehab 6,170 ft – Total	1,300 ft – New 15,860 ft – Existing 940 ft – Rehab 18,100 ft – Total	14,690 ft – New 6,170 ft – Existing 0 ft – Rehab 20,860 ft – Total
Number of Pump Stations	1 Existing	1 Existing +1 New	1 Existing +1 New
Volume of Storage	4 million gallons	0	0
Project Details			
Permitting	Permitting challenges for diluted by untreated sewage storage pond in the 100-year floodplain near residential area		Permitting challenges for new river crossing
Coordination with Agencies	Oregon DEQ, Clackamas County, and West Linn	Metro, Oregon DEQ and Oregon City	ODOT, Oregon DEQ and West Linn
Easement Acquisition	None required	1,300 LF of easement acquisition required	None required
Conveyance Capital Cost ($M)	$37.3	$21.5	$23.3
Capital Cost Savings for Reduced Treatment Plant Improvements ($M)	-$22	$0	$0
Conveyance O&M PW Cost ($M)	$7.1	$6.2	$7.5
O&M Cost Savings for Reduced Treatment Plant Improvements ($M)	-$18	$0	$0
Total PW Cost ($M)	$4.4	$27.7	$30.8

Table 8-11 compares the alternatives and summarizes the advantages and disadvantages of each.

Table 8-11. Comparison of Alternative Characteristics for West Linn/Willamette Area

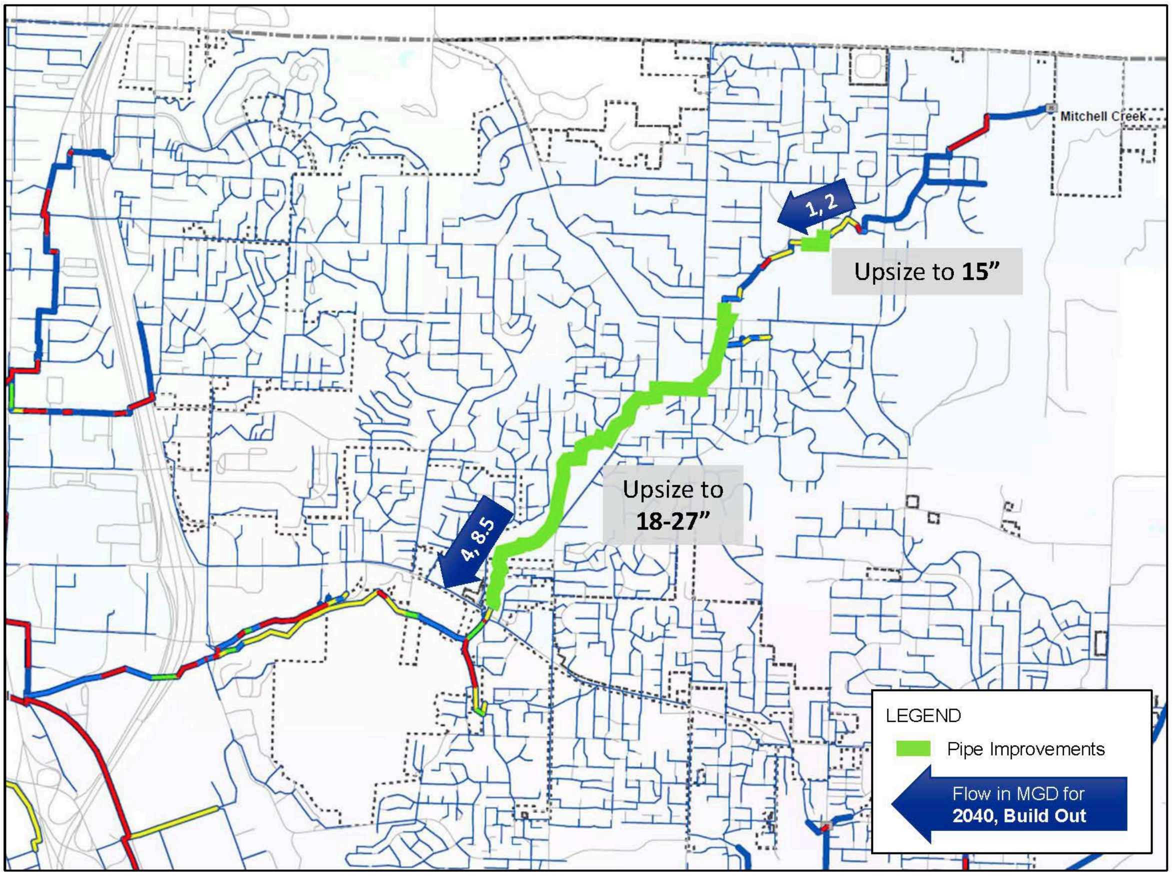
Category	Alt 2 - Storage	Alt 3 – Blue Heron Alignment	Alt 4 – New Force Main Alignment
Impact on Treatment Plant	Reduces peak flow to WRRF (11 mgd)	No impact	No impact
System Redundancy	No redundancy created	Creates an additional river crossing and PS	Creates an additional river crossing and PS
Total Dynamic Head Pumping Conditions	Only uses existing PS	Lower TDH pumping conditions	High head pump station
Use of Existing Infrastructure	Use of existing pond with sludge removal and rehabilitations	Use of existing Blue Heron piping – unknown condition upstream and downstream of river crossing and requires rehabilitation of river crossing	New force main required
Addressing Variable Timing of I/I Reduction and Effectiveness	Pond provides buffer for implementation of I/I reduction and its' associated effectiveness	Does not address variable timing of I/I reduction and effectiveness before 2040	Does not address variable timing of I/I reduction and effectiveness before 2040
Option to Abandon Assets in Future	No option to abandon existing assets	Option to abandon existing Willamette PS and FM after 2040 or with accelerated I/I reduction	Option to abandon existing Willamette PS and FM after 2040 or with accelerated I/I reduction
Flexibility to Implement a Different Solution Downstream	Does not preclude implementation of other downstream solutions	N/A	N/A
Construction Issues	Potential removal of contaminated materials required in existing pond	Risk of lining existing crossing	New Willamette River crossing
Permitting	Permitting challenges with pond related to odor and floodplain issues	No permits for rehabilitation operation anticipated.	Permitting 404, 401 & ESA §7 consultation for crossing
Neighbor Impacts	Neighbor challenges with acceptance of pond	No neighbor challenges expected	No neighbor challenges expected
Stakeholder Impacts	Stakeholder challenges for acceptance of pond	Need new pipeline easement in Blue Heron area that could impact development potential of Blue Heron property	Routing challenges for new FM alignment, including ODOT coordination at river crossing
Operations and Maintenance	Pond presents new O&M feature	Two pump stations in operation	Two pump stations in operation
Odor Control	Odor from pond potentially requires cleaning of pond after each storage event	None required	None required
Easement Acquisition	None required	Easement acquisition required for new pipeline in Blue Heron area	Some limited easements may be required

Accelerated I/I reduction in the contributing West Linn basins was investigated as a means to reduce the improvements required to the Willamette Pump Station or reduce the size of the storage pond required; however, it was found that the accelerated I/I reduction was not cost effective, as the accelerated I/I reduction cost more than the conveyance and treatment improvements. Accelerated I/I reduction to reduce improvements may be considered for noncost reasons but was not included in the alternatives at this time.

8.2.3.3 Mount Talbert/Happy Valley

The Mount Talbert/Happy Valley project was developed to address the capacity deficiencies and high I/I rates found in the Mount Talbert Interceptor and Happy Valley Interceptor. The Happy Valley Interceptor project involves upsizing segments of the Happy Valley Interceptor in place, as shown on Figure 8-10. The estimated capital cost for the improvements is $6.2 million.

Flow monitoring and investigations performed during the condition assessment work found very high I/I rates in the Happy Valley Interceptor, however, the source of the I/I was not determined from the monitoring. Because the system is a relatively newer system and it does not have a history of maintenance work orders, it is likely that the I/I could be from Mount Scott Creek flows entering a weakened part of the system or another concentrated inflow point. With the lack of I/I and condition assessment data, it is recommended to investigate and determine the source of the I/I. If the I/I source is found, then reduction can be implemented at the source to minimize or eliminate the upsizing of the interceptor. If the source is not found or the source cannot be reduced, then the Happy Valley Interceptor project could be implemented.



Happy Valley – *Potential Improvements*

PROJECT COMPONENTS

- Upsize Happy Valley Interceptor to 15-27”

COST ESTIMATE

Infrastructure	Capital ($M)	O&M ($M)
Happy Valley Interceptor	$6.2	$0
Total Present Worth	***$6.2***	

Figure 8-10. Mount Talbert/Happy Valley Alternative 2

8.2.3.4 Gladstone

The capacity deficiency in the Gladstone Pump Station due to the I/I and stormwater collected in the Gladstone Basin would require upsizing the Gladstone Pump Station to approximately 4,600 gallons per minute. However, the City of Gladstone has plans to disconnect the storm system from the sewer system. If the stormwater disconnection is completed, in addition to the 65 percent I/I reduction in targeted basins, then no improvements are required to the Gladstone Pump Station by 2040.

WES decided to move forward with applying the 65 percent I/I reduction program and requiring Gladstone to complete stormwater disconnection. Because WES is not responsible for additional improvements above the I/I program, the CIP list does not include a project for the Gladstone area.

8.2.3.5 Sieben Lane

An analysis was performed to evaluate replacing the existing Sieben Lane Pump Station and Force Main with a gravity main to reduce operations and maintenance requirements and risk associated with the pump station. The alternatives analysis is described in Appendix H and includes the following alternatives:

- Alternative 1 would include installing a new 3,100-foot, 15-inch diameter pipe in the creek corridor from the existing Sieben Lane Pump Station south to an existing 18-inch diameter pipe.
- Alternative 2 would maintain the existing Sieben Lane Pump Station and Force Main. Alternative 2 would include rehabilitating the pump station wetwell and refurbishing the existing pumps.

The lifecycle costs for each alternative are summarized in Table 8-12.

Table 8-12. Costs for Sieben Lane Alternatives

Alternative	Capital Cost ($)	60-Year Lifecycle Cost ($)
Construct New Sieben Creek Interceptor	$3,134,000	$3,134,000
Maintain Existing Sieben Pump Station and Force Main	$388,000	$2,026,000

The alternatives analysis determined that Alternative 2 has the lowest lifecycle cost and the lowest permitting risk, but has the highest operational risk.

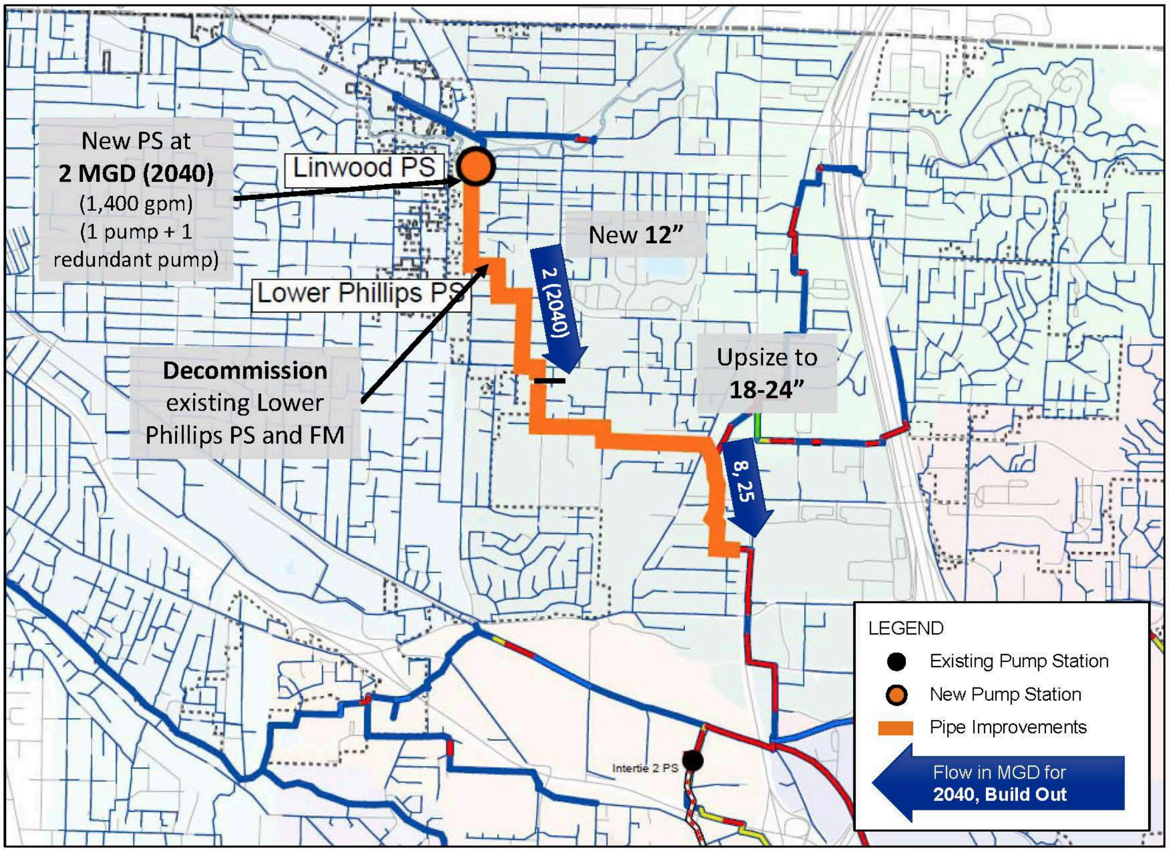
8.2.3.6 Upper and Lower Phillips

To address the capacity deficiencies in the Upper Phillips Interceptor and the Lower Phillips Interceptor, only one project was developed and refined. The project involves upsizing a section of the Lower Phillips Interceptor, installing a new Linwood Pump Station and Force Main, decommissioning the existing Lower Phillips Pump Station, and reconfiguring the Lower Phillips Force Main to flow to the new Linwood Pump Station. The alternative is shown on Figure 8-11.

Table 8-13 outlines the costs for each component of the Lower Phillips project.

Table 8-13. Costs for the Lower Phillips Project

Infrastructure	Capital ($M)	O&M ($M)
Lower Phillips PS (Decommission)	$0.1	$0
Linwood PS	$1.5	$1.8
Linwood FM	$1.4	$0
Lower Phillips Interceptor	$4.7	$0
TOTAL	**$7.7**	**$1.8**
TOTAL PRESENT WORTH	***$9.5***	



Lower Phillips Project

PROJECT COMPONENTS

- New Linwood PS at 2 MGD at 105 feet TDH
- New 12” Linwood FM
- Decommission existing Lower Phillips PS
- Reconfigure Lower Phillips FM to flow to new Linwood PS (no gravity improvements required)
- Upsize Lower Phillips Interceptor to 18-24”

COST ESTIMATE

Infrastructure	Capital ($M)	O&M ($M)
Lower Phillips Project	$7.7	$1.8
Total Present Worth	***$9.5***	

Figure 8-11. Lower Phillips Project

8.2.3.7 Newell Creek and Country Village

The Newell Creek and Country Village project was developed to address the capacity deficiencies in the Newell Creek Interceptor and the Country Village Interceptor. The project involves upsizing sections of both interceptors, as shown on Figure 8-12.

The cost for each component of the project is provided in Table 8-14.

