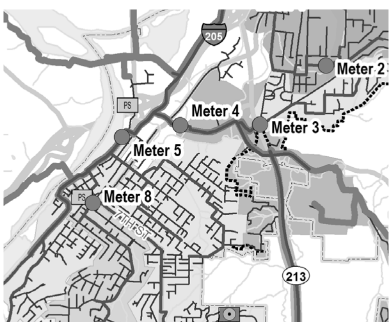
Prepared for

City of Oregon City

# Sanitary Sewer Master Plan

November 2014

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# Sanitary Sewer Master Plan

Prepared for
City of Oregon City, Oregon

October 1, 2014: Ordinance 14-1012
enacted which adopted the Plan

November 1, 2014: Effective date of
Ordinance 14-1012

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# Acknowledgements

The 2014 Sanitary Sewer Master Plan was a collaborative process among various public agencies, key stakeholders, and the community. Input and assistance by the following committees helped make the Plan possible:

**City Commission**

**Planning Commission**

A special acknowledgement goes out to all the Oregon City residents, business owners, and visitors who attended community meetings or submitted comments. Your input helped make this Plan possible.

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# List of Abbreviations

| | |
|---|---|
| AC | asbestos cement |
| BC | Brown and Caldwell |
| CCTV | closed-circuit television |
| CIP | Capital Improvement Plan |
| City | City of Oregon City |
| CSP | concrete sewer pipe |
| d/D | ratio of depth of water to pipe diameter |
| DEQ | Oregon Department of Environmental Quality |
| DIP | ductile iron pipe |
| DLCD | Oregon Department of Land Conservation and Development |
| F | Fahrenheit |
| FM | force mains |
| fps | feet per second |
| GIS | geographic information system |
| gpad | gallons per acre per day |
| gpcd | gallons per capita per day |
| gpm | gallons per minute |
| HDPE | high-density polyethylene |
| HDR | high density residential |
| HGL | hydraulic grade line |
| I/I | infiltration/inflow |
| IMD | Internal Management Directive |
| LDR | low density residential |
| LF | linear feet |
| MDR | medium density residential |
| mgd | million gallons per day |
| NA | not applicable |
| NOAA | National Oceanic and Atmospheric Admin-istration |
| NPDES | National Pollutant Discharge Elimination System |
| NSIP | National Streamflow Information Program |
| PACP | Pipeline Assessment and Certification Program |
| PRI | Pipe Rating Index |
| PVC | poly-vinyl chloride |
| Q | maximum predicted flow |
| Qm | pipe capacity |
| R&R | rehabilitation and replacement |
| RDII | rainfall derived infiltration/inflow |
| ROW | right-of-way |
| RTK | a unit hydrograph method |
| SCADA | Supervisory Control and Data Acquisition |
| SCS | Soil Conservation Service |
| SDC | system development charge |
| SFE | SFE Global, Inc. |
| SSMP | Sanitary Sewer Master Plan |
| SSO | sanitary sewer overflow |
| STEP | Septic Tank Effluent Pump |
| SWMM | Stormwater Management Model |
| TCSD | Tri-City Service District |
| UGB | urban growth boundary |
| USEPA | U.S. Environmental Protection Agency |
| USGS | U.S. Geological Survey |
| WES | Water Environment Services |
| WPCP | Water Pollution Control Plant |

# Executive Summary

The City of Oregon City (City) provides sanitary sewer collection services to nearly 33,000 people spread across an area of approximately 9.3 square miles. Current users of the sanitary sewer collection system total over 10,400 total connections, including 9,740 residential, approximately 520 commercial, and 130 industrial. The City owns the following infrastructure: over 148 miles of gravity pipelines, ranging in size from approximately 2 to 36 inches in diameter; 3,700 manholes; 12 (major) pumping stations; and 6 miles of sanitary force mains. A majority of the sewer system was built after 1980 with much of the sewer pipes being constructed of poly-vinyl chloride.

The City commissioned this Sanitary Sewer Master Plan (SSMP) to provide guidance on capital improvement projects for City projects as required to convey the existing and future wastewater flows to the Tri-City Sewer District (TCSD) trunks and interceptors TCSD and eventually to the Tri-City Water Pollution Control Plant. The City's buildout population is expected to reach 52,500 by the year 2035, with most of the growth occurring around the fringes of the existing city limits.

TCSD was formed in 1980 and is comprised of three primary jurisdictions: the Cities of Oregon City, Gladstone, and West Linn. TCSD's mission is to provide wastewater conveyance, treatment, and disposal services to the three cities. The Clackamas County Board of Commissioners governs the TCSD with the Tri-City Advisory Committee made up from representatives from each city. Current copies of the agreement and amendments between the City and TCSD are included in Appendix K.

## Flow Monitoring and Modeling

To understand the hydraulic needs of the sanitary sewer collection system, 12 flow meters were installed in January 2012 and monitored the City's system for approximately 3 months. In addition, data from six of the City's major pumping stations were collected. Flow and pumping station data were then input into a Storm Water Management Model and the model was used to simulate flows in the sanitary sewer collection system for existing and future flow conditions. The locations of flow monitors and pumping stations used to calibrate the model and the model extents are shown in Figure ES-1.

City staff approved the 10-year, 24-hour event (3.5 inches) for use as the design storm and to identify any deficiencies in the collection system. Designing new and replacement sewers around this storm event rather than the Oregon Department of Environmental Quality's minimum 5-year 24-hour event will provide an added level of protection against sanitary sewer overflows (SSO). The National Pollutant Discharge Elimination System (NPDES) permit for the TCSD Water Pollution Control Plant (WPCP) states that all discharges are prohibited. Planning and designing for an event larger than the 5-year event will reduce the likelihood for SSOs and thereby decrease the potential of fines from Oregon Department of Environmental Quality (DEQ) and legal action from third parties.

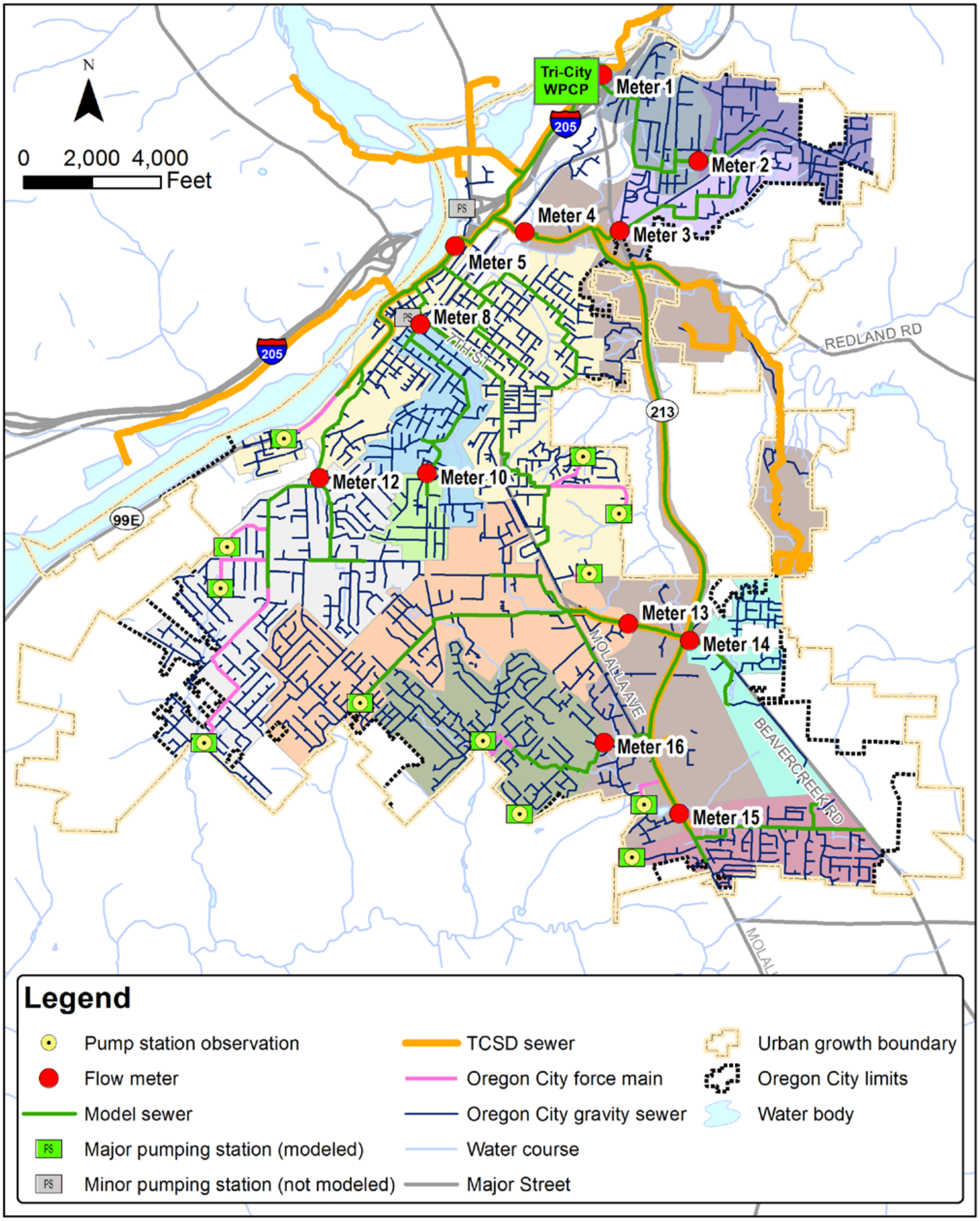



Figure ES-1. Flow meters and pumping stations used for model calibration

## Capital Improvements Needed to Convey Flows

This SSMP identifies $74.5 million in capital improvements recommended to provide sewer service to unserved areas and to convey peak wet weather flows projected for future conditions. Table ES-1 summarizes the overall costs for the required improvements by three categories: sewer upgrades, pumping station and force main improvements, and sewer extensions.

**Table ES-1. Cost of Recommended Future Improvements**

| Description of improvement | Estimated cost of improvements, dollars[a] |
|---|---|
| Sewer upgrades | 3,140,000 |
| Pumping station and force main improvements | 2,170,000 |
| Sewer extensions | 65,930,000 |
| Total | 71,240,000 |

*[a] Estimated costs include a 50 percent allowance for construction contingencies, engineering, and overhead. Costs are rounded to the nearest $10,000.*

Each of these categories is discussed in greater detail below.

Without infiltration/inflow (I/I) reduction, upsizing is needed for 68 pipes that can be grouped into six project areas at an estimated total cost of $3.1 million. Gravity sewer upsizing is largely confined to the older parts of the city within the South Zone meter basins as shown in Figure 3-1. The required pipe size increases are incremental, with all pipes requiring only a single pipe diameter increase to convey the flows. Table ES-2 summarizes the needed gravity sewer improvements.