Table 8-14. Costs for the Newell Creek and Country Village Project

Infrastructure	Capital ($M)	O&M ($M)
Newell Creek Interceptor	$3.5	$0
Country Village Interceptor	$0.9	$0
TOTAL PRESENT WORTH	$4.4	$0

8.2.3.8 Lower Willamette Interceptor

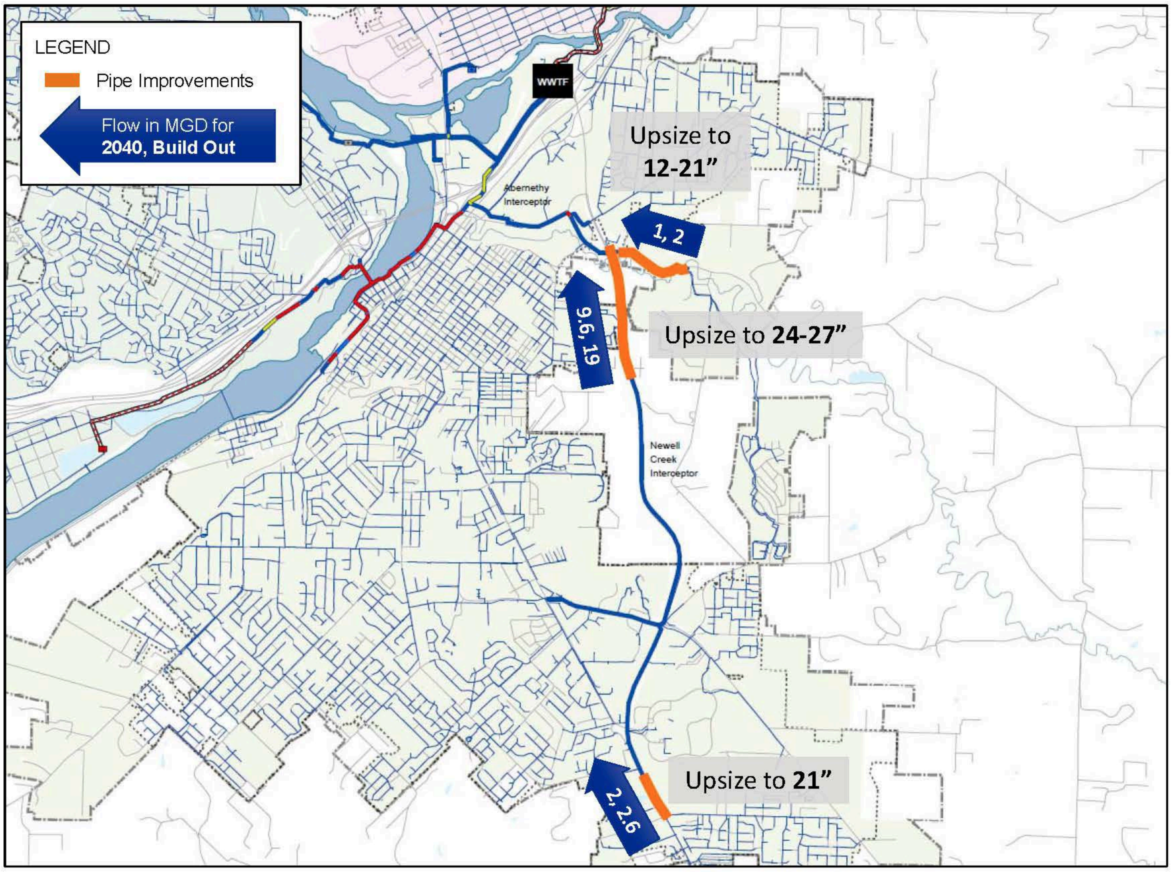
The Lower Willamette Interceptor improvements address the intermediate to mid-stage microbial induced corrosion (MIC) issues found during the condition assessment. The project involves lining the existing lower Willamette Interceptor, as shown on Figure 8-13. The existing interceptor ranges from 54 inches to 72 inches in diameter and the lining is estimated to have a capital cost of $11.8 million.

8.2.3.9 Oregon City Interceptor

The Oregon City Interceptor project addresses the condition issues in the Oregon City Interceptor. The improvements involve lining the existing interceptor and hydraulic modifications to the Gladstone Pump Station discharge to address flow backups by reducing losses through the flow structure. The project is shown on Figure 8-14 and the cost for each component is provided in Table 8-15.

Table 8-15. Costs for the Oregon City Interceptor Project

Infrastructure	Capital ($M)	O&M ($M)
Oregon City Interceptor rehab	$1.3	$0
Hydraulic Modifications at Gladstone Pump Station Discharge	$0.2	$0
TOTAL PRESENT WORTH	**$1.5**	**$0**



Newell Creek and Country Village Project

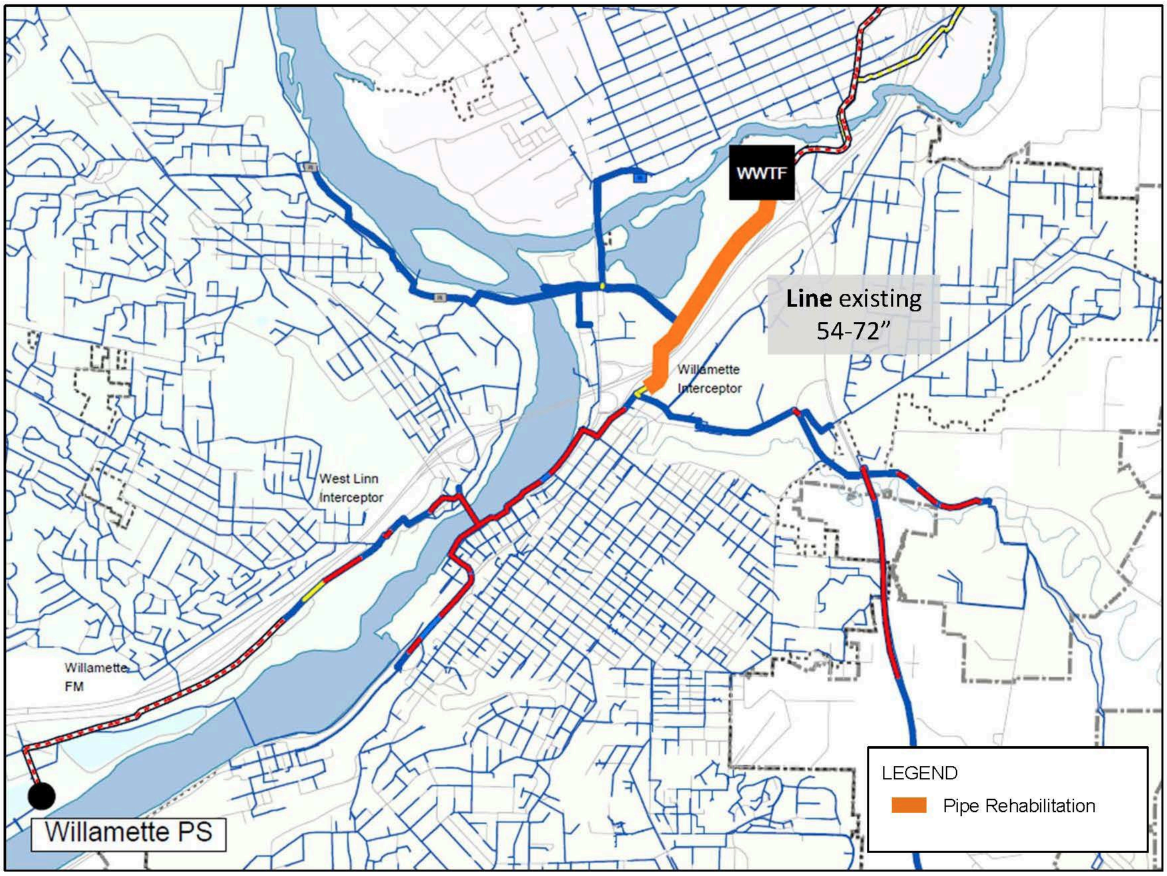
PROJECT COMPONENTS

- Upsize upper Newell Creek Interceptor to 21”
- Use existing middle Newell Creek Int.
- Upsize lower Newell Creek Interceptor. to 24-27”
- Upsize Country Village Interceptor to 12-21”

COST ESTIMATE

Infrastructure	Capital ($M)	O&M ($M)
Newell Creek Interceptor	$3.5	$0
Country Village Interceptor	$0.9	$0
Total Present Worth	**$4.4**	**$0**

Figure 8-12. Newell Creek and Country Village Project



Lower Willamette Interceptor Project

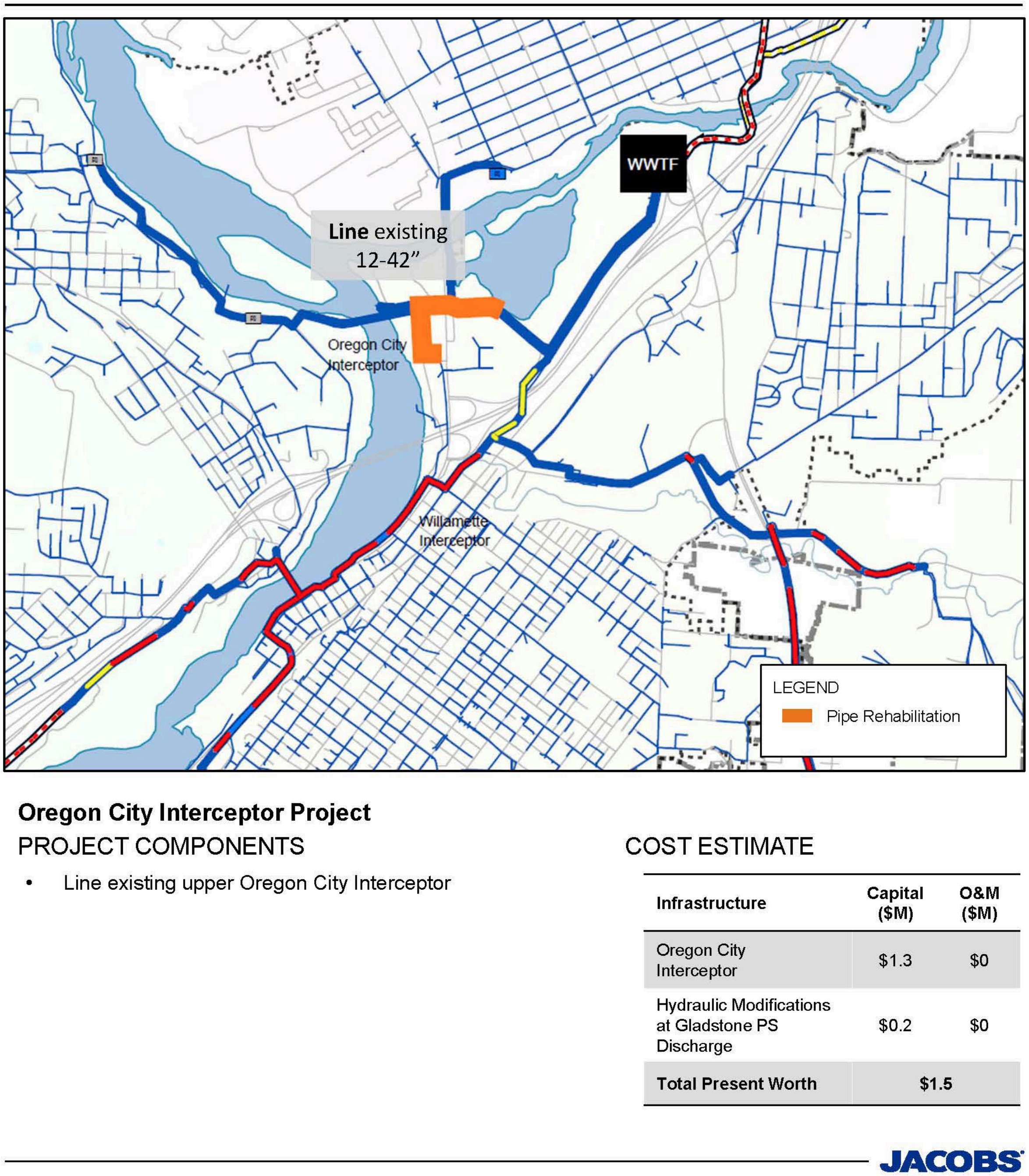
PROJECT COMPONENTS

- Line existing lower Willamette Interceptor

COST ESTIMATE

Infrastructure	Capital ($M)	O&M ($M)
Lower Willamette Interceptor	$11.8	$0
Total Present Worth	***$11.8***	

Figure 8-13. Lower Willamette Interceptor Project



Oregon City Interceptor Project

PROJECT COMPONENTS

- Line existing upper Oregon City Interceptor

COST ESTIMATE

Infrastructure	**Capital ($M)**	**O&M ($M)**
Oregon City Interceptor	$1.3	$0
Hydraulic Modifications at Gladstone PS Discharge	$0.2	$0
Total Present Worth	**$1.5**	

Figure 8-14. Oregon City Interceptor Project

8.2.3.10 Rock Creek Sewer Extension

The Rock Creek Interceptor project was developed to serve future growth in the Rock Creek area. The project includes a north extension with new interceptor piping ranging from 15 to 18 inches in diameter, and a 12-inch diameter east extension, as shown in red on Figure 8-15. The interceptor extension was developed to serve as a backbone for future growth up to the Multnomah County line at SE Cheldelin Road and easterly along SE Troge Road to SE Foster Road. While not shown on Figure 8-15, this pipe could eventually extend east from SE Foster Road between two hills to reach SE Tillstrom Road. The final alignment of this extension can be refined should this area develop the need for sanitary sewer in the future. The estimated capital cost for the Rock Creek Interceptor extension is provided in Table 8-16, including a 2,200-foot segment of trenchless installation in the North Extension where the sewer would be 25-35 feet deep.

Table 8-16. Costs for the Rock Creek Interceptor Extension Project

Infrastructure	Capital ($M)
Rock Creek Interceptor – North Extension	$9.1
Rock Creek Interceptor – East Extension	$1.0
TOTAL COST	**$10.1**

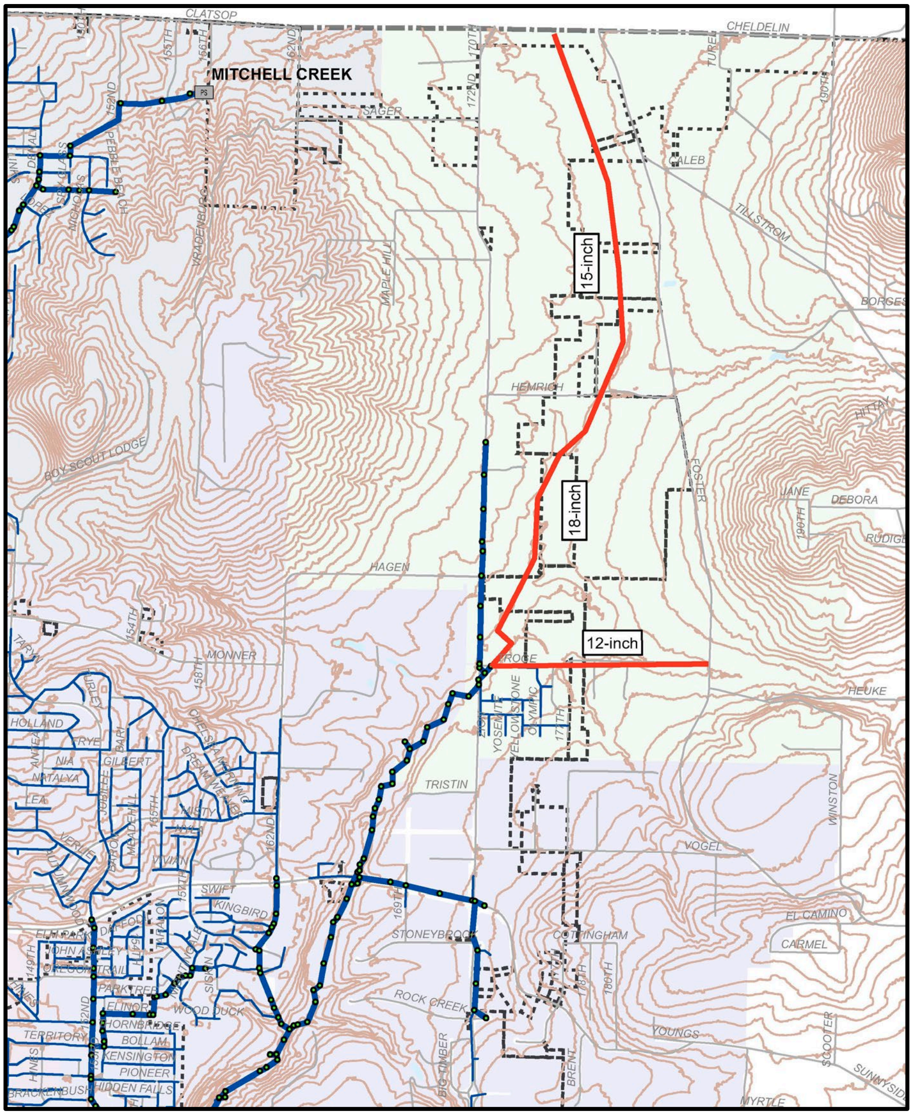


Figure 8-15. Rock Creek Interceptor Extension

8.3 Findings

The alternatives evaluation resulted in the selected projects and alternatives shown in Table 8-17 to mitigate risks associated with capacity and condition deficiencies and growth. Table 8-17 also summarizes alternatives that were not selected and the primary reason.