In addition, the modeling shows surcharging under the existing planning scenario, and surcharging and potential flooding (where manhole covers are not bolted down) for the future planning scenario in portions of the TCSD system. Appendix E identifies the TCSD sewers identified as surcharging.

These projects could be avoided with focused I/I reduction efforts in the immediate and upstream areas, but further investigations and analyses will be required to determine whether I/I reduction is cost effective.

**Table ES-2. Recommended CIPs: Sewer Improvements[a]**

| Project Number | Project Name | Estimated project cost, dollars[b] |
|---|---|---|
| 1 | 12th Street | 410,000 |
| 2 | 13th Street | 460,000 |
| 3 | Division Street | 420,000 |
| 4 | Linn Avenue | 470,000 |
| 5 | Hazelwood Drive | 1,320,000 |
| 6 | Holcomb Boulevard | 60,000 |
| Total all sewer improvements | | 3,140,000 |

*[a] See Section 5 for more detailed information on the recommended improvements.*

*[b] Estimated costs include a 50 percent allowance for construction contingencies, engineering, and overhead. Costs are rounded to the nearest $10,000. Costs assume an average depth of 10 feet using cost condition 2. See Appendix C for unit cost tables.*

The Settler's Point Pumping Station requires upgrades to convey the peak wet weather flows under future conditions. In addition, the Cook Street Pumping Station is barely undersized based on the modeling effort. No major upgrades to this station are recommended at this time, but City staff is advised to monitor incoming flows to see if they approach design capacity. Other pumping station upgrades and modifications (Canemah, Nobel Ridge, Hidden Creek, and Hilltop) are planned by City staff to extend longevity, increase reliability, and reduce maintenance. The total cost for these improvements is estimated to be $3.1 million. Table ES-3 summarizes the needed pumping station improvements.

| Table ES-3. Recommended Existing Pumping Station and Force Main Improvements[a,e] | | | |
|---|---|---|---|
| Project Number | Pumping station | Description of improvement | Estimated cost of improvements, dollars[b] |
| 7 | Canemah | Wet well refurbishment and update of control system | 360,000 |
| 8 | Settler's Point[d] | Upgrade pumping station | 300,000 |
| 9 | Nobel Ridge | Upgrade pumps and control systems | 260,000 |
| 10 | Hidden Creek | Upgrade controls | 60,000 |
| 11 | Hilltop[c] | Decommission existing pumping station and replace with 8-inch, 1,300-foot-long gravity sewer | 440,000 |
| 12 | Parrish Road[f] | Upgrade pumping station | 750,000 |
| Total all pumping station and force main improvements | | | 2,170,000 |

[a] *See Section 5 for more detailed information on the recommended improvements.*

[b] *Estimated costs include a 50 percent allowance for construction contingencies, engineering, and overhead. Costs are rounded to the nearest $10,000. Costs for gravity sewer extensions assume an average depth of 10 feet using cost condition 2. See Appendix C for unit cost tables.*

[c] *This gravity line is planned to serve future development and a portion for the installation costs will be system development charge-reimbursable to the future developer for this new gravity sewer line. The cost of this gravity sewer is not repeated in Section 5.2.3 on sewer extensions.*

[d] *The City has commissioned a study to determine a more comprehensive assessment of this station's condition and future needs.*

[e] *A study should be commissioned to evaluate the best course of action for replacing or de-commissioning existing force mains constructed of asbestos cement. The Environmental Protection Agency is studying the problem but has not yet completed the study or released preliminary recommendations on how best to handle this material.*

[f] *Upgrades to Parrish Road Pumping Station will be dependent on flows routed to the pumping station from the South End Road Concept Area. See Section 5 for description of flow routing options.*

Sewer extensions are required to provide service to those areas not presently served. Areas without sewer service include homes on septic systems, areas within the current urban growth boundary to be brought into the city limits within the foreseeable future (concept areas), and miscellaneous properties inside the city boundary that are not located near existing sewers. The estimated cost of extending sewer service is $68.3 million. Table ES-4 summarizes the sewer extensions and their associated costs.

| Table ES-4. Recommended CIPs: Sewer Extensions | |
|---|---|
| Description of improvement | Estimated cost of improvements, dollars[a] |
| Sewer extensions, Priority 1[b] | 6,090,000 |
| South End Road Concept Area | 22,310,000 |
| Beavercreek Road Concept Area | 15,580,000 |
| Park Place Concept Area | 9,820,000 |
| Sewer extensions, Priority 2[b] | 12,130,000 |
| Total all sewer extensions | 65,930,000 |

[a] *Estimated costs include a 50 percent allowance for construction contingencies, engineering, and overhead. Costs are rounded to the nearest $10,000. Costs assume an average depth of 10 feet using cost condition 2. See Appendix C for unit cost tables.*

[b] *The City may decide to fund Priority 1 sewer extensions through system development charge reimbursements. Priority 2 sewer extensions are expected to be paid directly by development and unlikely to be funded through system development charge reimbursements.*

Figure ES-2 shows the locations of the recommended improvements.

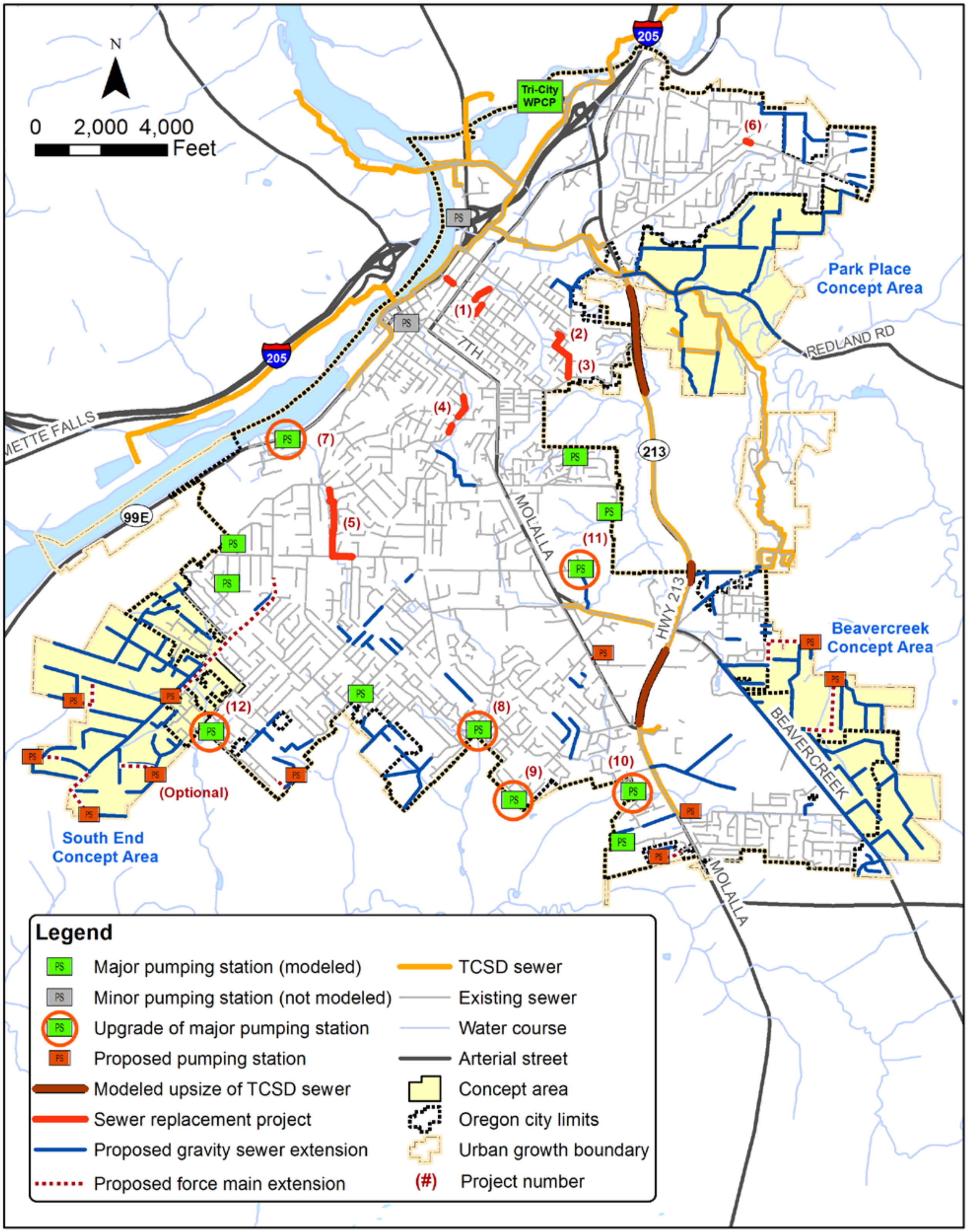



Figure ES-2. Recommended future capital improvements

## Infiltration/Inflow Reduction, Sewer Rehabilitation and Replacement

The City should develop and implement a sewer rehabilitation and replacement (R&R) program to preserve and upgrade the condition of the sewer system as well as to control and reduce infiltration/inflow (I/I). While many of the City's sewers are relatively new and in good condition, some areas are likely worse than others and defects will become more prevalent as the system ages. I/I is relatively high in some areas, contributing to capacity shortfalls in the City's and TCSD's systems.

The City will need to continue its inspection and condition assessment activities to support the R&R program. TV inspection is the primary tool for assessing and documenting the condition of sewers.

As part of the R&R program, the City should assess goals for I/I reduction. As shown in Table ES-5, Basins 8, 5, and 12 (all in the South Zone) contribute the highest I/I rates when normalized by sewershed area or pipe length. Basins 8 and 5 together contribute 49 percent of the peak wet weather I/I but comprise only 29 percent of the sewered area and 29 percent of the sewer main footage in the city. Further analysis is warranted to determine if an I/I reduction program is cost-effective and could defer or even eliminate the need for some predicted future capacity increase projects.