Table 8-17. Summary of Alternatives and Projects

Project Area	Alternative or Project	Status
Clackamas/Intertie 1/Intertie 2	Alternative 1 – Clackamas to Intertie 2	**Not selected** due the high risk of construction through a wetland in order to replace the lower Clackamas Interceptor
	Alternative 3 – Diversion to Jennifer/Intertie 1 (and potential modification to Alternative 3)	**Selected** for further analysis at the project predesign level
	Alternative 4 – Diversion to Jennifer/Intertie 2	**Selected** for further analysis at the project predesign level
West Linn/Willamette	Alternative 1 – Existing Alignment	**Not selected** due to anticipated limitations and challenges with replacing the West Linn Interceptor pipe on the Oregon City Bridge
	Alternative 2 – Storage	**Selected** for further analysis at the project predesign level
	Alternative 3 – Blue Heron Alignment	**Selected** for further analysis at the project predesign level
	Alternative 4 – New Force Main Alignment	**Selected** for further analysis at the project predesign level
Mount Talbert/Happy Valley	Happy Valley Interceptor Project	**Not selected** due to lack of I/I data and supporting evidence
	I/I Source Investigation	**Recommended** (not included as a CIP project)
Gladstone	Stormwater Disconnection and Targeted I/I Reduction	**Recommended** (not included as a CIP project)
Sieben Lane	Alternative 1 – New Force Main	**Not selected** due to higher lifecycle cost and higher permitting risk
	Alternative 2 – Wet Well and Pump Improvements	**Selected**
Upper and Lower Phillips	Lower Phillips Project	**Selected**
Newell Creek/Country Village	Newell Creek and Country Village Project	**Selected**
Lower Willamette Interceptor	Lower Willamette Interceptor Rehab Project	**Selected**
Oregon City Interceptor	Oregon City Interceptor Rehab Project	**Selected**
Rock Creek Sewer Extension	Rock Creek Interceptor North and East Extension Project	**Selected**

9. Project Recommendations and Implementation

Section 9 provides a summary of the selected alternatives detailed in Section 8. Following discussion of the alternatives developed and reviewed, WES decided to carry forward multiple alternatives for the system served by the Clackamas interceptor and Intertie 2 pump station; and for the West Linn/Willamette interceptor systems. In other locations, a single alternative is recommended. For the cases where multiple alternatives are carried forward, those alternatives will represent the starting point for subsequent predesign activities and selection of the preferred alternative.

This section also provides an implementation plan based on (1) the timing of the need for the project based on deficiency timing and 2) the requirements dictated by the interaction of an improvement relative to others in the system—for example, the recommendation to improve a system element downstream prior to an upstream improvement. This section identifies locations of system restrictions or “bottlenecks” that could be improved in the near term to delay, but not eliminate the need for the remaining elements of the recommended improvement.

9.1 Objectives

The objectives of this section are to:

- List the recommended project improvements in a single location associated with 2040 land use conditions for future reference.
- Provide a clear and defined starting point for ensuing predesign activities that may include final project selection.
- Indicate the priority of projects either based on timing of need or relationship to other projects.
- Identify restrictions that cause deficiencies that could be part of early action projects that provide relief without full implementation of the alternative.
- Provide other noncapital recommendations associated with the system.

9.2 Methodology and Analysis

The recommendations in this section are taken directly from Section 8 where alternatives were evaluated in detail, some eliminated, and those taken forward summarized here.

As described later in this Section, the project prioritization is driven primarily by the timing of the expected hydraulic or condition-based deficiency, either based on flow increases due to growth and I/I degradation or time if condition based. Risk scores to prioritize projects were not used directly to prioritize but may be used to complement capital improvement plan as details are developed.

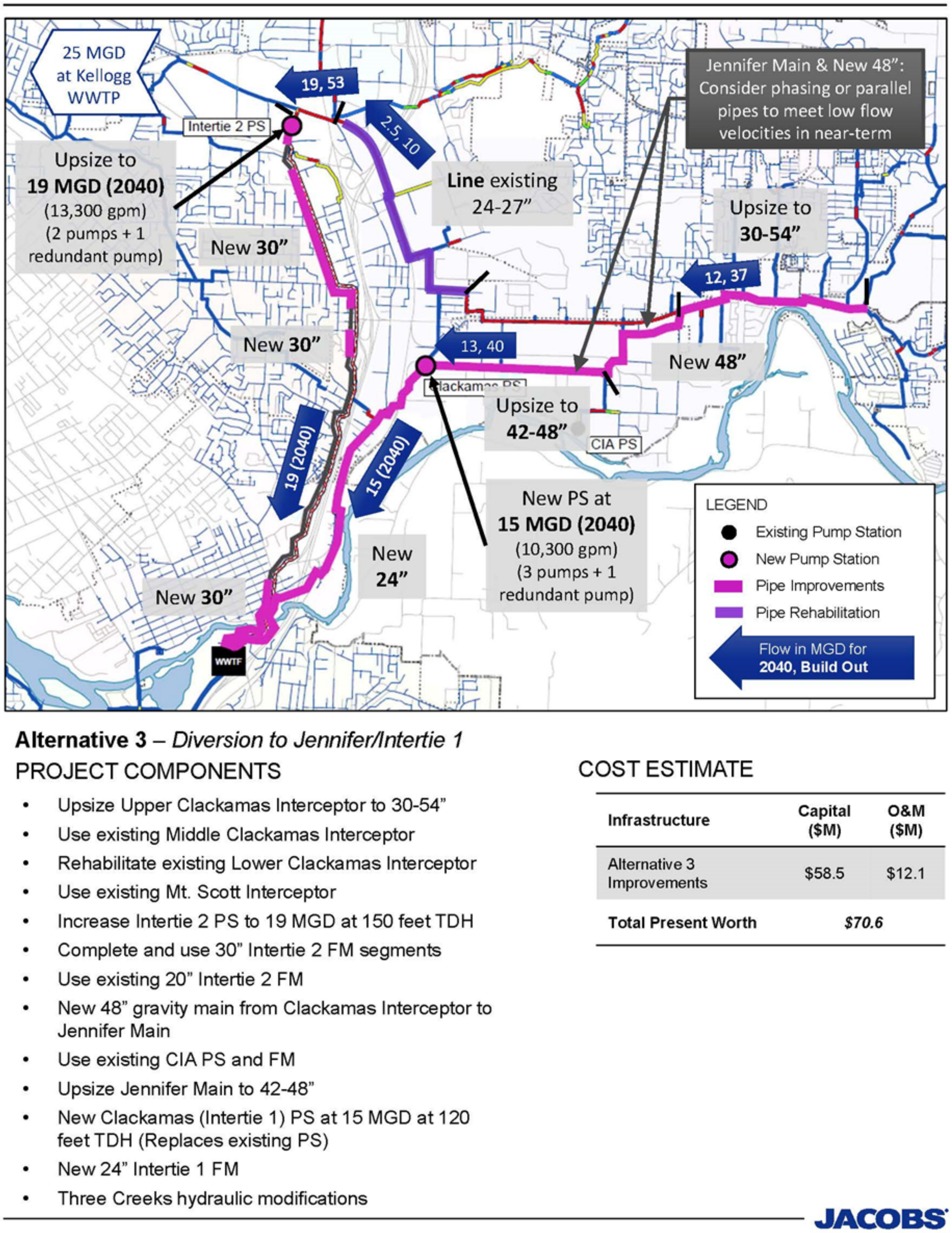
9.3 Findings

Section 9.3.1 provides a summary of recommended projects associated with cost-effective, capacity-based pipeline improvements and I/I reduction. Section 9.3.2 summarizes projects associated with condition-based findings and Section 9.3.3 provides prioritization and other project phasing information. Noncapital recommendations for system elements are made in Section 9.3.4.

9.3.1 Summary of Recommended Projects

9.3.1.1 Clackamas Interceptor/Intertie 1/Intertie 2

Alternatives 3 and 4 are recommended to be carried forward as summarized on Figures 9-1 and 9-2.



Alternative 3 – *Diversion to Jennifer/Intertie 1*

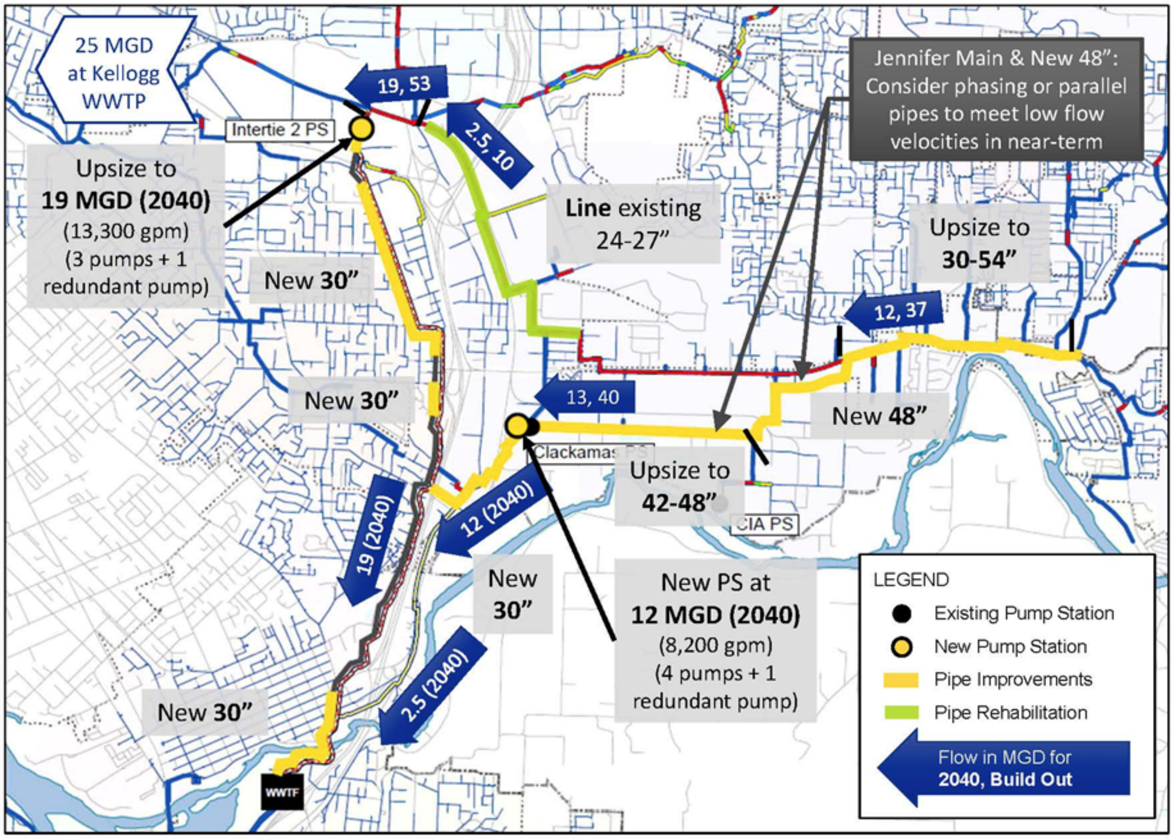
PROJECT COMPONENTS

- Upsize Upper Clackamas Interceptor to 30-54"
- Use existing Middle Clackamas Interceptor
- Rehabilitate existing Lower Clackamas Interceptor
- Use existing Mt. Scott Interceptor
- Increase Intertie 2 PS to 19 MGD at 150 feet TDH
- Complete and use 30" Intertie 2 FM segments
- Use existing 20" Intertie 2 FM
- New 48" gravity main from Clackamas Interceptor to Jennifer Main
- Use existing CIA PS and FM
- Upsize Jennifer Main to 42-48"
- New Clackamas (Intertie 1) PS at 15 MGD at 120 feet TDH (Replaces existing PS)
- New 24" Intertie 1 FM
- Three Creeks hydraulic modifications

COST ESTIMATE

Infrastructure	Capital ($M)	O&M ($M)
Alternative 3 Improvements	$58.5	$12.1
Total Present Worth	***$70.6***	

Figure 9-1. Clackamas/Intertie 1/Intertie 2 Alternative 3



Alternative 4 – *Diversion to Jennifer/Intertie 2*

PROJECT COMPONENTS

- Upsize Upper Clackamas Interceptor to 30-54"
- Use existing Middle Clackamas Interceptor
- Line existing Lower Clackamas Interceptor
- Use existing Mt. Scott Interceptor
- Increase Intertie 2 PS to 19 MGD at 185 feet TDH
- Complete Intertie 2 30" FM segments
- New 48" gravity main from Clackamas Interceptor to Jennifer Main
- Use existing CIA PS and FM
- Upsize Jennifer Main to 42-48"
- Use existing Clackamas (Intertie 1) PS & FM
- New second Clackamas (Intertie 1) PS at 12 MGD at 145 feet TDH
- New 30" FM from Clackamas PS to the 20" Intertie 2 FM (using Manfield Ct) and use lower segment of 20" existing Intertie 2 FM
- Three Creeks hydraulic modifications

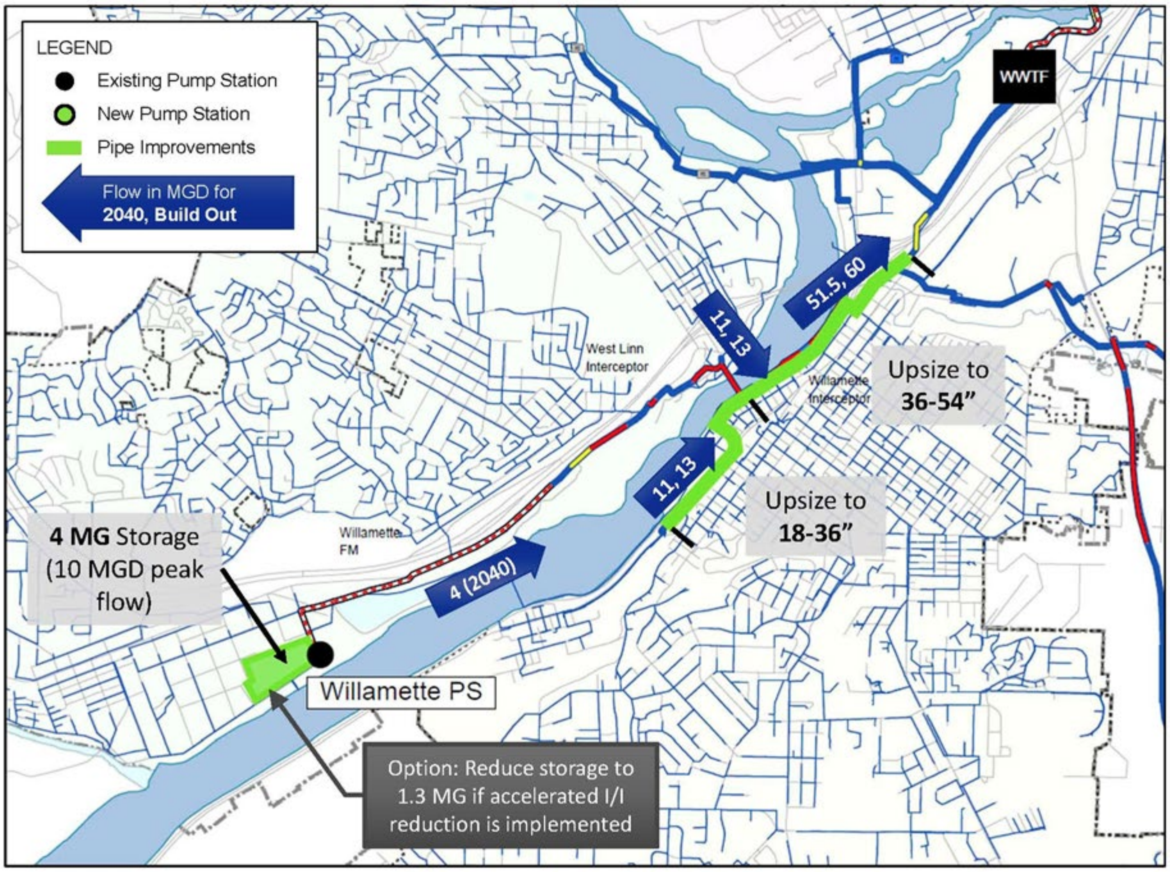
COST ESTIMATE

Infrastructure	Capital ($M)	O&M ($M)
Alternative 4 Improvements	$56.7	$14.3
Total Present Worth	***$71.0***	

Figure 9-2. Clackamas/Intertie 1/Intertie 2 Alternative 4

9.3.1.2 West Linn/Willamette

Alternatives 2, 3, and 4 are recommended to be carried forward as summarized on Figures 9-3, 9-4, and 9-5.



Alternative 2 – *Storage*

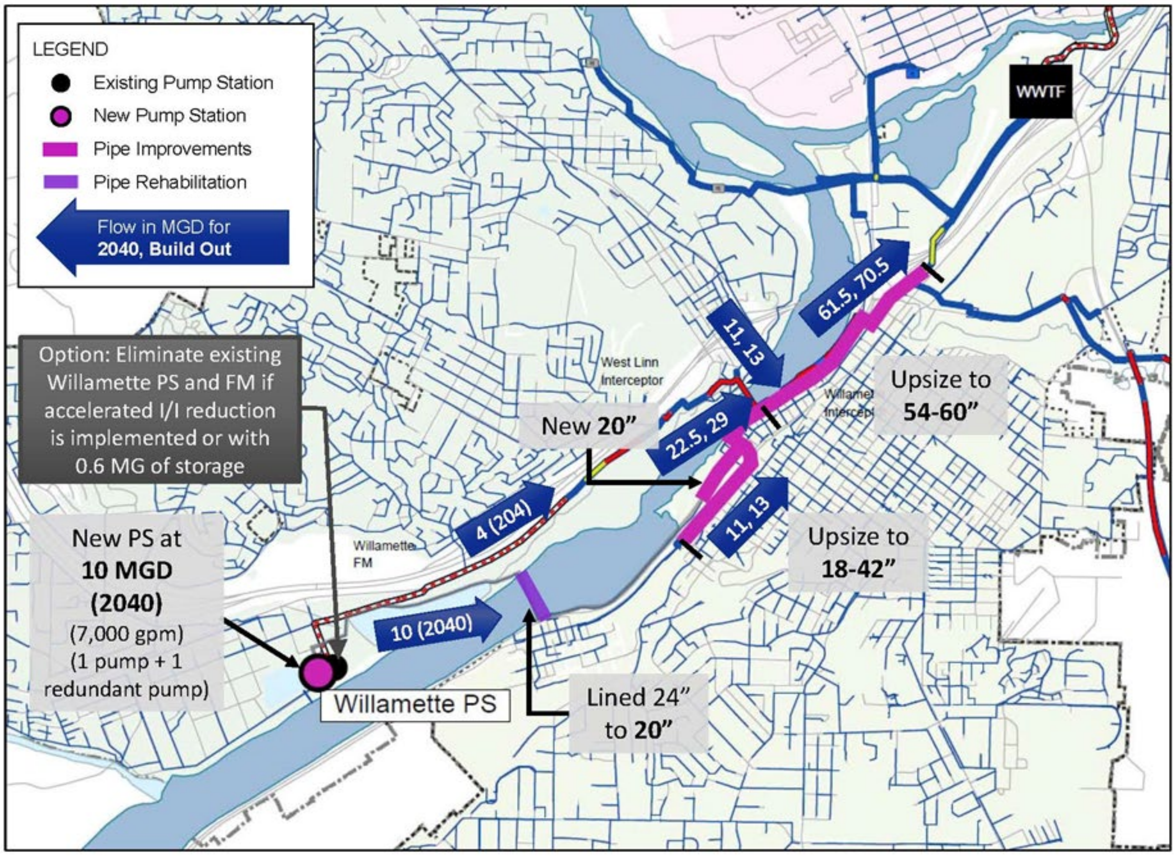
PROJECT COMPONENTS

- Maintain existing Willamette PS
- Use existing Willamette FM
- Retrofit of pond for storage of 4 million gallons of raw sewage (eliminates 11 MGD peak flow) (Storage can be reduced for Build Out flows) – Includes sludge removal and rehabilitation of existing open pond
- Use existing West Linn Interceptor
- Upsize Upper Willamette Interceptor to 18-36”
- Upsize Middle Willamette Interceptor to 36-54”

COST ESTIMATE

Infrastructure	Capital ($M)	O&M ($M)
Alternative 2 Improvements	$37.3	$7.1
Cost Savings for Reduced Treatment Plant Improvements	-$22	-$18
Total Present Worth	***$4.4***	

Figure 9-3. West Linn/Willamette Alternative 2



Alternative 3 – *Blue Heron Alignment*

PROJECT COMPONENTS

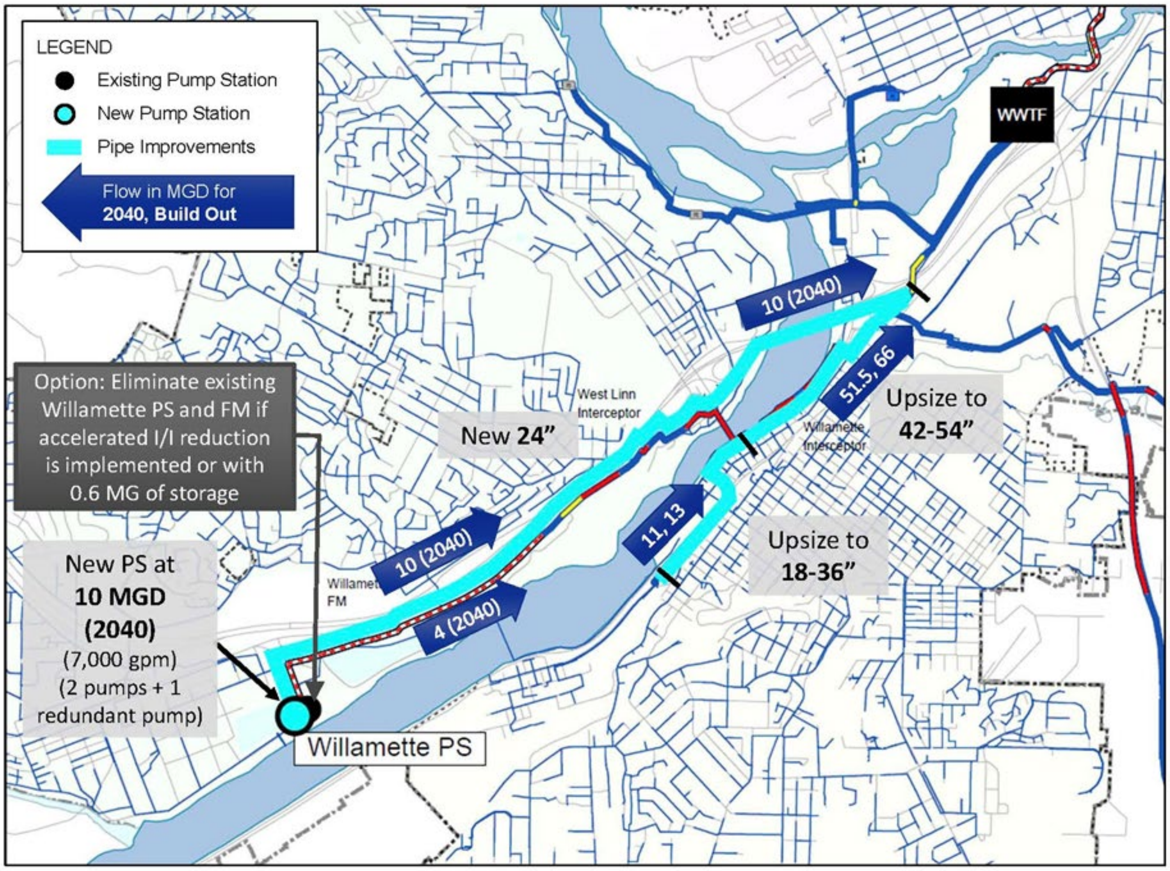
- New Willamette PS at 10 MGD at 80 feet TDH
- Use existing 28" HDPE and 24" CCP Blue Heron piping
- Rehab existing 24" FRP river crossing
- New 20" gravity from Blue Heron piping to Willamette Interceptor
- Maintain existing Willamette PS (Required for 2040 flows only, not needed at Built Out flows)
- Use existing Willamette FM (Required for 2040 flows only, not needed at Built Out flows)
- Use existing West Linn Interceptor
- Upsize Upper Willamette Interceptor to 18-42"
- Upsize Middle Willamette Interceptor to 54-60"

COST ESTIMATE

Infrastructure	Capital ($M)	O&M ($M)
Alternative 2 Improvements	$21.5	$6.2
Total Present Worth	***$27.7***	

JACOBS

Figure 9-4. West Linn/Willamette Alternative 3



Alternative 4 – *New Force Main Alignment*

PROJECT COMPONENTS

- New Willamette PS at 10 MGD at 185 feet TDH
- New 24" parallel Willamette FM (using I-205 crossing alignment)
- Maintain existing Willamette PS (Required for 2040 flows only, not needed at Built Out flows)
- Use existing Willamette FM (Required for 2040 flows only, not needed at Built Out flows)
- Use existing West Linn Interceptor
- Upsize Upper Willamette Interceptor to 18-36"
- Upsize Middle Willamette Interceptor to 42-54"

COST ESTIMATE

Infrastructure	Capital ($M)	O&M ($M)
Alternative 2 Improvements	$23.3	$7.5
Total Present Worth	***$30.8***	

Figure 9-5. West Linn/Willamette Alternative 4

9.3.1.3 Mount Talbert/Happy Valley

Alternative 1 is recommended to be carried forward. Instead of improving the interceptor based on estimated deficiencies, the recommendation is to refine the assessment of I/I rates and sources given that higher than expected rates were estimated from monitoring data. Give a relatively newer contributing system it was felt that there could be isolated locations of higher I/I or inflow sources that warrant future I/I isolation activities vs. increasing trunk system capacity. Further, portions of the trunk pipeline are located close to the Mount Scott Creek triggers the likelihood of potentially high replacement costs as well as the potential for discovering inflow sources and avoiding or minimizing expensive trunk line replacement. The trunk line is shown on Figure 9-6. Costs were not estimated for the monitoring and/or additional source detection work that is recommended as a next step.

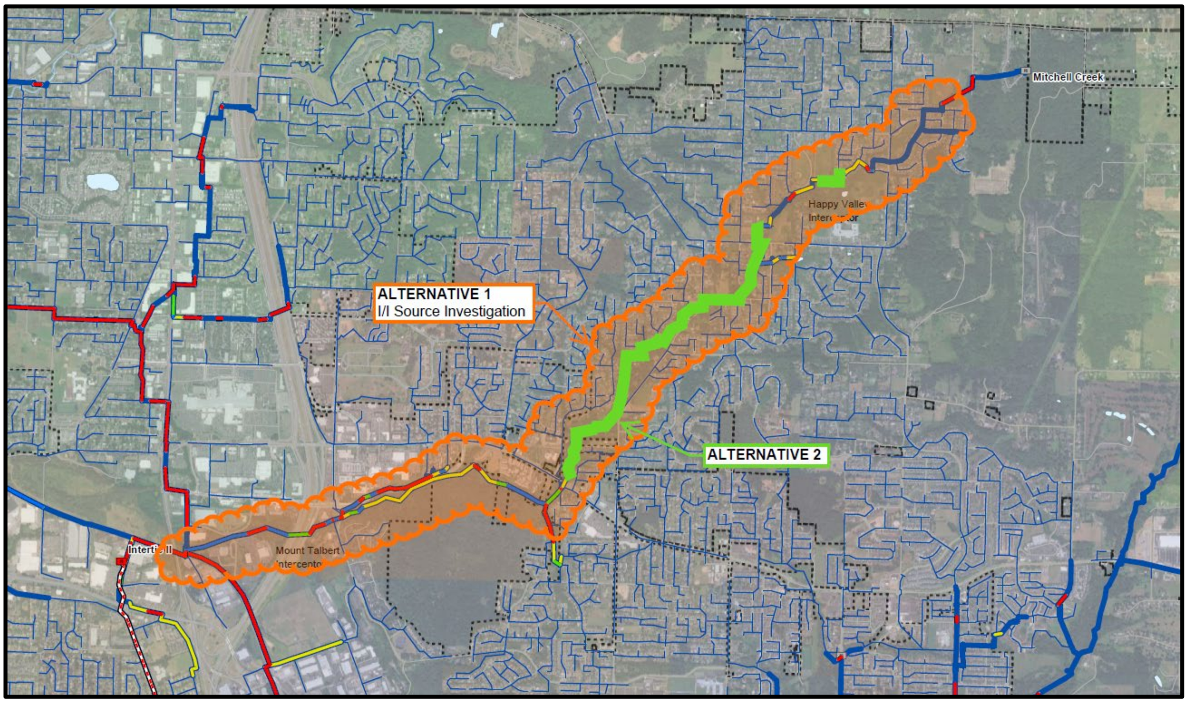


Figure 9-6. Mount Talbert/Happy Valley Alternatives

9.3.1.4 Sieben Lane

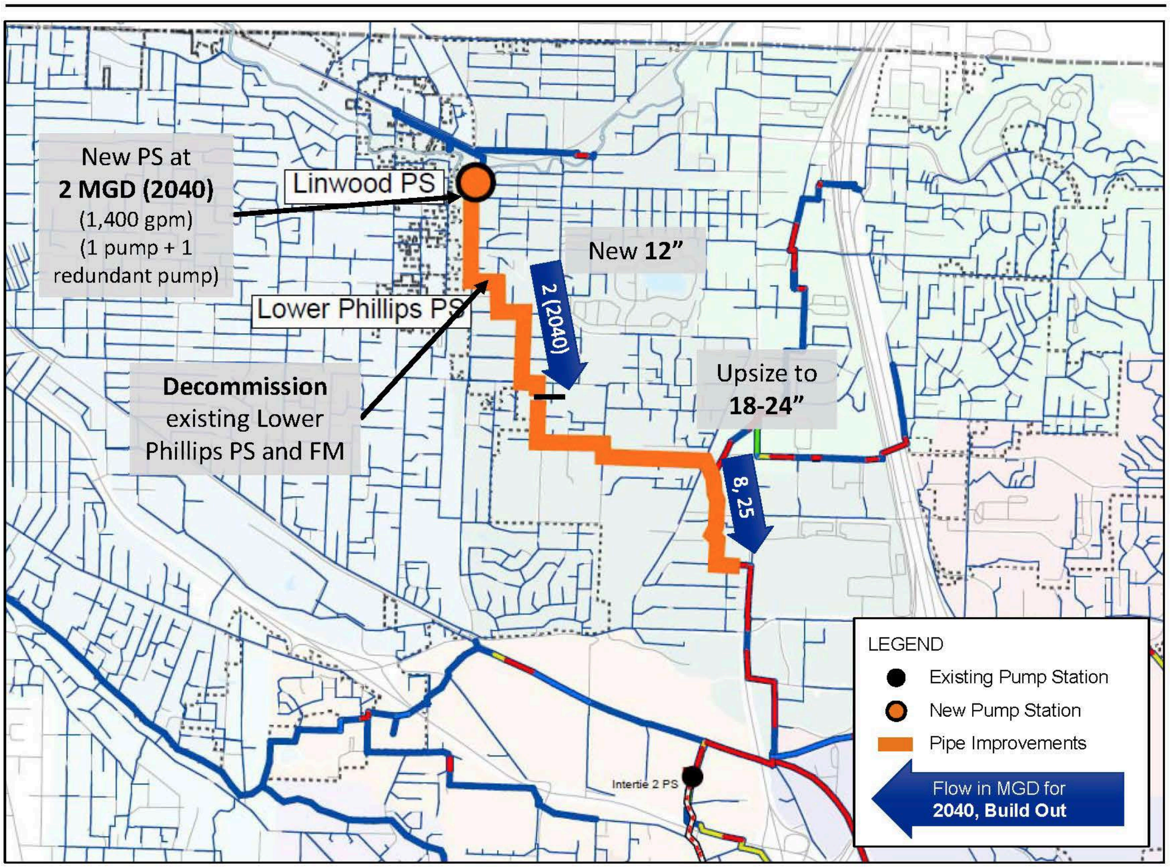
The recommended alternative is to maintain the existing Sieben Lane Pump Station and Force Main. Based on the analysis the improvements are rehabilitation of the pump station wet well and refurbishing the existing pumps. Based on the pump station condition assessment there may also be improvements needed to the electrical system. The estimated cost for these improvements (other than electrical) is provided in Table 9-1.