**Table ES-5. Wet Weather Flows for Existing Conditions**

| Meter no.[g] | Estimated sewershed[a], acres | Meter basin pipe length, inch-miles | Average dry weather flow, mgd[b] | Peak 10-year flow, mgd | Peak I/I flow, mgd | Peak I/I low, gpad[c] | Peak I/I flow, gallons per inch-mile per day[f] | Ratio of peak wet weather flow to average dry weather flow |
|---|---|---|---|---|---|---|---|---|
| 1 | 143 | 56 | 0.07 | 0.6 | 0.5 | 3,467 | 8,907 | 8 |
| 2 | 145 | 48 | 0.08 | 1.0 | 0.9 | 6,158 | 18,598 | 13 |
| 3 | 107 | 33 | 0.09 | 0.5 | 0.5 | 4,236 | 13,533 | 6 |
| 4 | 377 | 197 | 0.51 | 1.9 | 1.4 | 3,591 | 6,883 | 4 |
| 5[d] | 717 | 272 | 1.00 | 7.8 | 6.8 | 9,417 | 24,848 | 8 |
| 8[e] | 244 | 84 | 0.96 | 5.0 | 4.0 | 16,371 | 47,635 | 5 |
| 12 | 513 | 182 | 1.00 | 4.9 | 3.9 | 7,570 | 21,373 | 5 |
| 13 | 415 | 145 | 0.71 | 3.2 | 2.5 | 6,091 | 17,440 | 5 |
| 14 | 100 | 34 | 0.20 | 0.6 | 0.4 | 4,336 | 12,935 | 3 |
| 15 | 209 | 70 | 0.12 | 0.7 | 0.6 | 2,719 | 8,144 | 6 |
| 16 | 304 | 103 | 0.25 | 1.8 | 1.6 | 5,255 | 15,505 | 7 |

*[a] The sewershed is estimated as the area within a 200-foot buffer of all sewer mains in the meter basin.*

*[b] Dry weather flow estimated based on observed flow data for the period of February 1 to 8, 2012, which was the longest dry period during monitoring.*

*[c] The peak I/I flow per acre is based on the sewershed as the contributing area.*

*[d] The peak simulated flow shown for Meter 5 excludes approximately 16 mgd, which is the estimated contribution from the TCSD conveyance system originating in the City of West Linn.*

*[e] The values for Meter Basin 8 include Meter Basin 10, which was not used for calibration.*

*[f] The gallons per inch-mile per day value is calculated by dividing the peak I/I flow per day by the length of sewer times its diameter in inches.*

*[g] Numbering of flow monitoring locations is not sequential. Data from flow meter No. 10 is not used since flow monitoring results for this site could not be collaborated with City observations.*

Lastly, defining cost-effective I/I projects requires consideration of the costs of conveying and treating the flows. Since Oregon City is part of the Tri-City Service District managed by TCSD, discussions should be initiated and mutual decisions made to determine the appropriate scope and funding for I/I reduction projects in Oregon City versus upsizing of TCSD conveyance and treatment facilities.

## Section 1

# Introduction

The City of Oregon City (City) provides sanitary sewer collection services to nearly 33,000 people spread across an area of approximately 9.3 square miles. Current users of the sanitary sewer collection system total over 10,400 total connections, including 9,740 residential, approximately 520 commercial, and 130 industrial. The City owns over 148 miles of gravity pipelines ranging in size from approximately 2 to 36 inches in diameter, 3,700 manholes, 12 (major) pumping stations, and 6 miles of sanitary force mains. A majority of the sewer system was built after 1980 with much of the sewer pipe constructed of poly-vinyl chloride.

The City commissioned this Sanitary Sewer Master Plan (SSMP) to provide guidance on capital improvement projects required to convey existing and future wastewater flows to the Tri-City Service District (TCSD) trunks and interceptors and eventually to the Tri-City Water Pollution Control Plant.

This section describes the purpose and scope of work for the master planning project.

## 1.1 Need for the Plan

The City recognizes that changes have occurred in the population, the area available for development, and land uses since the development of the last SSMP in 2003. A new hydrologic/hydraulic model and guidance on the capital improvement needs of the collection system are required as part of prudent planning for the future and for continued reliable and effective sanitary service to the community.

The current population of Oregon City is 32,755 according to the U.S. Census website for 2012. At full build-out to the current Urban Growth Boundary (UGB), the population will grow to approximately 52,500. The service area will grow with approximately 1,799 acres of new land inside the current UGB that may be annexed into the City within the foreseeable future. The SSMP is required to provide up-to-date recommendations for maintaining and expanding the sanitary sewer collection system.

## 1.2 Plan Objectives

The objectives of the SSMP include the following:

- Evaluate the current and future flows and system conveyance capacity.
- Identify capital improvements and their costs as required to convey current and future flows.
- Identify potential additions or extensions of the collection system associated with future growth.
- Identify probable future condition and serviceability of the system due to aging.
- Document the above activities in a new contemporary SSMP.

## 1.3 Approach

In general, the following approach was used for the project:

- Acquisition and review of the geographic information system data with respect to land use, zoning, and the layout of the sanitary sewer system.
- Field survey of key manholes to determine manhole rim elevations and elevations of pipes.
- Identification of data gaps and a request to the City to fill the gaps.

- Development of a hydrologic/hydraulic model.
- Calibration of the model based on flow information from the previous year's wet weather flow monitoring task.
- Additional calibration of the model based on the City's supervisory control and data acquisition information from pumping stations.
- Identification of existing (current) system hydraulic deficiencies and the improvements required.
- Identification of future system hydraulic deficiencies and the improvements required.
- Description of the major elements of a sewer rehabilitation program and why such a program is important for long-term collection system management success.
- Development of the SSMP documenting all of the above.

## 1.4 Plan Organization

The SSMP is organized as follows:

**Executive Summary**

**Section 1** Introduction: defines why the SSMP was developed and its purpose

**Section 2** Basis of Planning: documents the primary elements that formulate the basis of the planning effort

**Section 3** Flow Projections and Modeling: documents the flow projections used in the modeling and the modeling process

**Section 4** Hydraulic Analysis: identifies hydraulic deficiencies for the existing and future planning scenarios

**Section 5** Capital Improvement Plan: identifies capital improvements and their costs associated with existing and future planning scenarios

Appendices A through L provide supporting information for Sections 1 through 5.

## Section 2

# Basis of Planning

This section includes an overview of study area characteristics including location, topography, soils, land use, rainfall, and sanitary sewer collection system conditions.

## 2.1 Background and History

The City of Oregon City (City) was the first permanent Euro-American settlement in the Willamette Valley (1829) and the first incorporated city west of the Rocky Mountains (1844). In the early years, the City was primarily home to fur traders and missionaries and went by the name of Willamette Falls. In the very early years, the Hudson's Bay Company instituted British rule over the region. In 1842, the name of the city was changed to Oregon City. In 1843, the people of Oregon split with British rule with the establishment of the Provisional Government of Oregon. The Oregon Treaty of 1846 formally established the region within the jurisdiction of the U.S. In 1849, the area was officially recognized by the U.S. government as the Oregon Territory with Oregon City as the capital of the territory. Also of note is that the City served as "the end of the Oregon Trail" to large numbers of immigrants who braved the dangers of crossing the North American continent.

In 1849, the City had a population of about 900. By 1880, the City had reached a population of nearly 1,300, then more than doubling by 1890, and reaching nearly 3,500 people by 1900. It was during the 20-year period prior to 1900 that the City's first sewer pipes were installed on the lower terrace and growth started to occur on the upper terrace. Growth continued but slowed during the Great Depression with a population of just over 5,700 in 1930. The City saw substantial growth after World War II, reaching a population of nearly 7,100 in 1950. Growth continued at a rapid pace with a nearly 60 percent increase in population between 1970 and 1990. By 2000, the population was 25,754. The estimated current population is 32,755 based on the 2012 U. S. Census Bureau.

The City's collection system discharges into sewers operated by the Tri-City Service District (TCSD). The TCSD sewers convey the wastewater flows to the Tri-City Water Pollution Control Plant (WPCP) northwest of the city where the water is treated and discharged into the Willamette River.

TCSD was formed in 1980 and is comprised of three primary jurisdictions: the Cities of Oregon City, Gladstone, and West Linn. TCSD's mission is to provide wastewater conveyance, treatment, and disposal services to the three cities. The Clackamas County Board of Commissioners governs the TCSD with the Tri-City Advisory Committee made up from representatives from each city.

## 2.2 City Location

Oregon City is located within the southern portion of the Portland Area Metropolitan Service District's Urban Growth Boundary (UGB) in Clackamas County. Figure 2-1 shows the City's location within the region.

Oregon City is approximately 13 miles south of downtown Portland at the confluence of the Clackamas and Willamette Rivers and is bordered by the City of Gladstone and the Clackamas River to the north, the City of West Linn and the Willamette River to the west, and several large rural unincorporated areas including South End Road Concept Area, Beavercreek Road Concept Area, Park Place Concept Area, and several miscellaneous smaller areas around the perimeter of the city.

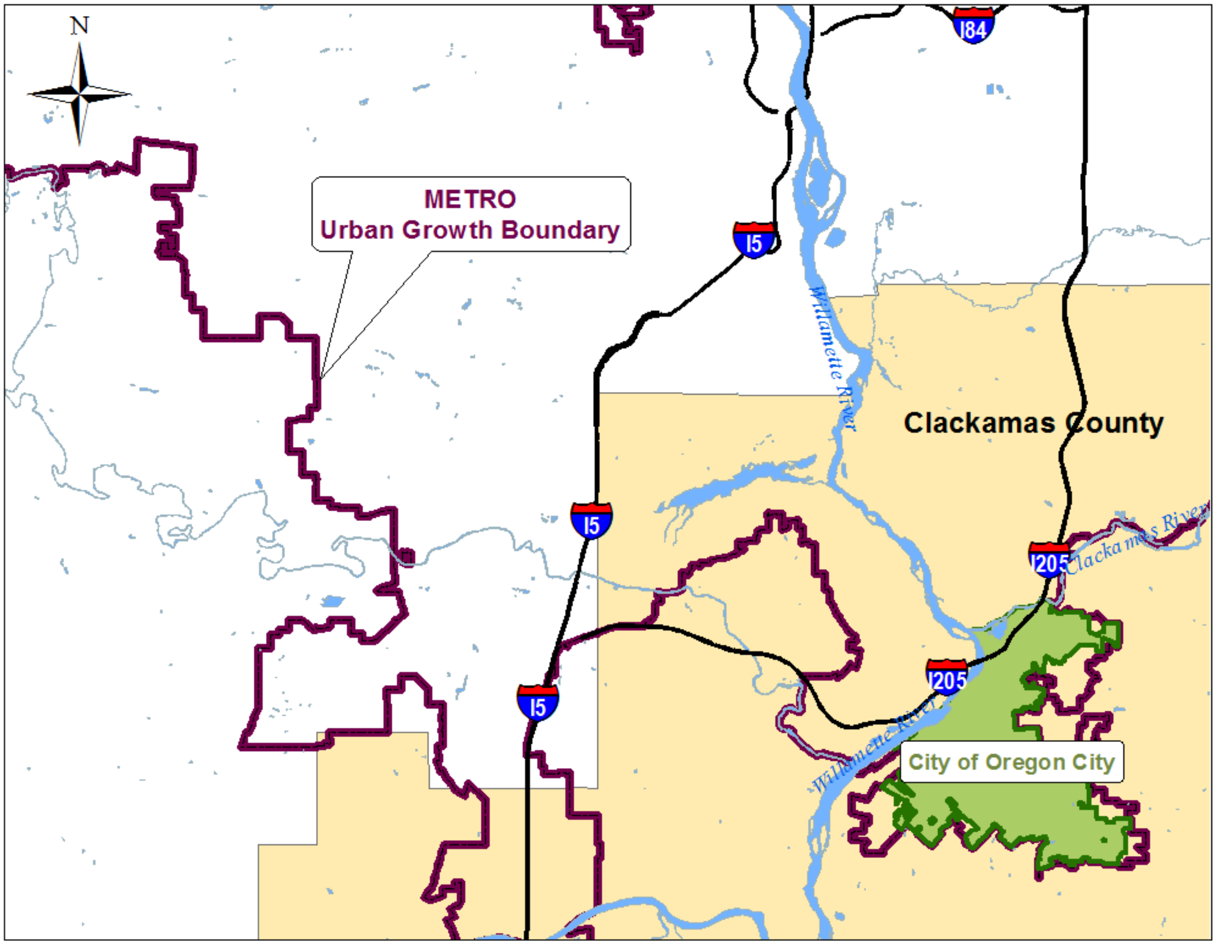



Figure 2-1. Vicinity map

## 2.3 Service Area Description

The City provides wastewater collection services to its residents, commercial establishments, institutional customers, and a number of industries. Sewer service is provided only to customers within the city limits. Figure 2-2 is a general map of the collection system that includes the major pumping stations and portions of the TCSD sewers.