Table 9-1. Sieben Lane Recommended Improvement

Improvement Description	Capital Cost ($)	50-Year Lifecycle Cost ($)
Improve and Maintain Existing Sieben Pump Station	$388,000	$1,915,000

9.3.1.5 Upper and Lower Phillips

Force main, pump station and gravity line improvements are recommended for this location as shown on Figure 9-7. Additional near-term condition-based pipe improvements of the Lower Phillips Interceptor with a capital cost estimate of $0.17M are recommended.



Lower Phillips Project

PROJECT COMPONENTS

- New Linwood PS at 2 MGD at 105 feet TDH
- New 12” Linwood FM
- Decommission existing Lower Phillips PS
- Reconfigure Lower Phillips FM to flow to new Linwood PS (no gravity improvements required)
- Upsize Lower Phillips Interceptor to 18-24”

COST ESTIMATE

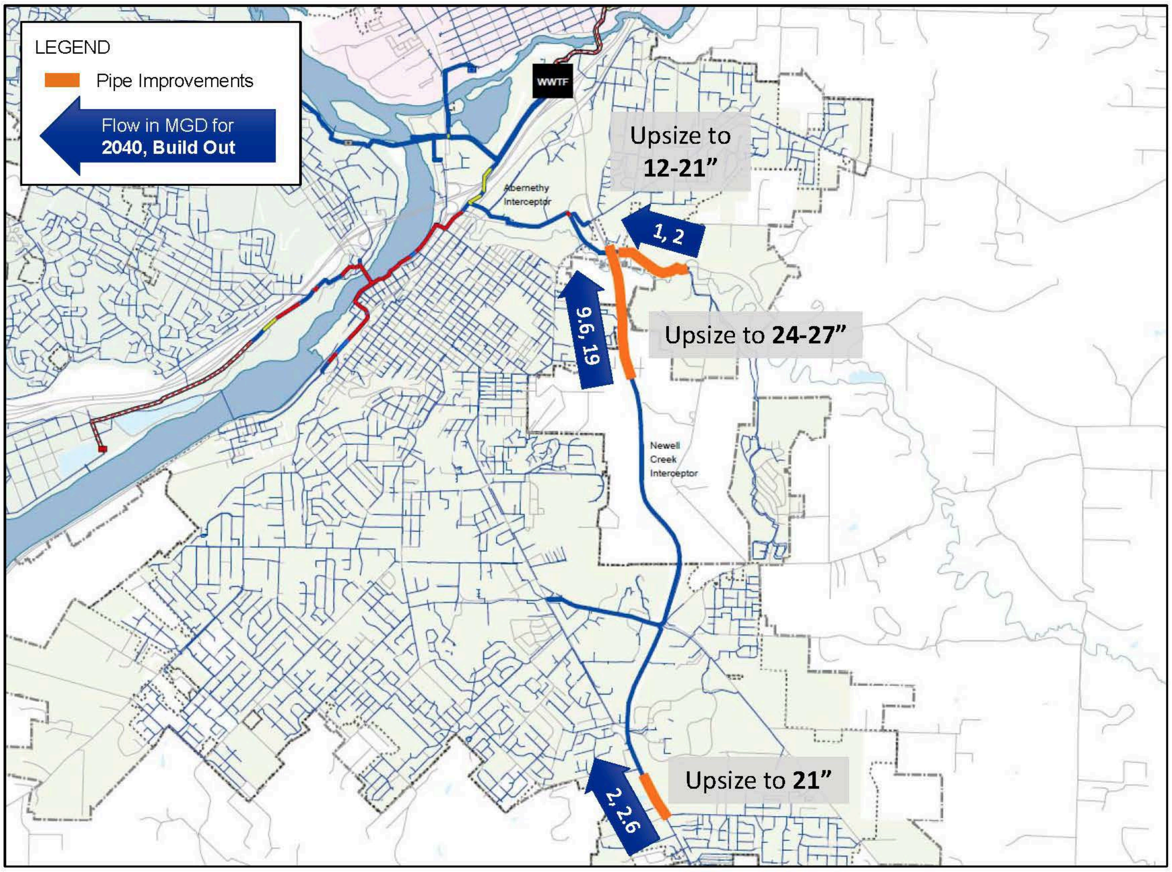
Infrastructure	Capital ($M)	O&M ($M)
Lower Phillips Project	$7.7	$1.8
Total Present Worth	***$9.5***	

JACOBS

Figure 9-7. Lower Phillips Project

9.3.1.6 Newell Creek and Country Village

Gravity pipeline upsizing is recommended for locations on both interceptors as shown on Figure 9-8. Upsizing of Country Village interceptor would alleviate the need for far-term phased rehabilitation of the interceptor and would take place in lieu of chemical corrosion control in the near term.



Newell Creek and Country Village Project

PROJECT COMPONENTS

- Upsize upper Newell Creek Interceptor to 21”
- Use existing middle Newell Creek Int.
- Upsize lower Newell Creek Interceptor. to 24-27”
- Upsize Country Village Interceptor to 12-21”

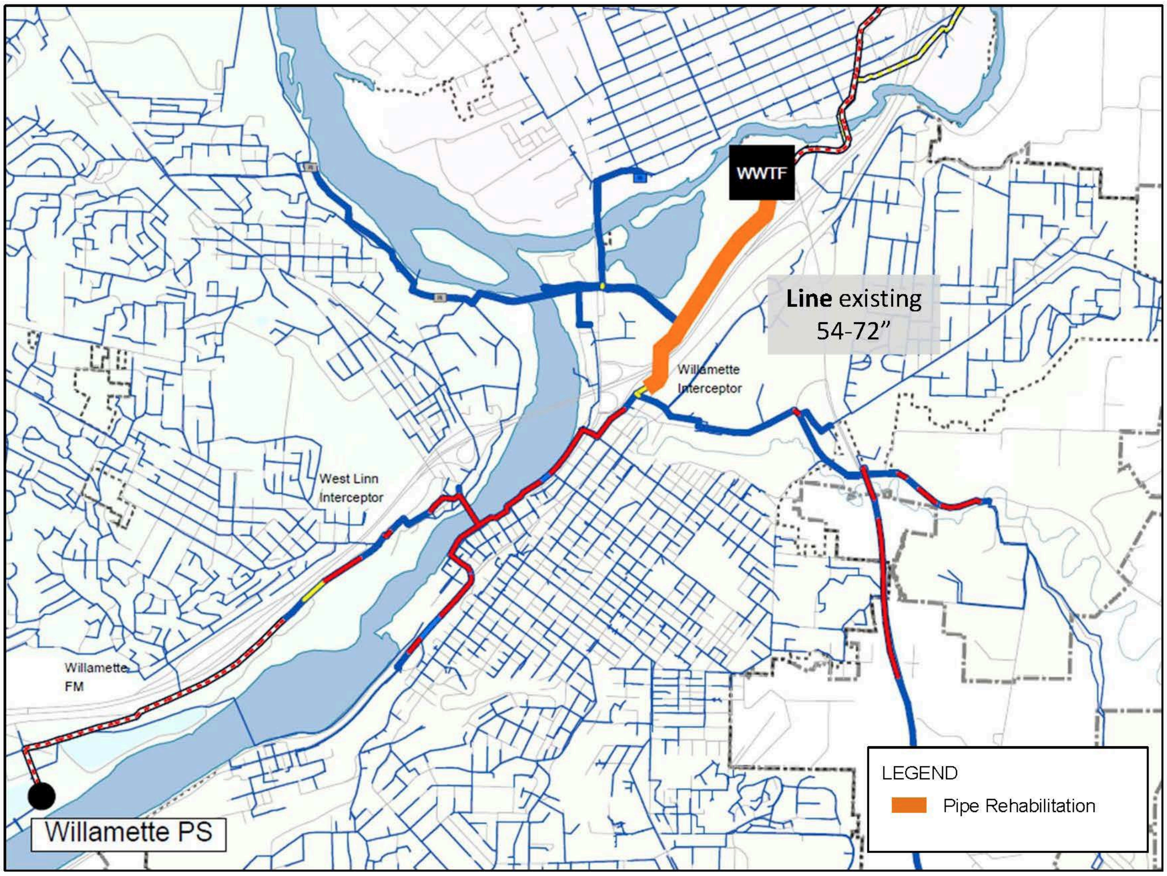
COST ESTIMATE

Infrastructure	Capital ($M)	O&M ($M)
Newell Creek Interceptor	$3.5	$0
Country Village Interceptor	$0.9	$0
Total Present Worth	**$4.4**	**$0**

Figure 9-8. Newell Creek and Country Village Interceptors Project

9.3.1.7 Lower Willamette Interceptor

The Lower Willamette Interceptor project location is shown on Figure 9-9 and is a condition driven recommendation for lining the existing pipeline.



Lower Willamette Interceptor Project

PROJECT COMPONENTS

- Line existing lower Willamette Interceptor

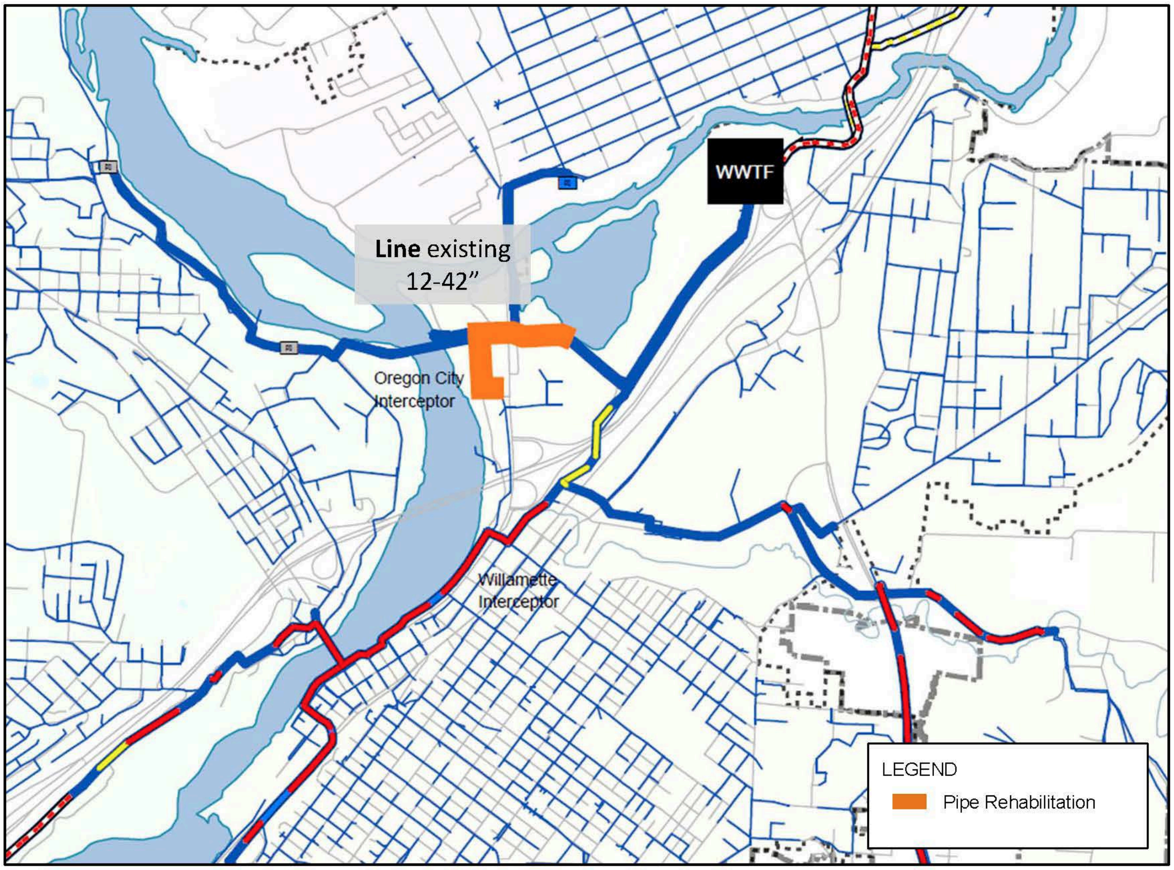
COST ESTIMATE

Infrastructure	Capital ($M)	O&M ($M)
Lower Willamette Interceptor	$11.8	$0
Total Present Worth	***$11.8***	

Figure 9-9. Lower Willamette Interceptor Project

9.3.1.8 Oregon City Interceptor

Similar to the Lower Willamette improvement project, this project is condition driven and includes a pipeline lining recommendation as shown on Figure 9-10.



Oregon City Interceptor Project

PROJECT COMPONENTS

- Line existing upper Oregon City Interceptor

COST ESTIMATE

Infrastructure	Capital ($M)	O&M ($M)
Oregon City Interceptor	$1.3	$0
Hydraulic Modifications at Gladstone PS Discharge	$0.2	$0
Total Present Worth	**$1.5**	

Figure 9-10. Oregon City Interceptor Project

9.3.1.9 Lower Kellogg Interceptor Project

This project is condition based and consists of continued monitoring with isolated spot repairs to remove active infiltration in response to the interceptor's susceptibility to flood impacts. The estimated cost for the repairs for this project is $0.2M.

9.3.1.10 Bolton and River Street Force Main Rehabilitation Project

This project is condition based and consists of coating, rehabilitation and/or replacement of pipe spools and appurtenances exposed in vaults. The estimated cost for this project is $20,000.

9.3.1.11 Gladstone Force Main Painting Project

This project is condition based and consists of inspection of the bridge superstructure and assessment of needed painting touchups. The cost estimate for this project is $0.1M.

9.3.1.12 Willamette Force Main Rehabilitation Project

This project is condition based and consists of demolition of existing unused air-vacuum relief valve and vault. The estimated cost for this project is $7,000.

9.3.1.13 Service Needs

This project is a recommendation for an extension to the existing system to serve future growth in the Rock Creek area. The alignment is shown on Figure 9-11.