## 2.4 Topography

The topography of Oregon City influences how the sanitary sewer system was constructed. In general the city is divided into several terraces with the older section located on the lower terrace adjacent to the Willamette River and the newer section located on the uppermost terrace. Gravity sewers convey the flow down hills and toward the Tri-City WPCP. Pumping stations convey flows up hills and over divides, ultimately discharging into the gravity sewers.

The city covers an area of approximately 9.3 square miles and ranges from about 10 to 550 feet in elevation. The topography along the northern and western margins of Oregon City is influenced by the Clackamas and Willamette River drainages. To the north, the Clackamas River runs westward, forming the city's northern boundary with the City of Gladstone and to the west, the Willamette River flows northward forming the city's western boundary with the City of West Linn. The historic Willamette Falls are located on the western boundary of the city.

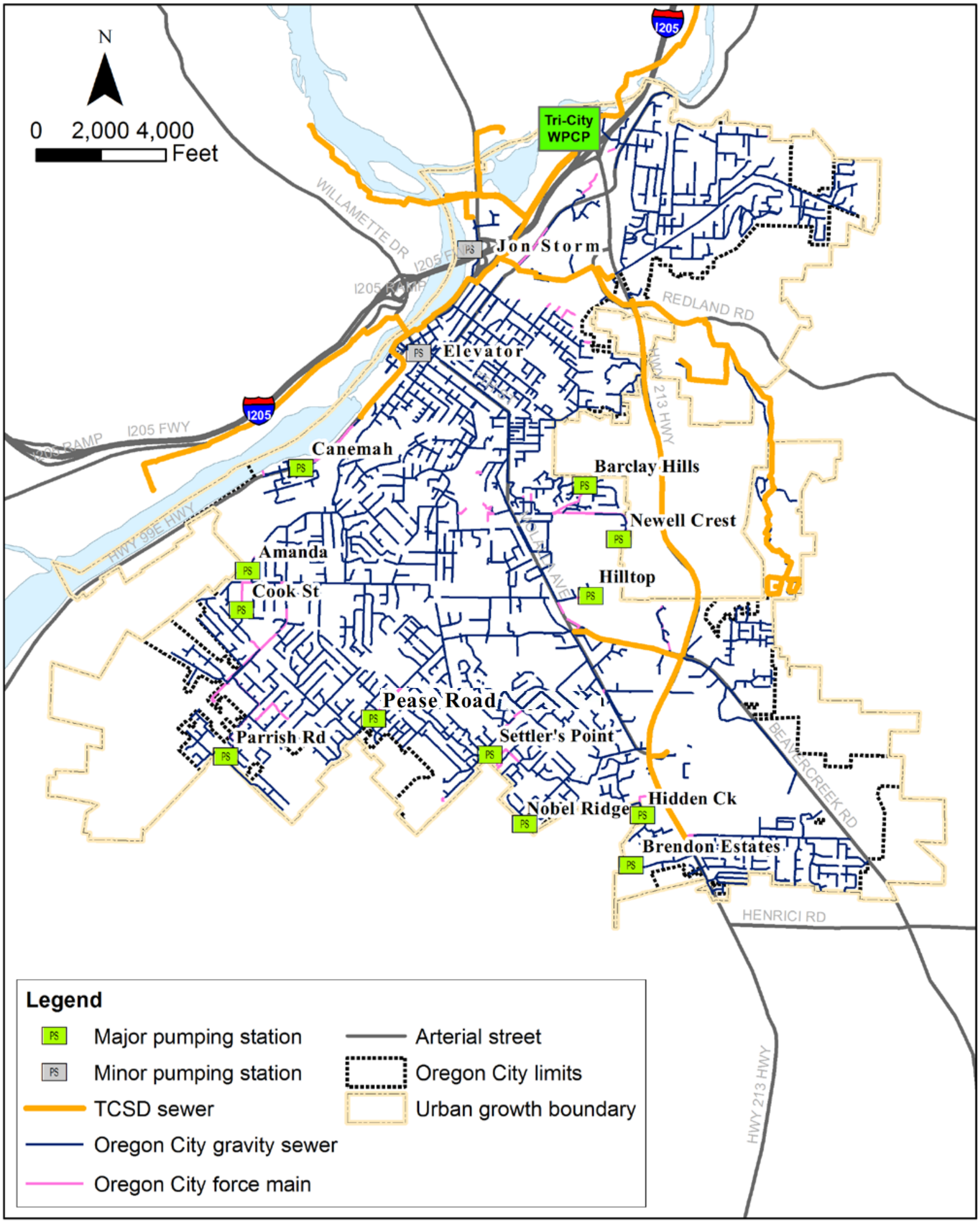



Figure 2-2. Collection system map

The city's unique topography includes three basalt terraces, which rise above the east bank of the Willamette River. The perimeter of the city is dominated by small drainage networks including creeks and springs that radiate outward from the central upland areas of the city. The existing sewer system is influenced by these small drainage networks where pumping stations serve to convey flows from the lowland areas upslope into gravity sewers that ultimately discharge into the TCSD interceptors and the WPCP. As the city grows outward, sewer extensions and additional pumping stations will be required to convey the flow to the existing sanitary sewer collection system.

## 2.5 Climate and Rainfall

Oregon City experiences a similar temperate climate to the surrounding Portland metropolitan area, with relatively warm dry summers and mild wet winters. Winter temperatures average 45 degrees Fahrenheit (F) and summer temperatures average 65 degrees F.

The majority of rainfall occurs during the months of November through April. The driest months are July and August, which typically average approximately 1 inch of monthly rainfall. The average annual precipitation for Oregon City is 47 inches.

## 2.6 Population

The 2012 U. S. Census Bureau shows the population of the City to be 32,755. The Population Research Center at Portland State University calculates the 2013 population to be 33,900. The Oregon City Transportation System Plan (June, 2013) predicts 21,000 households or approximately 52,500 people by 2035. Most of the growth will occur around the fringes of the existing city limits, with the highest population increases expected in lands inside the current UGB that must be annexed by the City. These areas include the South End Concept Area, Beavercreek Road Concept Area, Park Place Concept Area, and areas around the south side of the city.

## 2.7 Land Use and Zoning

Land use and zoning provide the basis for developing future unit wastewater flows and overall wastewater flow projections for buildout conditions. Understanding the nature and distribution of the various land use classifications is important for accurate identification of future wastewater flow rates and the phasing of required improvements. This section describes both the existing and proposed future land uses for the study area.

Land use and zoning are largely governed by the local topography and by decisions made by the City, its citizens, and the Oregon Department of Land Conservation and Development (DLCD). Expansion of the UGB must be approved by DLCD before such actions can be adopted.

Information on current and future land use was obtained from geographic information system (GIS) data provided by the City. The existing land use classifications are shown in Figure 2-3. The existing land use was compared to future zoning to estimate development in the future, which is shown in Figure 2-4.

The future development includes four general categories: redevelopment, new development (of currently vacant land), conversion of areas currently served by septic systems, and concept plan areas. The redevelopment and new development areas were identified by comparing the existing land use and the proposed zoning, and through discussions with City staff. The concept plan areas represent three significant developments located within the UGB (but mostly outside the city). Existing planning efforts provided details on how these concept plan areas are expected to develop. Lands unsuitable for development were incorporated into each category of these future estimates.

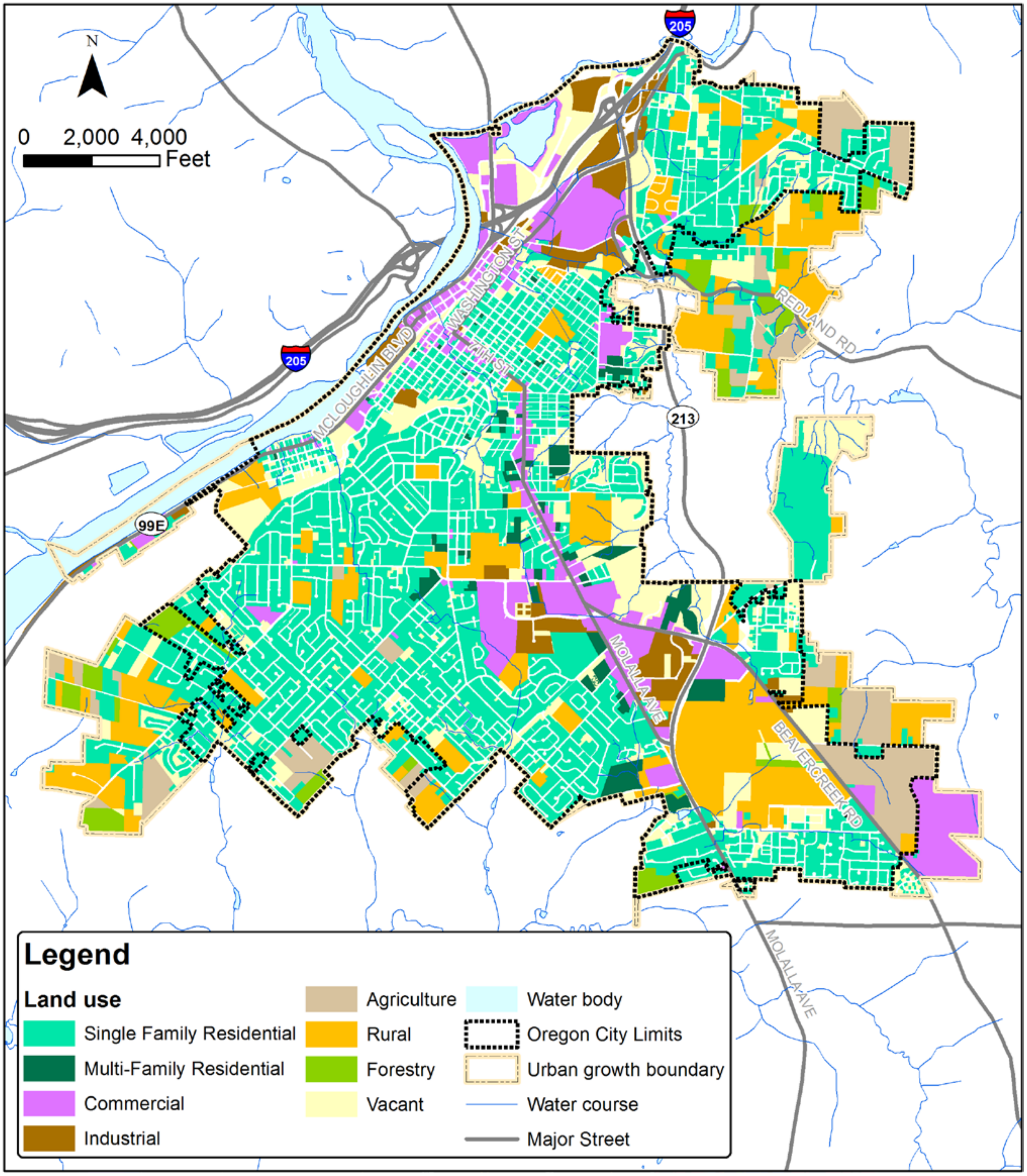



Figure 2-3. Existing land use classifications

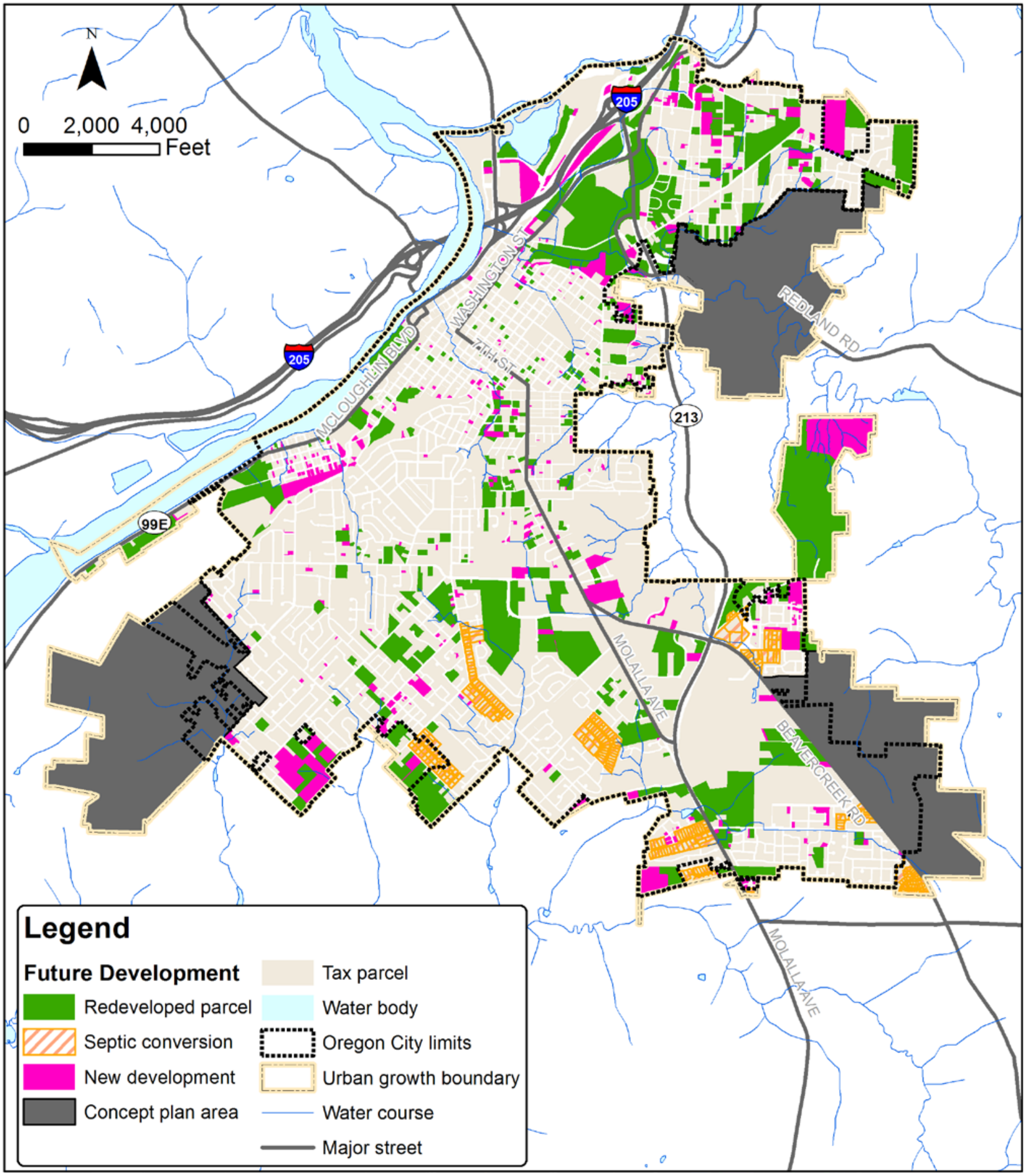



Figure 2-4. Future development for buildout conditions

## 2.8 Description of Existing Collection System

According to the City's GIS, the sanitary collection system includes approximately 148 miles of sanitary sewers, 6 miles of force mains, 3,700 manholes, and 12 major pumping stations, not including homes with a grinder pump system. Figure 2-2 shows the locations of the pumping stations and other major components of the sanitary collection system. The number of service connections or laterals is estimated to be nearly 10,400 with approximately 130 industrial, 520 commercial, and 9,740 residential connections. Laterals are the responsibility of the City from the mainline to the face of curb or edge of pavement when no curb is present. Cleanouts are required by code, but not all laterals have cleanouts and the City does not have a value for the number of cleanouts in the system.

According to GIS data, approximately 73 percent of the City's sanitary sewer system was constructed since 1980. As shown in Figure 2-5, growth was very strong in the 1980s and 1990s but has slowed somewhat since the early 2000s. Age data on the sewers constructed prior to the 1940s is not reliable. Figure 2-6 shows the locations of sewers by age. A review of City sewer age-related documents revealed gaps in the age data. The data suggest that approximately 33,000 linear feet (LF) of sewers were constructed prior to 1940, but the exact date of construction is unknown. Earliest records for sewer construction were found that date back to about 1900.