9.3.1.14 RDI/I Reduction

As concluded in Section 5, a combination of I/I reduction and pipeline and pump station improvements is recommended. Each recommendation in this section assumes the implementation of I/I reduction in selected basins shown on Figure 9-12 and listed in Table 9-2. The cost-effective recommendation was associated with a 65 percent I/I reduction in the identified basins. For purposes of cost-estimating, this included improving or replacing the following: mainline, lateral within the public right-of-way, lateral (often on private property) to service location (home, business, etc.). Jacobs recommends that WES and the member agencies develop an I/I reduction plan specific to local conditions to achieve the 65 percent cost effective reduction. Member agencies are encouraged to include in their plans other potentially less expensive means of achieving the reduction. The following provides additional information regarding the I/I reduction recommendations:

- RDI/I reduction in the Milwaukie Subbasin is identified as critical by 2040 to maintain Kellogg WRRF peak flow rates below the planned expansion capacity of 25 mgd. The Intertie 2 Pump Station provides substantial relief to the Kellogg WRRF; however, the maximum estimated diversion at the pump station is inadequate for full relief. To achieve a maximum of 25 mgd at the Kellogg WRRF, RDI/I reduction is required in downstream basins. Reduction in the Milwaukie Subbasin was selected based on RDI/I rates. Milwaukie reduction would eliminate an estimated 13 mgd of excess flow at Kellogg. Alternately, an equivalent reduction may be achieved in a combination of the Milwaukie, Harmony, and Lower Kellogg subbasins by 2040.
- Mount Talbert basin I/I reduction costs may be decreased if direct creek contributions or other inflow sources are identified. The potential to eliminate sources at fewer locations with high removal potential would likely be less expensive than full rehabilitation of all pipes in the basin

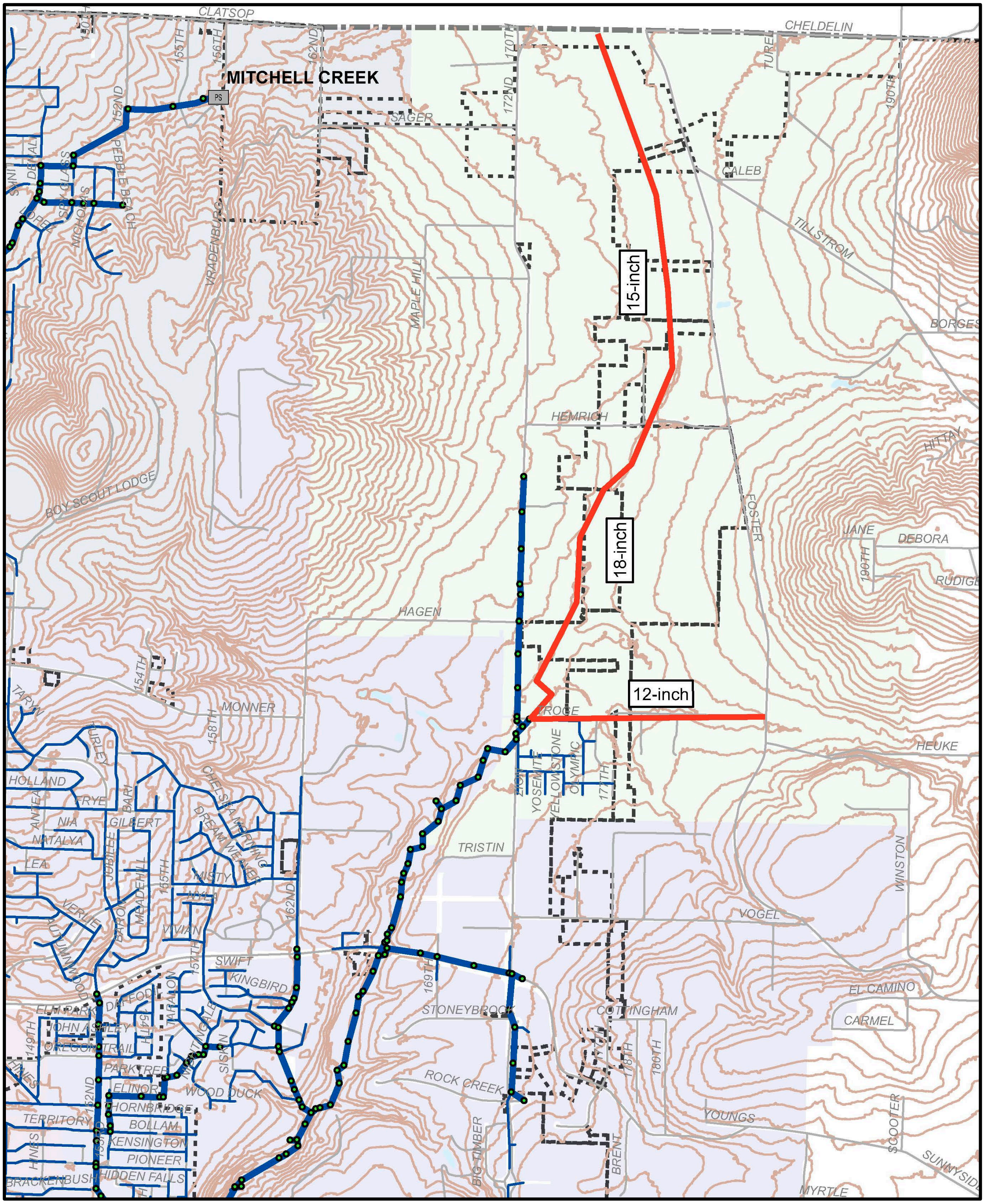


Figure 9-11. System Extension for Future Service

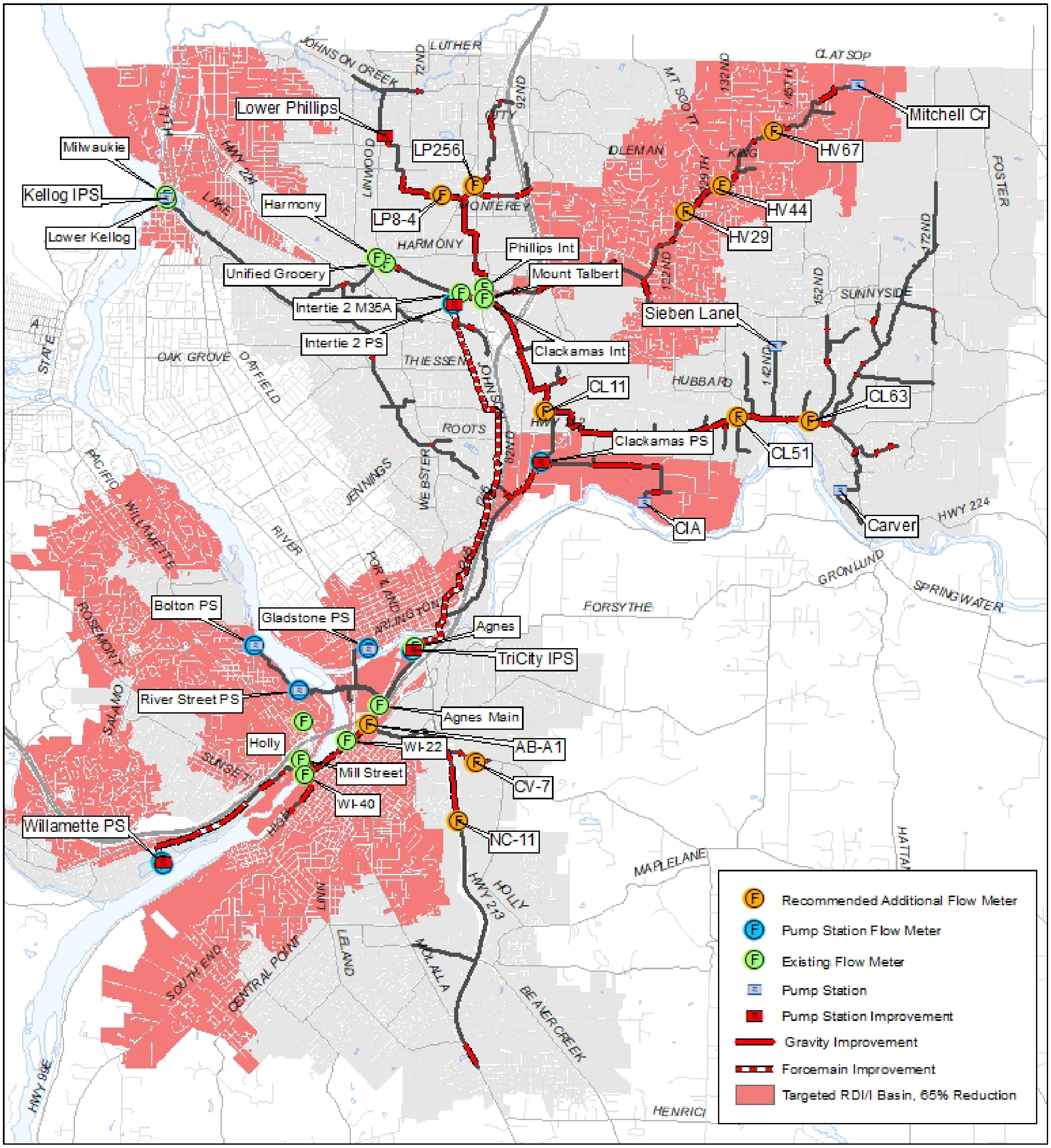


Figure 9-12. Flowmeter Recommendations for Capital Improvement Triggers and Targeted RDI/I Reduction Basins by 2040

Table 9-2. Basin Details Identified for RDI/I Reduction by 2040

Priority	MAP ID	Subbasin	Basin	Jurisdiction	Acres	RDI/I Rate at Timeframe of Reduction Target	Estimated CIPP Rehab Length (miles)	Estimated Lateral Services	Category 1, Percentage (R&R Program)[a]	Category 2, Percentage (RDI/I Rehab Program)[b]
1	25	OC_M08	WI-40	Oregon City	107	54,600	9.7	300	100%	0%
2	26	OC_M10	WI-40	Oregon City	70	47,600	4.2	210	100%	0%
3	37	WL_2	Mill_Street	West Linn	148	31,500	8.0	1,410	87%	13%
4	32	Hwy_43	Holly	West Linn	354	28,000	20.2	1,570	79%	21%
5	18	US_1_10100&DS_2_20400	Gladstone_PS	Gladstone	0.2	28,000	0.3	10	79%	21%
6	40	Buck_Street_2A-19	Holly	West Linn	106	27,600	3.6	290	78%	22%
7	8	1_10100	Gladstone_PS	Gladstone	191	25,400	7.3	1,320	73%	27%
8	41	Holly	Holly	West Linn	94	24,500	3.4	540	71%	29%
9	27	OC_M12	WI-40	Oregon City	522	24,500	30.9	1,920	71%	29%
10	9	2_20400	Gladstone_PS	Gladstone	201	23,700	9.5	1,020	69%	31%
11	34	River_Street	River_Str_PS	West Linn	64	23,200	2.1	490	68%	32%
12	43	WL_1_2B-1-0	Bolton_PS	West Linn	89	21,500	3.2	260	64%	36%
13	36	Willamette_9C-3	Willamette_PS	West Linn	113	20,600	10.2	670	62%	38%
14	42	Mill_Street	Willamette_PS	West Linn	287	19,700	19.7	990	60%	40%
15	24	OC_M05	Agnes_Main	Oregon City	509	19,300	42.7	2,180	59%	41%
16	5	Mount_Talbert	Mount_Talbert	Clackamas Co	1603	18,900	93.7	6,800	58%	42%
17	39	Bolton_3A-8	Bolton_PS	West Linn	284	18,000	21.1	1,450	56%	44%
18	19	Milwaukie	Milwaukie	Milwaukie	1087	17,100	41.9	5,850	54%	46%
19	2	Clackamas_PS	Clackamas_PS	Clackamas Co	466	15,000	12.9	2,130	53%	47%

[a] Category 1, R&R Program: Percentage of piping/laterals within the subbasin excluded from the cost effectiveness analysis and attributed to local pipe repair and replacement.

[b] Category 2, RDI/I Program: Percentage of piping/laterals within the subbasin included in the cost effectiveness analysis and attributed to RDI/I reduction.

As stated in Section 5, the system-wide cost effectiveness incorporated two categories of cost:

- Category 1 – Costs of an R&R Program to invest in aging infrastructure funded by local rate payers and administered by local cities or jurisdictions. The result is a cost-effectiveness analysis that incorporates the reduction of I/I due to local asset management actions. Therefore, the costs for Category 1 pipe repair or replacement were excluded from the RDI/I cost-effectiveness evaluation because the local investment is assumed to be built into local rate structures for improvement of piping that reaches the end of its useful design life.
- Category 2 – Costs were developed for additional RDI/I reduction to supplement the Category 1 reduction, cost-effectively minimize system peak flow rates, and reduce conveyance and treatment costs. Category 2 costs were included in the RDI/I cost-effectiveness analysis as rehabilitation costs (CIPP lining and lateral repair/replacement) to further reduce overall system conveyance and treatment improvements to cost-effective levels. In some cases, cost- effective rehabilitation occurs prior to the “standard” end of useful pipe design life.

Category 2 costs are included in the cost-effectiveness analysis but are not included in this section. The reason for excluding Category 2 costs is that local jurisdiction selection of I/I reduction methodology will likely differ in approach and cost from the full mainline and lateral rehabilitation assumptions in this analysis. The recommendation is for WES and local jurisdictions to work jointly to develop programs that achieve the targeted amount of reduction for the least cost.

9.3.2 Condition-based Recommendations

As described and further detailed in Section 5, the recommendations for the gravity pipelines fall into the following categories:

- Maintain—Regular inspection and maintenance on a schedule commensurate with the risk rating.
- Special Monitoring—Regular inspection and maintenance with special attention to particular defects (such as corrosion, infiltration, or debris).
- Phased Rehabilitation (Near Term)—Structural rehabilitation of the interceptor should be scheduled for the next reasonable capital planning window (1 to 5 years).
- Phased Rehabilitation (Far Term)—Structural rehabilitation of the interceptor should be scheduled for the future capital planning window (5 to 10 years).
- Rehabilitation—Structural rehabilitation of the interceptor should be scheduled as soon as funding and resources are available.

Figure 9-13 displays a map of the inspected interceptor assets with a summary of the condition-based recommendations for gravity pipelines. These recommendations have been incorporated into the projects previously identified in this section.

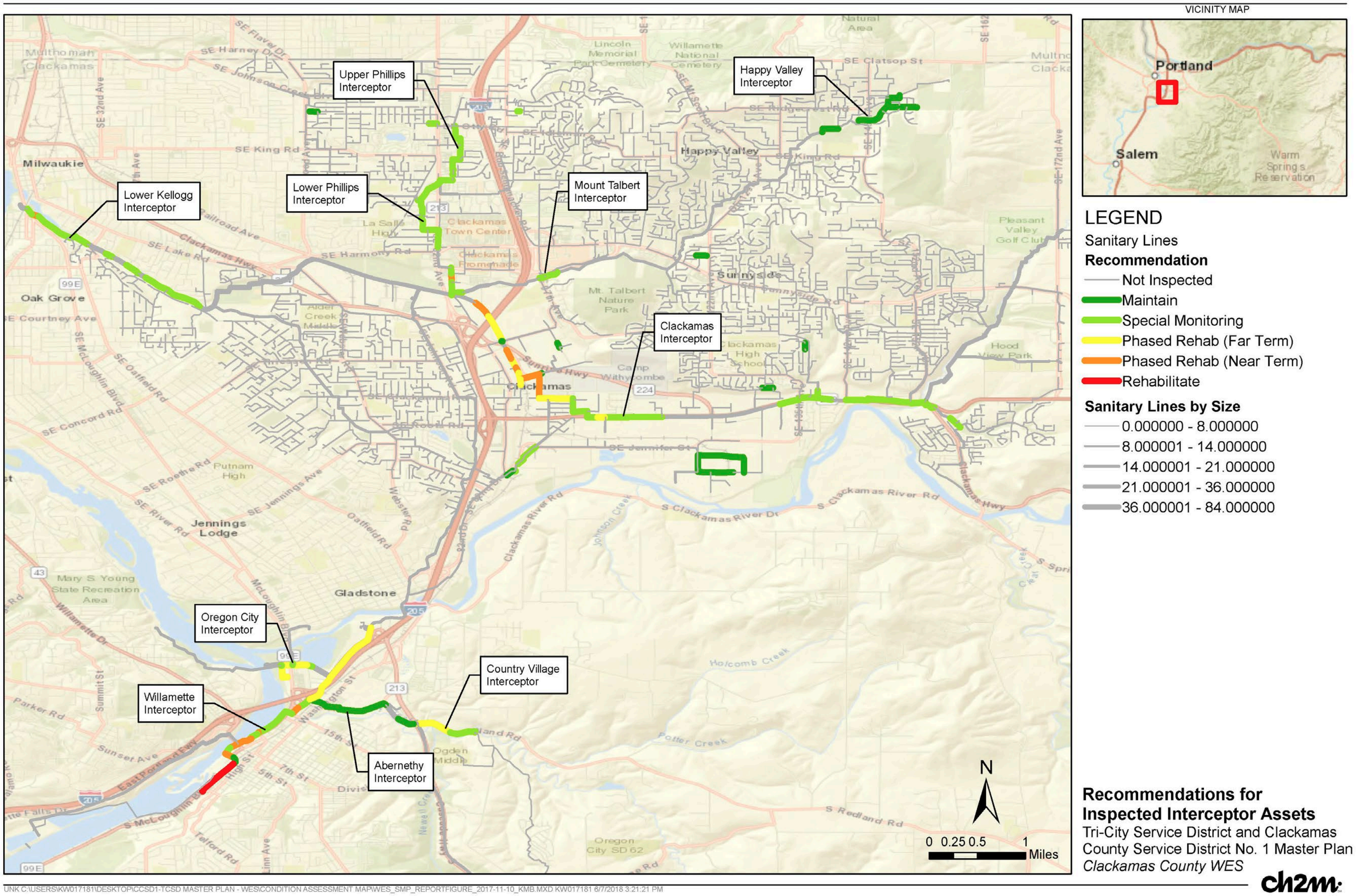


Figure 9-13. Condition Assessment Recommendations for Inspected Interceptor Assets

9.3.3 Treatment Plant Improvements

The estimate for the 2040 peak wet weather flow at the Tri-City plant accounting for growth, I/I increases through degradation, and 65% I/I reduction resulting from rehabilitation in targeted basins is 104.4 mgd.