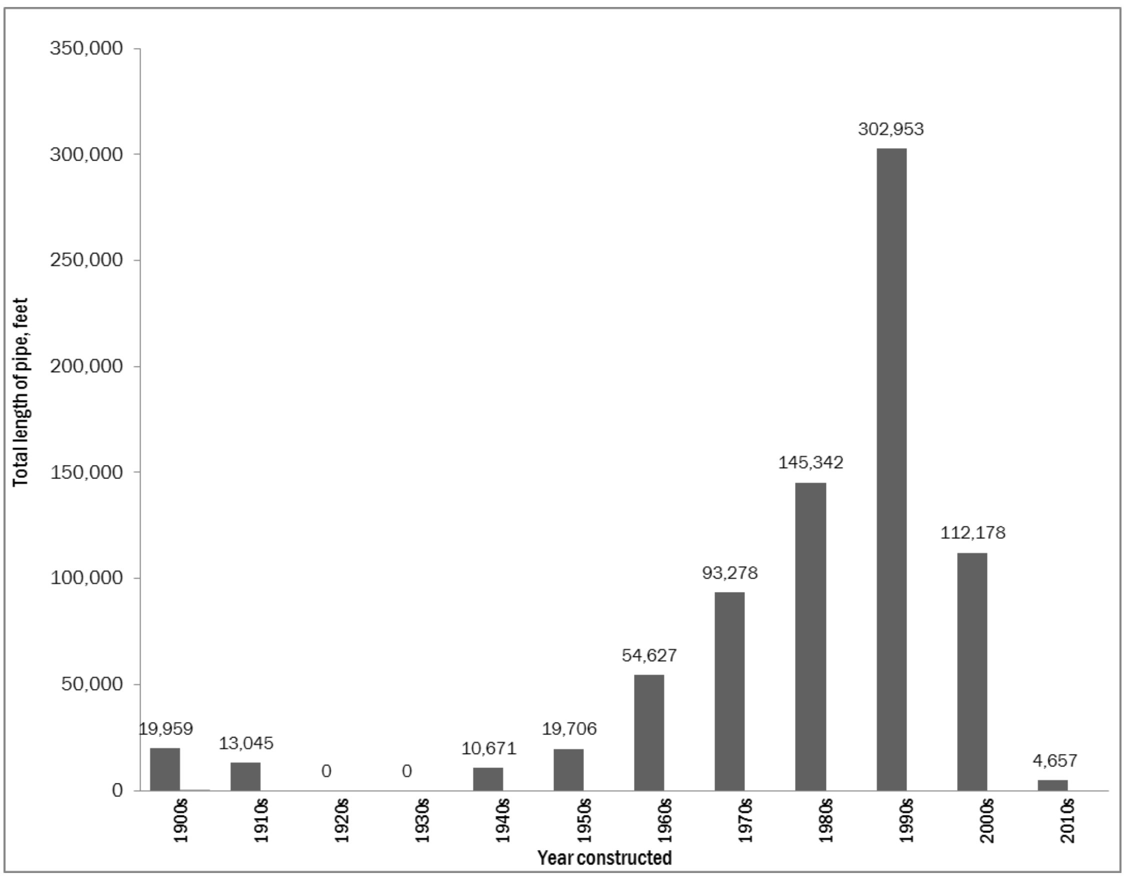



**Figure 2-5. Pipe age distribution**

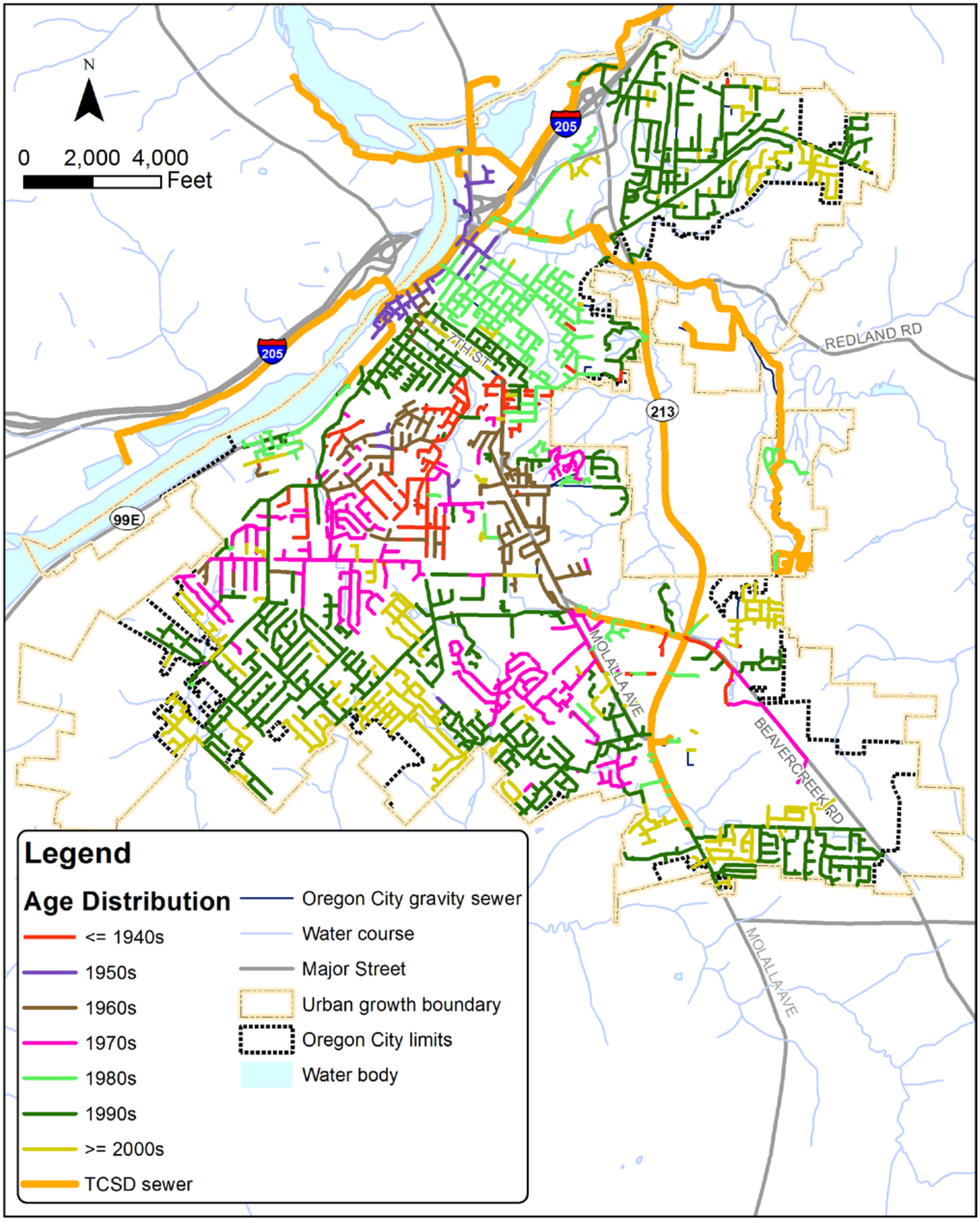



**Figure 2-6. Pipe age location**

The size distribution of pipes within the sanitary collection system is shown in Figure 2-7. Approximately 82 percent of the sanitary sewer collection system consists of pipes 8 inches in diameter and smaller. The larger diameter pipes shown in Figure 2-7 represent sewers owned by TCSD but located within the city limits.

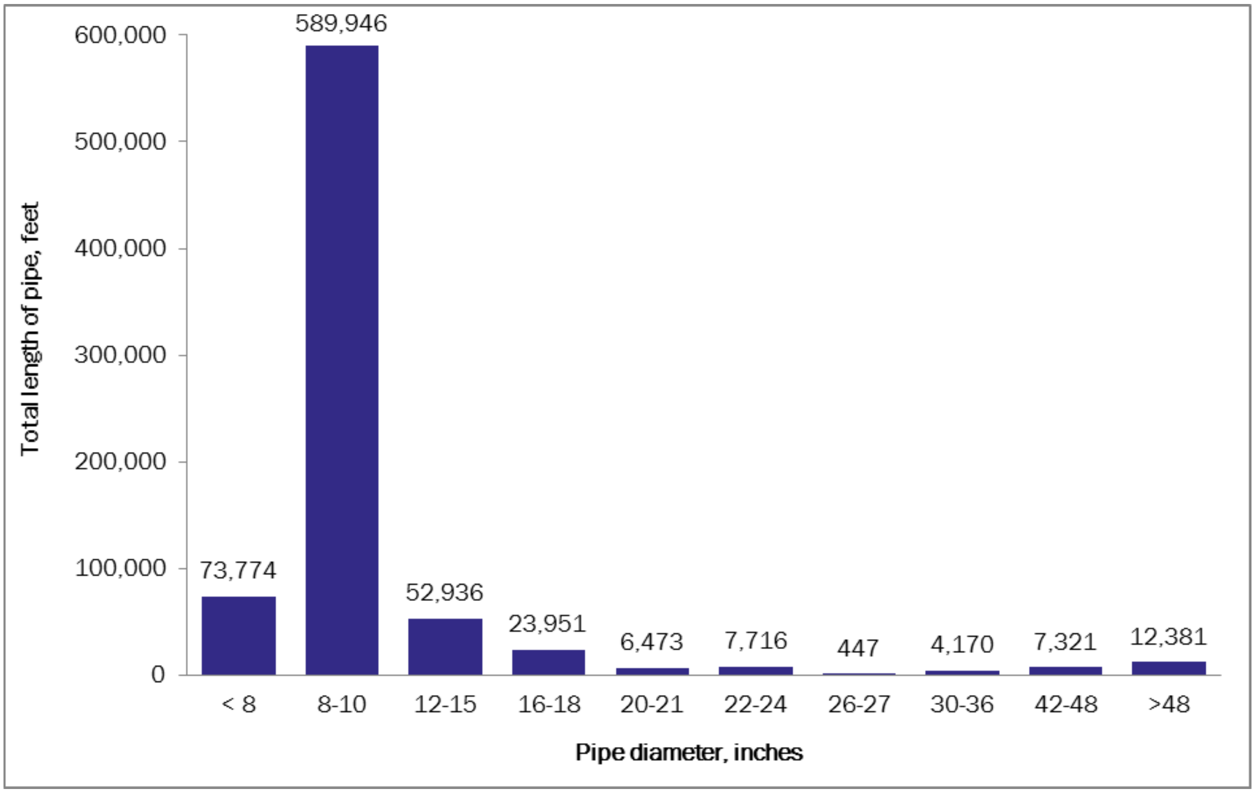



**Figure 2-7. Pipe size distribution**

The distribution of pipe materials used throughout Oregon City is based on data extracted from the City's GIS. Approximately 44 percent of the pipes did not have a material identifier. The distribution of materials shown in Figure 2-8 is based on the pipes for which pipe material was identified. This figure includes the LF of force mains and gravity sewers. Figure 2-9 shows the location of pipe materials as used throughout the collection system.

The most widely represented pipe materials are poly-vinyl chloride (PVC) and concrete sewer pipe (CSP). Most new construction has used PVC pipe as the material of choice. Most, if not all, of the high-density polyethylene (HDPE) and ductile iron pipe (DIP) included in the inventory are used for force mains. Also, some of the City's force mains are constructed of PVC and four pump stations have force mains constructed in part, or in total of asbestos cement.

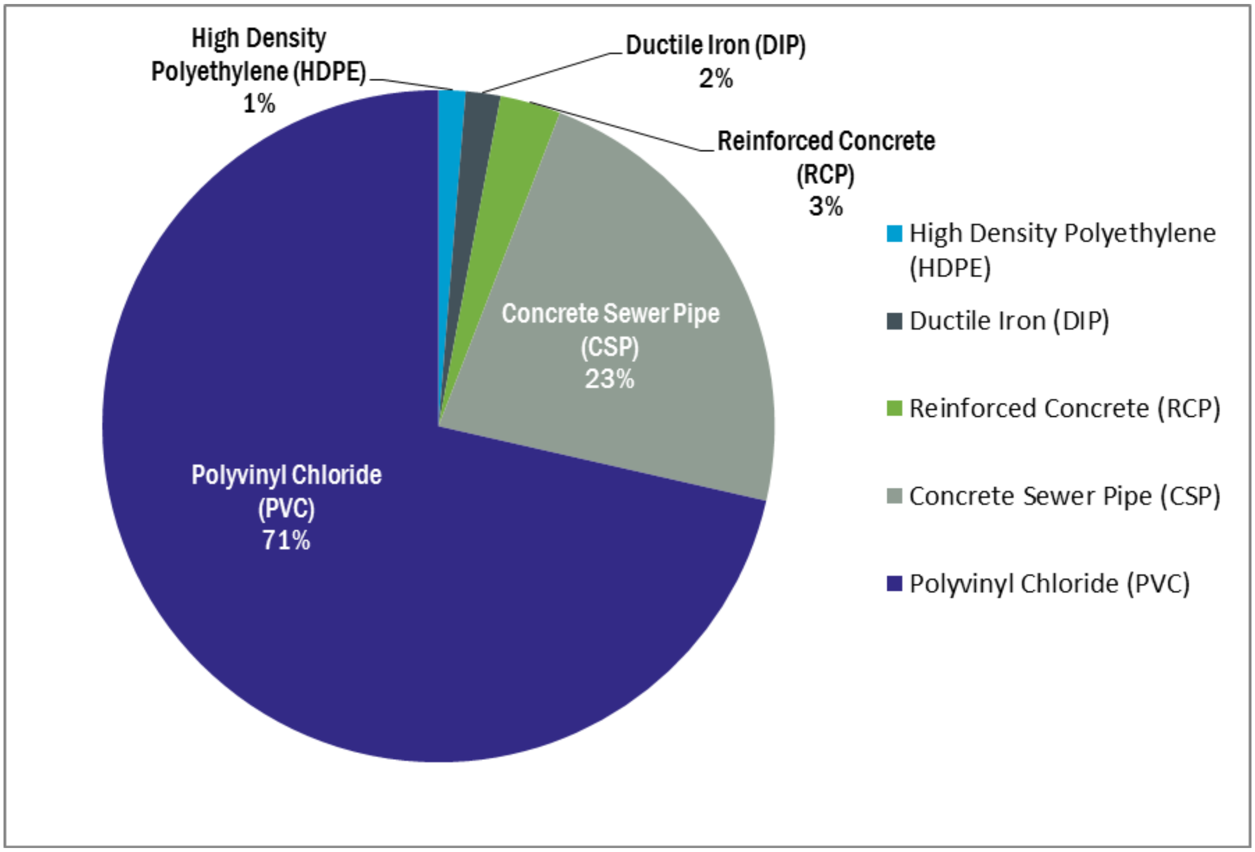



Figure 2-8. Pipe material distribution

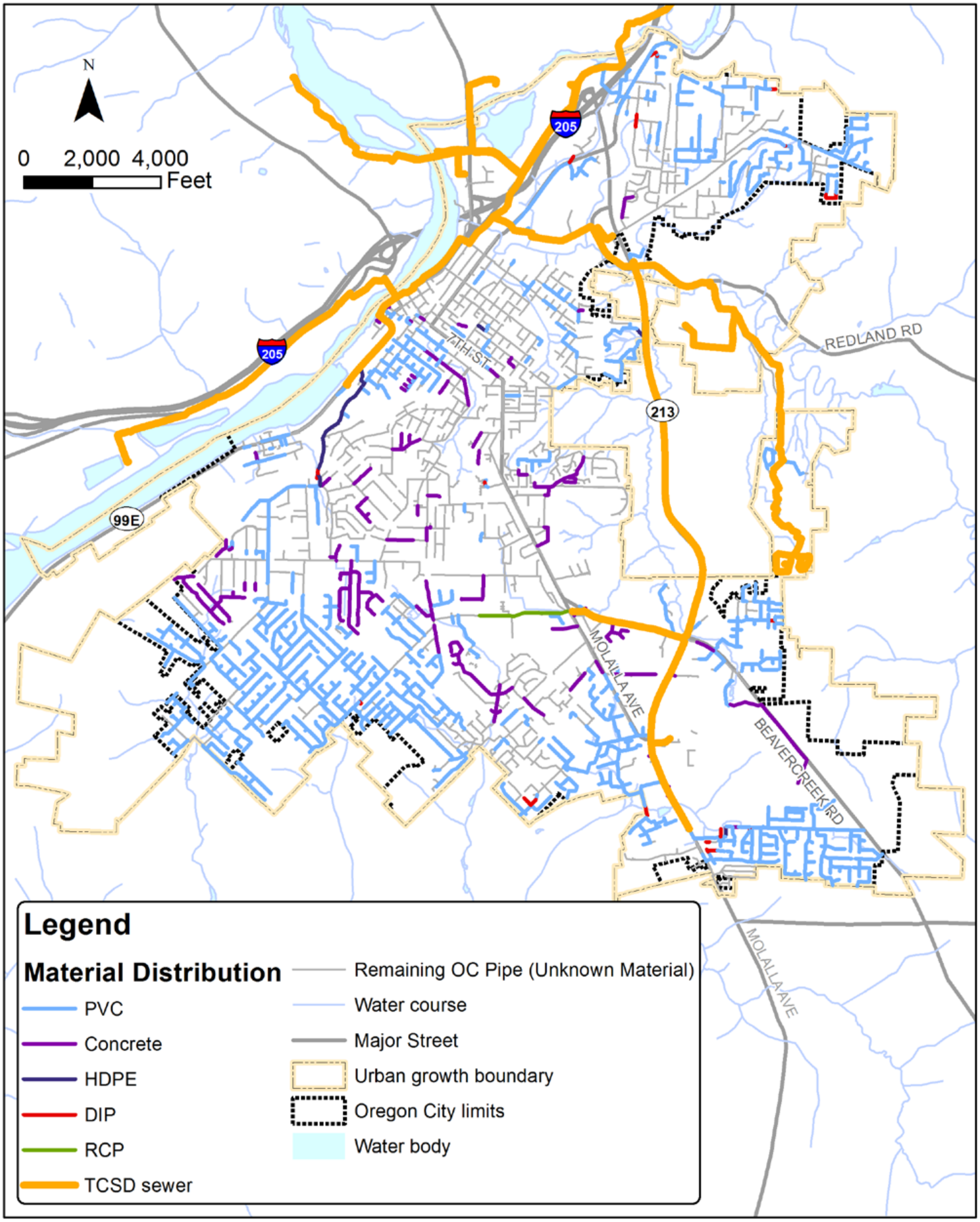



Figure 2-9. Pipe material location

## 2.9 Description of Pumping Stations

The topography of Oregon City has required that pumping stations be used to serve a number of areas throughout the city. Currently, there are 12 major stations within the service area owned and operated by the City. In addition, the City owns several minor pumping stations (i.e., Jon Storm Park and Elevator) and approximately seven residences with individual septic tank effluent pumping (STEP) systems.

A summary of each of the City's 12 pumping station's capacity and general information is provided in Table 2-4. Septic tank effluent pumping systems and grinder pump facilities are not included. More detailed information on each major pump station is provided in Appendix B.

**Table 2-4. Pumping Station Summary**

| Pumping station | Current pumping rated capacity[a], gallons per minute (gpm) | No. of pumps | Force main size, inches | Force main material[f] | Force main length, feet | Year constructed[b] | Year upgraded[c] |
|---|---|---|---|---|---|---|---|
| Amanda Court | 170 | 2 | 4 | Asbestos cement (AC) | 1,655 | 2007 | NA |
| Barclay Hills | 350 | 2 | 6 | AC/DIP | 1,463 | 1973 | NA[d] |
| Brendon Estates | 100 | 2 | 4 | PVC[f] | 225 | 1995 | NA |
| Canemah | 1,200 | 2 | 10 | PVC | 2,097 | unknown | 1994 |
| Cook Street | 620 | 2 | 6 | AC/DIP | 2,350 | 2008 | NA |
| Hidden Creek | 404 | 2 | 6 | PVC | 1,226 | 1992 | NA |
| Hilltop | 95 | 2 | 4 | AC | 485 | 1972 | 2007 |
| Newell Crest | 120 | 2 | 4 | PVC | 3,110 | 1994 | 2007 |
| Nobel Ridge | 140 | 2 | 4 | PVC[e] | 350 | 2000 | NA |
| Parrish Road | 760 | 2 | 10 | PVC | 6,100 | 1998 | NA |
| Pease Road | 1,040/750[f] | 3 | 8 | DIP/PVC | 1,300 | 2010 | NA |
| Settler's Point | 831 | 2 | 8 | PVC | 950 | 1998 | NA |

*[a] The rated pumping capacity is based on one pump operation without the use of the second (redundant) pump. Use of all the pumps at a pumping station does not provide pumping redundancy as per Oregon Department of Environmental Quality/U.S. Environmental Protection Agency (USEPA) requirements.*

*[b] Year constructed is based on force main pipe GIS data if record drawings were unavailable.*

*[c] Year upgraded is based on information provided by the City. Pump configuration and sizes and force main geometries are shown for current conditions.*

*[d] Upgrades to the Barclay Hills Pumping Station are planned for 2014.*

*[e] Not confirmed.*

*[f] The 1,040 gpm flow rate is based on two-pump operation and represents the firm capacity of the pumping station. The 750-gpm is one pump operation.*

Four of the pump stations shown in Table 2-4 use force mains constructed in part, or in total of asbestos cement. The USEPA has identified asbestos as a hazardous material requiring special precautionary handling and disposal procedures. The USEPA is studying the problem (specifically in regards to asbestos cement pipe used in municipal water and sewer systems) but has not completed the study or released preliminary recommendations on how best to handle this material. The City should commission a study to evaluate the best course of action for replacing or de-commissioning the existing asbestos cement force mains. Projects and costs for replacing asbestos cement pipe are not specifically identified at this time but should be included as part of the city-wide sewer rehabilitation and replacement program as discussed in Section 5 should they be found to be in poor condition.

As part of the SSMP effort, City pumping station operation and maintenance staff were interviewed to qualitatively assess the condition of the major stations. The findings of the interviews are included as Appendix B.

## 2.10 Flow Monitoring Activities

Twelve flow meters were installed from mid-January through mid-April 2012 to collect information about wastewater flows in the conveyance system. Flow meters were distributed throughout the wastewater conveyance system to capture flow data for each of the major branches of the piped system. Several flow monitors were installed in Tri-City Service District (TCSD) sewers due to their critical locations throughout the City system.

SFE Global, Inc. (SFE), under contract with Brown and Caldwell, installed and maintained the flow monitors. SFE used an ISCO Model 2150 area-velocity flow monitor at each site. The flow monitoring information was used to develop dry weather flow diurnal patterns and calibrate wet weather response to rainfall.

The flow data included 5-minute averages for a range of conditions including a large storm event (i.e., 2.23 inches in 24-hours) in January and periods of both wet and dry weather. Rainfall for the overall flow monitoring period was approximately 35 percent above average; however, February was about 41 percent below average for the month. The January 17th storm event was just under (in depth) to the 2-year, 24-hour storm event as defined by National Oceanic and Atmospheric Administration (NOAA),

Observations of wet well depth and pump run time at six stations, recorded during the flow monitoring period, were also used for calibration of wet weather response to rainfall. The pump run time information was recorded by the City's Supervisory Control and Data Acquisition (SCADA) system located at the major pump stations. Pump run time and nameplate pump capacity were used to estimate the flows pumped from the pump stations. Actual pump capacity could be less than the nameplate value dependent on force main and impeller conditions. A more accurate representation of these flows would require calibrated flow monitors installed in the force main, or extensive pump draw down testing. This additional effort was not deemed appropriate for this planning document. The flow monitoring sites and associated tributary areas, along with pumping station observation locations, are shown in Figure 2-10.

Additional information on the flow monitoring and pump station run time data and how this information was used to calibrate the model is presented in Appendix A.