Additional treatment capacity and associated capital costs for the expansion of the Tri-City WRRF were estimated by WES (Estimated Cost to Treat Projected Peak Wet Weather Flow at Tri-City WRRF, December 4, 2017). The expansion would be accomplished in three phases.

The treatment cost estimates are represented by a step curve up to a maximum capacity of 108 mgd and extrapolated linearly for degraded peak flow rates greater than 108 mgd. Operations and maintenance costs for the Tri-City WRRF were estimated based on the operations costs for 2016-2017 as provided by the WES operations team, and were estimated as present-worth costs using a 3-percent discount rate over 60 years. Costs are summarized in Section 8 and detailed in Appendix A.

9.3.4 Project Prioritization

Because some deficiency areas carry multiple alternatives forward, the specific projects are not yet selected. As a result, the prioritization of specific projects is not possible. Therefore, prioritization information is established based on the timing of deficiencies, both for areas where multiple alternatives remain, and for specific projects recommended in this section. As project implementation timing is established through the CIP process, it is recommended that the collection system model be used to assess the changes to system deficiencies which could in turn modify the project priorities.

The Willamette Pump Station, Clackamas Pump Station, and Intertie 2 Pump Station improvements all contribute to higher flow requirements at the Tri-City WRRF. These pump station improvements are identified for timing based on required conveyance capacity, but should also be coordinated with planned timing of future treatment upgrades.

The prioritization locations are in parallel with the conveyance, pump station and I/I reduction elements of the recommended cost-effective solution are the treatment capacity upgrades. These increases to treatment capacity, particularly wet weather treatment must be coordinated with the other elements of the plan to ensure available treatment capacity as collection system improvements allow for increases to the flows at the plant.

The prioritization locations within the collection system are listed in Tables 9-3 and 9-4.

Table 9-3. Summary of Recommended Capital Improvement Projects

Area	Project Components	Capital Cost ($M)	Required Timeframe for Project to be in Service
West Linn/ Willamette	**Alternative 2 – West Linn/Willamette Storage Project** Retrofit existing lagoon for storage of 4 million gallons of untreated wastewater (eliminates 11 mgd peak flow) (Storage can be reduced for Build Out flows) – Includes sludge removal and rehabilitation of existing open lagoon Upsize Upper Willamette Interceptor to 18-36” Upsize Middle Willamette Interceptor to 36-54”	$37.3	Current
	Alternative 3 – West Linn/Willamette Blue Heron Alignment Project Construct new Willamette PS at 10 mgd at 80 feet TDH Use existing 28” HDPE and 24” CCP Blue Heron piping Rehabilitate existing 24” FRP river crossing Install new 20” gravity pipe from Blue Heron piping to Willamette Interceptor Upsize Upper Willamette Interceptor to 18-42” Upsize Middle Willamette Interceptor to 54-60”	$21.5	

Table 9-3. Summary of Recommended Capital Improvement Projects

Area	Project Components	Capital Cost ($M)	Required Timeframe for Project to be in Service
	Alternative 4 – West Linn/Willamette New Force Main Alignment Project Construct new Willamette PS at 10 mgd at 185 feet TDH Install new 24" parallel Willamette FM (using I-205 crossing alignment) Upsize Upper Willamette Interceptor to 18-36" Upsize Middle Willamette Interceptor to 42-54"	$23.3	
Mount Talbert/ Happy Valley	**Mount Talbert Interceptor Project** I/I source investigation	--	Current
Sieben Lane	**Sieben Lane Pump Station Project** Wet well and pump rehabilitation	$0.4	Current
WES Service Area	**I/I Reduction Program** Develop 65% I/I reduction program for 19 basins	--	Current
Clackamas/ Intertie 1/ Intertie 2	**Alternative 3 – Clackamas Diversion to Jennifer/Intertie 1 Project** Upsize Upper Clackamas Interceptor to 30-54" Increase Intertie 2 PS to 19 mgd at 150 feet TDH Complete and use 30" Intertie 2 FM segments Install new 48" gravity main from Clackamas Interceptor to Jennifer Main Upsize Jennifer Main to 42-48" Construct new Clackamas (Intertie 1) PS at 15 mgd at 120 feet TDH (Replaces existing PS) New 24" Intertie 1 FM Implement three Creeks hydraulic modifications	$52.6	Current (Intertie 2 PS and FM); 2020 (Clackamas Interceptor, Clackamas PS, Intertie 1 FM, Jennifer Main)
	Alternative 4 – Clackamas Diversion to Jennifer/Intertie 2 Project Upsize Upper Clackamas Interceptor to 30-54" Increase Intertie 2 PS to 19 mgd at 185 feet TDH Complete Intertie 2 30" FM segments Install new 48" gravity main from Clackamas Interceptor to Jennifer Main Upsize Jennifer Main to 42-48" Construct new second Clackamas (Intertie 1) PS at 12 mgd at 145 feet TDH Install new 30" FM from Clackamas PS to the 20" Intertie 2 FM (using Manfield Ct) and connect to lower segment of 20" existing Intertie 2 FM Implement three Creeks hydraulic modifications	$50.8	
Lower Clackamas	**Lower Clackamas Interceptor Rehabilitation Project** Rehabilitate existing Lower Clackamas Interceptor	$5.9	2025
Upper and Lower Phillips	**Lower Phillips Project** New Linwood PS at 2 mgd at 105 feet TDH New 12" Linwood FM Decommission existing Lower Phillips PS Reconfigure Lower Phillips FM to flow to new Linwood PS (no gravity improvements required) Upsize Lower Phillips Interceptor to 18-24"	$7.7	2025
Rock Creek	**Rock Creek Interceptor Extension Project** 12"-18" extension to existing interceptor	$6.2	2025
Lower Willamette	**Lower Willamette Interceptor Rehabilitation Project** Line existing lower Willamette Interceptor	$11.8	2030
Oregon City	**Oregon City Interceptor Rehabilitation Project** Line existing upper Oregon City Interceptor	$1.5	2030

Table 9-3. Summary of Recommended Capital Improvement Projects

Area	Project Components	Capital Cost ($M)	Required Timeframe for Project to be in Service
Newell Creek and Country Village	**Newell Creek Interceptor and Country Village Interceptor Project** Upsize upper Newell Creek Interceptor to 21” Use existing middle Newell Creek Int. Upsize lower Newell Creek Interceptor. to 24-27” Upsize Country Village Interceptor to 12-21”	$4.4	2040
Tri-City WRRF	**Treatment Plant Improvements with Storage** If West Linn/Willamette Alternative 2 (Storage) is implemented, increase treatment capacity to 93 mgd	$90	2020-2040[a]
	Treatment Plant Improvements Without Storage If any other alternatives are implemented, increase treatment capacity to 104 mgd	$112	

[a] The 93 mgd or 104 mgd capacity is not required until 2040; however, it is WES’s intention to perform the full capacity increase in the 2020 to 2030 timeframe. The existing peak flow of 78.3 mgd exceeds current treatment capacity of 68 mgd.

Table 9-4. Summary of Recommended Minor Condition-Based Improvement Projects

Area	Project Components	Capital Cost	Timeframe
Bolton and River Street Force Mains	**Bolton and River Street Force Main Rehabilitation Project** Coating, rehabilitation, and/or replacement of pipe spools and appurtenances exposed in vaults	$20,000	Existing
Gladstone Force Main	**Gladstone Force Main Painting Project** Inspection of the bridge superstructure and assessment of needed painting touchups	$100,000	Existing
Willamette Force Main	**Willamette Force Main Rehabilitation Project** Demolition of existing unused air-vacuum relief valve and vault	$7,000	Existing
Lower Kellogg	**Lower Kellogg Interceptor Project** Monitoring with isolated spot repairs to remove active infiltration	$200,000	2025

9.3.4.1 Early Action Projects to Delay Capital Costs Action

There are limited locations that represent restrictions that are not common to an entire reach or area. Therefore, key locations in the system and the associated conveyance system components have been identified here for potential phased implementation to delay other elements of the recommended capital improvements. The following early projects are recommended to provide flexibility for CIP implementation in coordination with planned flow monitoring.

1) Early RDI/I source identification and RDI/I rehabilitation within the Mount Talbert and Happy Valley Interceptor Basin. Elimination of 2 to 3 mgd peak wet weather flow in the basin will minimize interceptor capacity projects and provide partial relief to capacity limitations at the Intertie 2 Pump Station, Kellogg WRRF, and Tri-City WRRF. With the peak flow reduction in the basin, capacity at the Intertie 2 Pump Station and Tri-City WRRF can be used for near-term growth-related flow increases in the Clackamas Interceptor Basin. Utilize recommended flowmetering at HV29, HV44, HV67, and the permanent Mount Talbert meter to evaluate source location and track the effectiveness of rehabilitation project work.

2) Early RDI/I source identification and RDI/I rehabilitation within the Milwaukie Basin. An estimated 4 to 5 mgd peak flow reduction will provide immediately relief to the Kellogg WRRF (assuming 25 mgd expanded peak flow capacity) and allow phasing of additional diversion capacity at the Intertie 2 Pump Station. Based on the maximum available diversion at the Intertie 2 Pump Station by 2040, 13 mgd peak flow reduction in the Milwaukie Basin is required to maintain Kellogg WRRF capacity at 25

mgd. Early reduction of 4 to 5 mgd will help to meet the 2040 targeted reduction of 13 mgd. Utilize the Milwaukie permanent flowmeter and local flowmetering with in the City of Milwaukie to evaluate source location and track the effectiveness of rehabilitation project work.

3) For the Early Action Projects identified in 1 and 2 above it is recommended that a pilot program be used to implement pipeline rehabilitation projects and assess through flow monitoring the corresponding effectiveness of I/I reduction improvements. The results should be used to define the approach to and elements of the remaining I/I reduction activities. The pilot programs can be located by selecting representative subbasins from the larger basin areas. The pilot for item 2 above should occur in coordination with the City of Milwaukie.

4) Early projects on the Clackamas Interceptor, Jennifer Main, Clackamas Pump Station, and Intertie 2 Pump Station are recommended to create flexibility for full implementation over a 5 to 7-year time frame. The following sequencing is recommended:

    a) Near-term improvements to the upper portion of the Clackamas Interceptor, a diversion from the Clackamas Interceptor to the Jennifer Main, and the Jennifer Main are required to accommodate growth in the Clackamas Basin. Once the additional capacity is implemented in the Jennifer Main and the diversion structure on the Clackamas Interceptor is operational, peak flow diversions can be controlled to optimize the flow split between the Clackamas Pump Station and the Intertie 2 Pump Station. This will allow WES to utilize 2 to 3 mgd of available capacity in the middle to lower Clackamas Interceptor and phase improvement projects at the two pump stations.

    b) Implement pump capacity increases at the Intertie 2 Pump Station and complete approximately 3,000 feet of parallel 30-inch force main at the southern end of the force main alignment. Prior to completion of the full parallel force main, this near-term project expands the Intertie 2 Pump Station capacity by 2 to 3 mgd. Coordinate pump selection with the 2040 planned capacity at the pump station.

    c) Implement new pumps, electrical, mechanical, and wet well capacity at the Clackamas Pump Station. Prior to completion of the Clackamas Pump Station force main, this near-term project expands the Clackamas Pump Station capacity by 1 mgd. Coordinate pump selection with the 2040 planned capacity at the pump station.

    d) Utilize recommended flowmetering at CL51, CL63, CL11, the permanent Clackamas Interceptor meter, and the permanent meter at the Clackamas Pump Station to evaluate optimal diversion flow split. Coordinate project timing with RDI/I reduction in the Mount Talbert and Happy Valley Interceptor Basin including potential relief to Intertie 2 Pump Station associated with the reduction.

5) Early RDI/I source identification and RDI/I rehabilitation within the Willamette Pump Station Basin. Elimination of 3 to 4 mgd peak wet weather flow in the basin will provide partial relief to capacity limitations in the Willamette Pump Station, Willamette Interceptor, and West Linn Interceptor.

    Utilize permanent Willamette Pump Station, Mill Street, Holly, WI-40, and WI-22 meters to track capacity and effectiveness of rehabilitation project work.

6) Early projects on the Willamette Interceptor and Willamette Pump Station are recommended to create flexibility for full implementation over a 5-year timeframe. The following sequencing is recommended:

    a) Near-term improvements to the upper portion of the Willamette Interceptor (between WI-54 and WI-22).

    b) If Alternative 3 is selected for the West Linn/Willamette deficiencies, inspection, preparation, and rehabilitation of existing Blue Heron river crossing and pipeline for use as new force main to the Willamette Pump Station. Extension of gravity sewer between the Blue Heron pipeline and the Willamette Interceptor.

    c) Also associated with West Linn/Willamette deficiencies, implement new pumps, electrical, mechanical, and wet well capacity at the Willamette Pump Station including split wet well option for use of new Blue Heron force main and the existing Willamette Pump Station force main. This improvement will allow WES to optimize the flow split between the West Linn Interceptor and the

Willamette Interceptor. Coordinate pump selection with the 2040 planned capacity at the pump station.

For items (b) and (c) utilize permanent Willamette Pump Station, Mill Street, Holly, WI-40, and WI-22 meters to track capacity and to evaluate optimal diversion flow split. Coordinate project timing with RDI/I reduction in the Willamette Pump Station Basin.

9.3.5 Noncapital Master Plan Recommendations

9.3.5.1 Monitoring of I/I Trends, Degradation, and Success of I/I Reduction

The cost-effective solution identified in this Master Plan is dependent on the combined benefits of I/I reduction and improvements in the collection system to increase capacity. Because the rate and amount of both I/I increase over time and the effectiveness of I/I removal are estimated, it is critical to monitor flows in the system relative to these estimates. Initial monitoring should be associated with the pilot project locations recommended above. Subsequent monitoring locations similar to those used in the Master Plan will allow for the most direct comparisons of future actual flows and those estimated in this plan. Improvement timing can then be assessed for acceleration or delay based on the analysis of these data. Permanent monitoring that allows for the capture of multiple wet weather events is recommended in order to best compare the wet weather peak flows in the Master Plan to future system flows as the system ages, and I/I reduction and capacity improvements are implemented.

Flow monitoring data can also serve to monitor key locations as indicators or flow triggers for both capacity improvements and tracking of the 65-percent reduction level. Recommended flow monitoring and flow trigger locations are summarized in Table 9-5 and Figure 9-14 for tracking by 2040.

Note that the recommendations in this section will likely require the acquisition of flow monitors in addition to those currently available from WES.

Table 9-5. Flow Target and Flow Trigger Recommendations

Meter/Pump Station	Meter Status	Basin	Target 2040 Peak Flow with 65-percent RDI/I Reduction (mgd)[a]	Metering Objective	Improvement Trigger Description	RDI/I Capacity Flow Trigger (mgd)[b]	DWF Capacity Flow Trigger (mgd)[c]
CL63	Recommended	Clackamas Int	10.1	Improvement flow trigger	Upper Clackamas Interceptor Capacity	4.4	0.9
CL51	Recommended	Clackamas Int	13.2	Improvement flow trigger	Upper Clackamas Interceptor Capacity, Jennifer Diversion	7.2	1.4
CL11	Recommended	Clackamas Int	15.0	Improvement flow trigger	Middle Clackamas Interceptor Capacity, Jennifer Diversion	8.1	1.6
Clackamas Int	Existing	Clackamas Int	16.3	Improvement flow trigger, Targeted flow may vary for alternatives where Clackamas Interceptor is rerouted to Jennifer Main & Clackamas PS	Lower Clackamas Interceptor Capacity	12.2	2.4
Clackamas PS	Existing (Pump Station)	Clackamas PS	2.0	Improvement flow trigger, Targeted flow may vary for alternatives where Clackamas Interceptor is rerouted to Jennifer Main & Clackamas PS	Jennifer Main and Clackamas Pump Station Capacity,	0.6 (Jennifer Main), 2.5 mgd (Clackamas PS)	0.1 (Jennifer Main), 0.5 mgd (Clackamas PS)
HV67	Recommended	Happy Valley	0.8	Improvement flow trigger, RDI/I meter	RDI/I Source Investigation, RDI/I Reduction, Happy Valley/Mount Talbert Capacity	1.2	0.2
HV44	Recommended	Happy Valley	2.6	Improvement flow trigger, RDI/I meter	RDI/I Source Investigation, RDI/I Reduction, Happy Valley/Mount Talbert Capacity	2.9	0.4
HV29	Recommended	Happy Valley	3.0	Improvement flow trigger, RDI/I meter	RDI/I Source Investigation, RDI/I Reduction, Happy Valley/Mount Talbert Capacity	4.8	0.7
Mount Talbert	Existing	Mount Talbert	8.7	Improvement flow trigger, RDI/I meter	RDI/I Source Investigation, RDI/I Reduction, Happy Valley/Mount Talbert Capacity	15.8	3.2
LP8-4	Recommended	Lower Phillips	2.5	Improvement flow trigger	Upper and Lower Phillips Interceptor Capacity	2.2	0.4

Table 9-5. Flow Target and Flow Trigger Recommendations

Meter/Pump Station	Meter Status	Basin	Target 2040 Peak Flow with 65-percent RDI/I Reduction (mgd)[a]	Metering Objective	Improvement Trigger Description	RDI/I Capacity Flow Trigger (mgd)[b]	DWF Capacity Flow Trigger (mgd)[c]
LP256	Recommended	Upper Phillips	4.2	Improvement flow trigger, monitored upstream of deficient piping	Upper and Lower Phillips Interceptor Capacity	5.0	1.0
Phillips Int	Existing	Phillips Int	8.7	Improvement flow trigger, monitored downstream of deficient piping	Lower Phillips Interceptor Capacity	12.0	2.4
Harmony	Existing	Harmony	5.9	RDI/I meter	RDI/I Reduction	-	-
Milwaukie	Existing	Milwaukie	7.0	RDI/I meter	RDI/I Reduction	-	-
Lower Kellogg	Existing	Lower Kellogg	18.1	RDI/I meter, includes contributions from all basins downstream of Intertie 2 PS with the exception of Milwaukie	RDI/I Reduction	-	-
Unified Grocery	Existing	Unified Grocery	10.4	RDI/I meter	RDI/I Reduction	-	-
Tri-City WRRF	Existing (Pump Station)	Tri-City IPS	70.6	Improvement flow trigger, RDI/I meter	Tri-City IPS Capacity, Tri-City WRRF Capacity, RDI/I Reduction	67.7	-
Tri-City WRRF	Existing	Combination of Intertie 2 PS and Clackamas PS	33.8	Improvement flow trigger, RDI/I meter	Tri-City WRRF Capacity, RDI/I Reduction	12.5	-
Intertie 2 M35A	Existing	Intertie 2 M35A	31.8	Improvement flow trigger, RDI/I meter, Targeted flow may vary for alternatives where Clackamas Interceptor is rerouted to Jennifer Main & Clackamas PS	Intertie 2 Pump Station Capacity	10.0	-
Intertie 2 PS	Existing (Pump Station)	Intertie 2 PS	31.8	Improvement flow trigger, RDI/I meter, Targeted flow may vary for alternatives where Clackamas Interceptor is rerouted to	Intertie 2 Pump Station Capacity	10.0	-

Table 9-5. Flow Target and Flow Trigger Recommendations

Meter/Pump Station	Meter Status	Basin	Target 2040 Peak Flow with 65-percent RDI/I Reduction (mgd)[a]	Metering Objective	Improvement Trigger Description	RDI/I Capacity Flow Trigger (mgd)[b]	DWF Capacity Flow Trigger (mgd)[c]
				Jennifer Main & Clackamas PS			
Kellogg IPS	Existing (Pump Station)	Kellogg IPS	25.0	Improvement flow trigger, RDI/I meter	RDI/I Reduction, Intertie 2 Pump Station Capacity	18.0 (current), 25.0 (expanded)	-
WI-22	Existing	WI-22	41.5	Improvement flow trigger, RDI/I meter, Targeted flow may vary for alternatives where Willamette PS is rerouted to Upper Willamette Interceptor	RDI/I Reduction, Willamette Interceptor Capacity	38.0	4.8
WI-40	Existing	WI-40	7.6	Improvement flow trigger, RDI/I meter, Targeted flow may vary for alternatives where Willamette PS is rerouted to Upper Willamette Interceptor	RDI/I Reduction, Willamette Interceptor Capacity	5.8	0.7
Willamette PS	Existing (Pump Station)	Willamette PS	9.6	Improvement flow trigger, RDI/I meter	RDI/I Reduction, Willamette PS and Force Main Capacity	4.4	0.9
CV-7	Recommended	Country Village	1.2	Improvement flow trigger	Country Village Capacity	1.0	0.2
NC-11	Recommended	Newell Creek	9.0	Improvement flow trigger	Newell Creek Capacity	7.9	1.6
Agnes	Existing	Agnes	1.7	RDI/I meter	RDI/I Reduction	-	-
Agnes Main	Existing	Agnes Main	50.4	RDI/I meter	RDI/I Reduction	-	-
Holly	Existing	Holly	<1.0	RDI/I meter, Target assumes significant reroute of flows via diversion structures to River Street PS and/or Bolton PS; ideal RDI/I contribution with diversion reroutes is ~0 mgd	RDI/I Reduction	-	-
Mill Street	Existing	Mill Street	12.2	RDI/I meter, Targeted flow may vary for alternatives where Willamette PS is	RDI/I Reduction	-	-

Table 9-5. Flow Target and Flow Trigger Recommendations

Meter/Pump Station	Meter Status	Basin	Target 2040 Peak Flow with 65-percent RDI/I Reduction (mgd)[a]	Metering Objective	Improvement Trigger Description	RDI/I Capacity Flow Trigger (mgd)[b]	DWF Capacity Flow Trigger (mgd)[c]
				rerouted to Upper Willamette Interceptor			
River Street PS	Existing (Pump Station)	River Street PS	0.7	RDI/I meter	RDI/I Reduction	-	-
Bolton PS	Existing (Pump Station)	Bolton PS	4.0	RDI/I meter	RDI/I Reduction	-	-
Gladstone PS	Existing (Pump Station)	Gladstone PS	4.1	RDI/I meter	RDI/I Reduction	-	-
AB-A1	Recommended	Oregon City (DS end)	12.8	RDI/I meter	RDI/I Reduction	-	-

[a] The flow target indicates peak flow estimate by 2040 with 65-percent RDI/I reduction in select subbasins. The flow estimates are intended to be used in measuring effectiveness of RDI/I reduction. Targets are established from modeling of the WES design storm.

[b] Estimated RDI/I flow trigger is based on surcharge allowance with minimum 2 feet freeboard for gravity sewers and firm capacity for pump stations. Trigger is intended for measurement during wet weather flow conditions such as the WES design storm. If measured flow is greater than trigger flow during winter months, associated capital improvements are recommended.

[c] Estimated dry weather flow trigger is based on the wet weather flow trigger divided by a location specific RDI/I to DWF peaking factor. Peaking factors range from 4 to 10 throughout the system. Because the wet weather flow trigger may only occur during infrequent large storm events, the dry weather flow trigger is a better measurement of required improvement timing. If measured flow is greater than trigger flow during summer months, associated capital improvements are recommended.

Note: All flow targets and flow triggers are preliminary. Refinement of flow estimates is recommended as additional flow monitoring data are collected or capacity limitations are observed in the system.

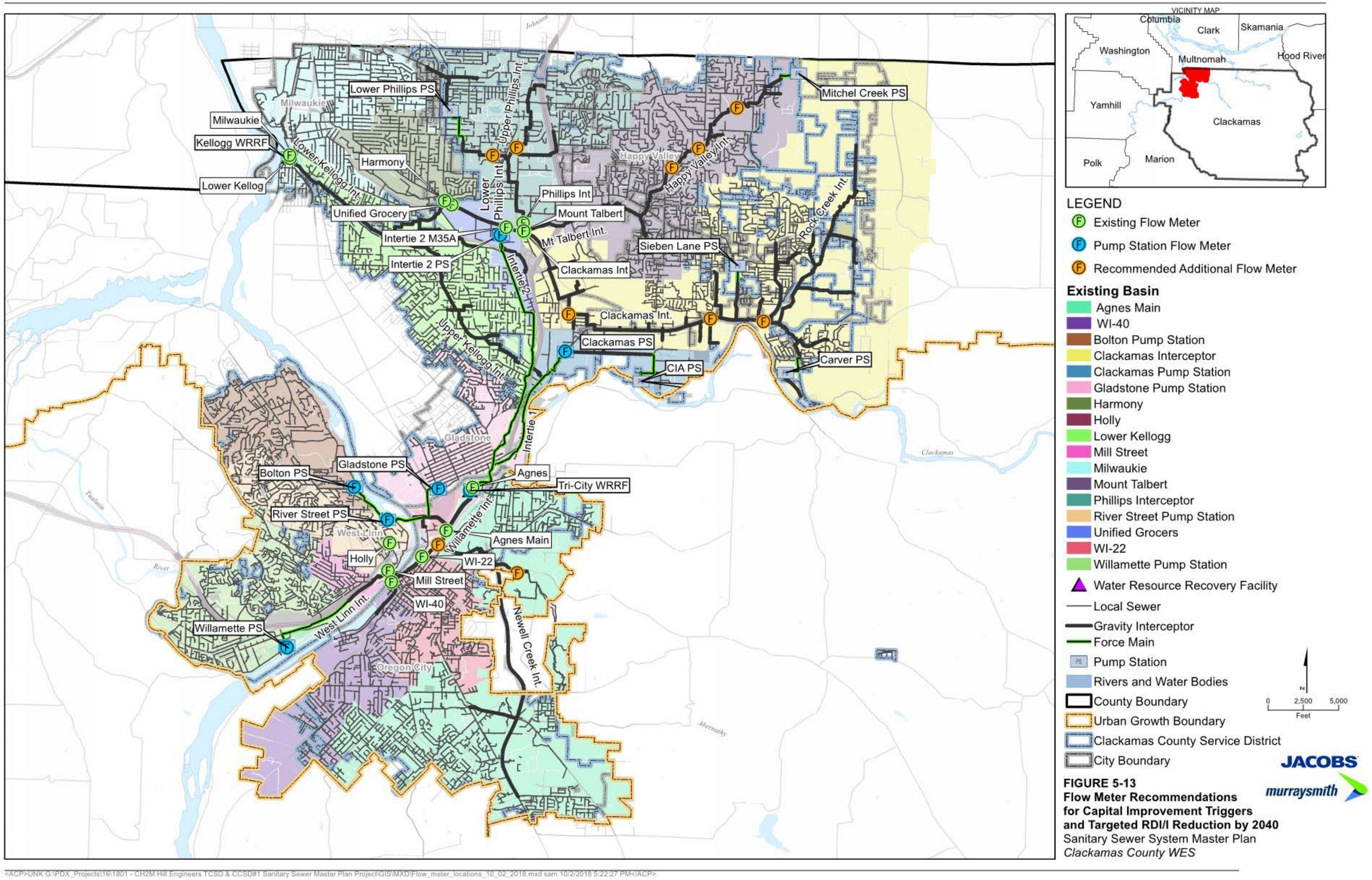


Figure 9-14. Flowmeter Recommendations for Capital Improvement Triggers and Targeted RDI/I

9.3.5.2 General Preventive Maintenance

It is recommended that the interceptors be put on a regular maintenance cycle that includes the following activities:

- Pipe and manhole assets should be inspected on a frequency based on their overall risk rating, as shown in Table 9-6. The methods of inspection should mirror those used in the tiered approach followed during this study.
- For the interceptors that were not inspected as part of this study, inspection should proceed on a schedule prioritized by their current risk rating until more detailed condition assessment data can be collected to supplant the institutional knowledge ratings (similar to the process followed in this study).

For the force mains it is also recommended to perform a regular maintenance cycle which includes the following activities:

- Air relief valves should be flushed at least every year. In addition, they should be disassembled, cleaned, and rebuilt every 2 to 3 years.
- Control valves should be exercised every 1 to 2 years.

Pipe and vault assets should be inspected on a frequency based on their overall risk rating, as shown in Table 9-6. The methods of inspection should mirror those used in the tiered approach followed during this study.

Table 9-6. O&M Recommendations Based on Likelihood and Consequence Scoring

High	5	4-yr cycle	2-yr cycle	2-yr cycle	2-yr cycle	2-yr cycle
	4	6-yr cycle	6-yr cycle	4-yr cycle	2-yr cycle	2-yr cycle
Likelihood	3	8-yr cycle	6-yr cycle	6-yr cycle	4-yr cycle	2-yr cycle
	2	10-yr cycle	8-yr cycle	6-yr cycle	6-yr cycle	4-yr cycle
Low	1	10-yr cycle	10-yr cycle	8-yr cycle	8-yr cycle	6-yr cycle
		1	2	3	4	5
		Low		**Consequence**		High

9.3.5.3 Tier 3 Inspections for Gravity Pipelines

Large diameter rehabilitation projects can be more effectively designed and constructed if Tier 3, high resolution, multisensor information data are available. Multi-sensor inspection may include laser profiling, sonar, and/or pipe penetrating radar. For the rehabilitation projects identified in this report, it is recommended that Tier 3 inspection be performed prior to detailed design or construction.

9.3.5.4 Tier 3 Inspections for Force Mains

Based on the findings of the prior tiers, additional Tier 3 methods including acoustic surveying, in-line inspection tools, and dewatered CCTV were evaluated for some of the force mains. As of the time of this writing, no additional Tier 3 investigation were conducted as part of the Sanitary Sewer Master Plan, but recommendations are made to conduct additional future Tier 3 investigation for select force mains.

9.3.5.5 Pump Station Asset Obsolescence

Pump station assets were place in three categories relative to their obsolescence as follows:

- 1 is Current – Supported
- 3 is Not Current – Supported (Asset is out of date, but parts/repairs are available)
- 5 is Obsolete – Not supported (Asset is out of date and parts/repairs are not available)

Six electrical components in the Tri-City pump stations were found to be Not current--Supported, and four others were found to be Obsolete--Not supported. Table 9-7 lists the assets.

Table 9-7. Tri-City Pump Station Assets That Are Not Current or Obsolete

Pump Station	Asset	Score	Description
58-Bolton	Generator Transfer Switch	5	Obsolete – Not Supported
58-Bolton	Level Control Panel	3	Not Current – Supported
59-Willamette	Level Control Panel	3	Not Current – Supported
59-Willamette	Pump Control Panel	3	Not Current – Supported
59-Willamette	Generator Transfer Switch	5	Obsolete – Not Supported
63-River St.	Generator Transfer Switch	5	Obsolete – Not Supported
63-River St.	Level Control Panel	3	Not Current – Supported
63-River St.	Pump Control Panel	3	Not Current – Supported
70-Gladstone	Pump Control Panel	3	Not Current – Supported
70-Gladstone	Generator Transfer Switch	5	Obsolete – Not Supported
80-82nd Drive	Pump Control Panel	3	Not Current – Supported

Replacement of the assets listed in Table 9-7 should be considered when developing planned capital improvements.

10. References

CH2M. 2017. F*orce Main Condition Assessment Tier 2 and 3 Investigation Plan (Revised).* April.

EcoNorthwest. 2016. *Population Forecast for Clackamas County Service Memorandum*. August.

Health Research, Inc. 2004. *Recommended Standards for Wastewater Facilities*. Accessed September 2018. http://10statesstandards.com/wastewaterstandards.html.

Metcalf and Eddy. 2004. *Wastewater Engineering, Treatment and Reuse*.

Metro. 2009a. *Employment Demand Factors & Trends, Task 1 Report – Metro Employment & Economic Trends Analysis*.

Metro. 2009b. *2009 – 2030 Urban Growth Report*, Appendix 6.

Metro. 2012a. *Regional Forecast Distribution Methodology & Assumptions*.

Metro. 2012b. *Regional 2035 Forecast Distribution.* Accessed September 2018. www.oregonmetro.gov/regional-2035-forecast-distribution.

Oregon Department of Environmental Quality (DEQ), Business Oregon, Rural Community Assistance Corporation, and United States Department of Agriculture. 2018. *Preparing Wastewater Planning Documents and Environmental Reports for Public Utilities Financed by Business Oregon, Oregon Department of Environmental Quality, Rural Community Assistance Corporation, and United States Department of Agriculture*. Accessed October 2018. https://www.oregon.gov/deq/Rulemaking%20Docs/FacilitiesPlansGuidelines.pdf.

Richwine Environmental, Inc. 2013. *Tri-City WPCP Site Master Plan*. June.

Water Environment Services. 2017. C*lackamas County Service WES No. 1 Hoodland Master Plan for Wastewater Services*. January.

JETT Number: AX0907181122PDX