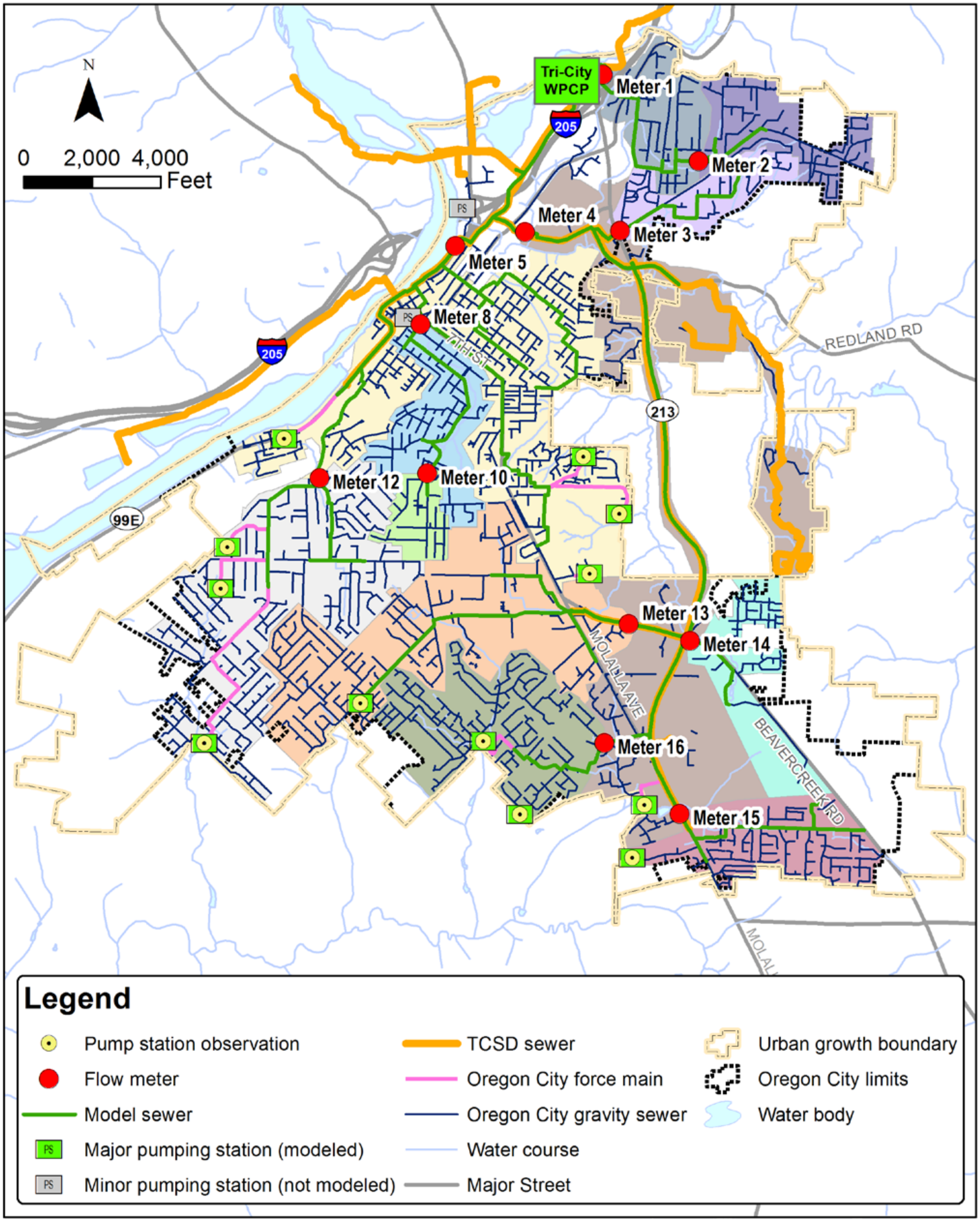



**Figure 2-10. Flow monitoring sites**

Section 3

# Flow Projections and Modeling

Hydraulic modeling of the City of Oregon City's (City) trunk sewer system was performed to identify hydraulic capacity deficiencies in the existing wastewater collection system for both existing and future planning scenarios. This section documents the modeling process that was performed.

As part of the modeling effort, a hydrologic/hydraulic model was constructed. Base wastewater flows and rainfall-derived infiltration/inflow (RDII) were loaded into the model and calibrated. A capacity analysis was performed to determine hydraulic capacity issues during a design storm for current and future development planning scenarios.

## 3.1 Model Development

The Storm Water Management Model (SWMM) urban hydrology and conveyance system hydraulics software was used for this effort. The following were completed as part of the model development:

- The model network was created using the City's pipe and manhole geographic information system (GIS) data. Elevation data contained in the GIS was supplemented with a survey of select structures, values from a previous model, record drawings, and surface elevation contours. The vertical datum used to report elevations in this plan is the North American Vertical Datum of 1988 (NAVD88).
- The major pumping stations were included in the model with a simulated peak flow equivalent to their published firm capacity.
- Pipe elevation profiles of the trunk sewers were reviewed for continuity error and adverse pipe slope.

*Note: although SWMM is named as a stormwater model, its hydrologic and hydraulic modeling components make it a model of choice for many engineers who model wastewater collection systems.*

## 3.2 Model Extents

The model includes all major trunk lines and the larger pumping stations. The model was divided into three model zones (north, central, and south) that represent distinct areas of the system (model). Figure 3-1 shows the model extents and model zones. An E size (34- by 44-inch) folded map insert is provided in the back of the report for a more detailed sewer map of modeled sewers.

The model includes the City's major trunk sewer system and sewers that could be impacted by future growth. In addition, the model includes portions of the Tri-City Service District (TCSD) interceptor system. Elements of the TCSD system were included in the model where it was deemed necessary for under-standing the City's sewer system response to flows. For example, high water surface elevations and surcharging in TCSD sewers could increase the quantity and frequency of surcharging and flooding in the City sewers.

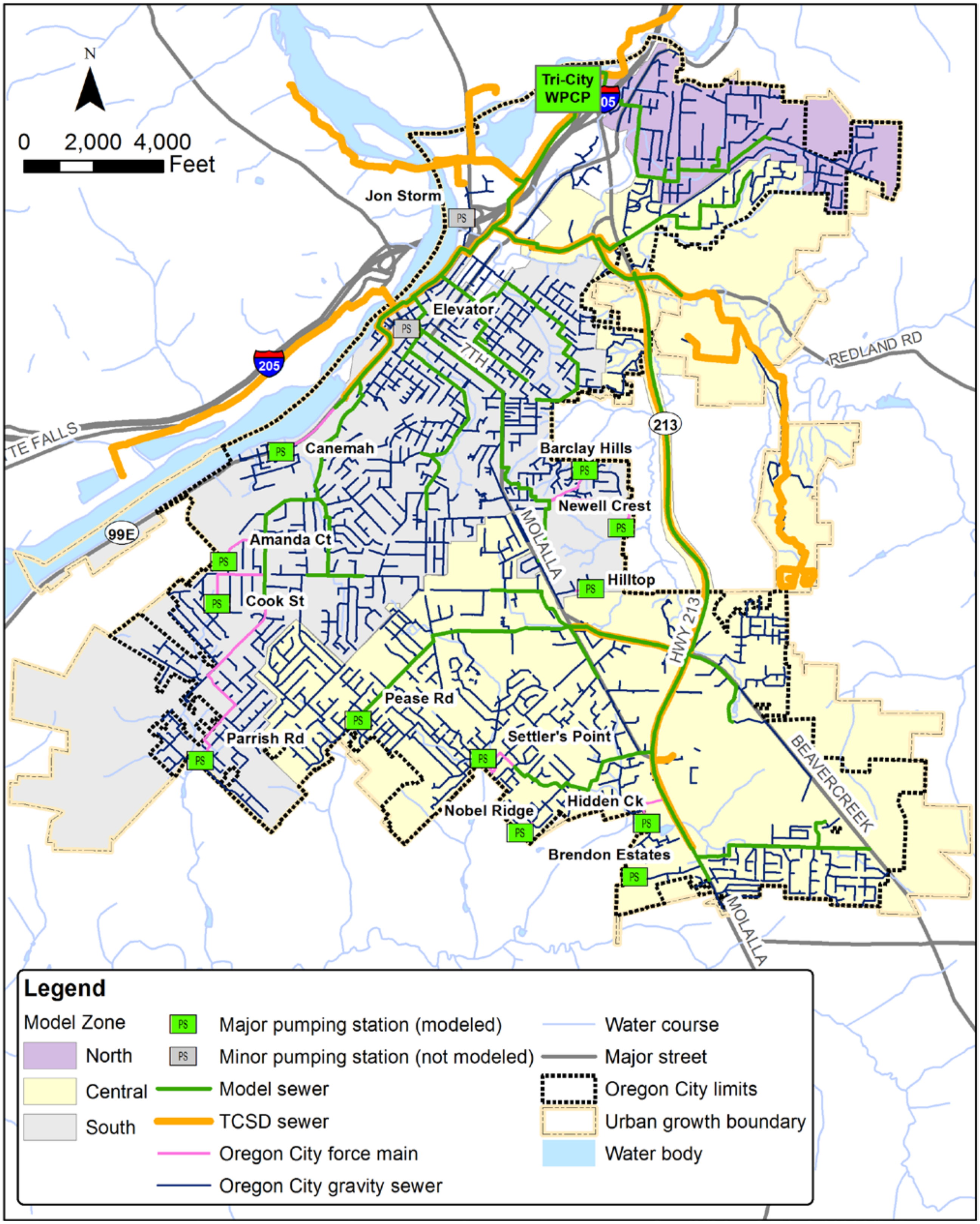



**Figure 3-1. Model extents**

## 3.3 Base Flows

Base sanitary sewer flows in the existing sanitary sewer collection system were developed from February 2012 recorded flows. February rainfall was about 41 percent below average for the month with very little rain falling the first week. The flow monitoring record showed that after one week of drier weather the base flow rate stabilized. The base flow includes wastewater contributions from residential, commercial, and industrial sources and long term ground water infiltration that finds its way into sewers and manholes through cracks, joint separations, and other defects. Rainfall derived infiltration and inflow (I/I) is not included in the base flow; whereas, long-term groundwater is included. The groundwater contributions may include perched water sources that only contribute groundwater infiltration during the wet season. The flow monitoring record includes the groundwater sources so that with the addition of the wet weather I/I, the modeling portrays all of the wet weather flow regime.

## 3.4 Wet Weather Flows

RDII sewer flow was developed through the RTK method. The flow meter data were used to calibrate the RTK parameters and compare modeled flows to observed flows. Once calibrated, the model was used to simulate the design storm and determine capacity deficiencies in the system for both current and future development planning scenarios.

### 3.4.1 RTK Method

The RTK method uses a set of triangular unit hydrographs to generate flows. The hydrograph shapes are described by three parameters, R, T and K, described as follows:

- R is the fraction total precipitation that enters the sewer system as RDII
- T is the time to peak of the hydrograph
- K is the ratio of the recession time to time to peak

A typical hydrograph is shown in Figure 3-2.

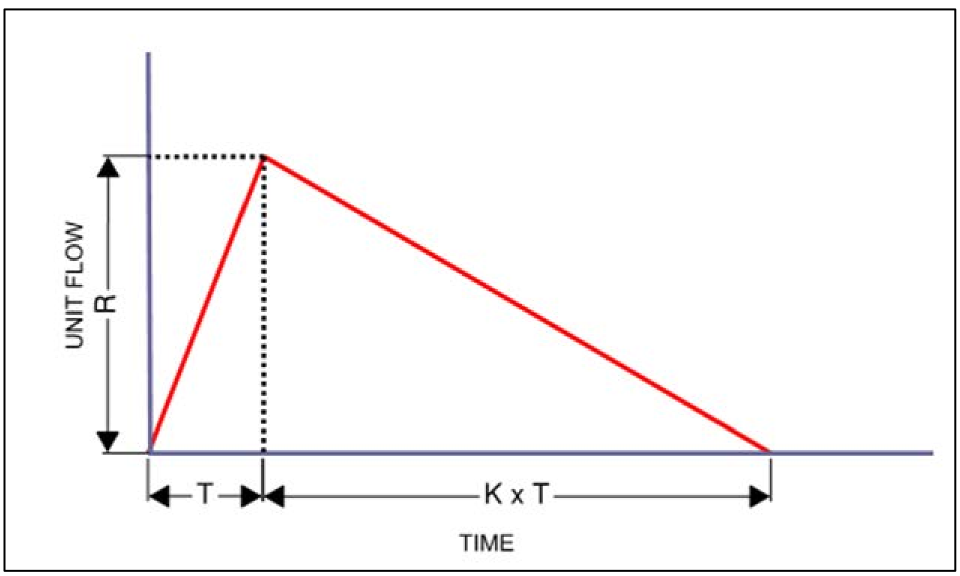



**Figure 3-2. RTK unit hydrograph**

Actual RDII hydrographs do not look like the simple triangular plot shown in Figure 3-2, since they are influenced by several different phenomena including inflow from rainfall sources, rainfall derived infiltration, and direct infiltration from groundwater sources. To model this varied phenomenon, the RTK analysis is represented by three unit hydrographs corresponding to rapid inflow, moderate groundwater infiltration, and slow groundwater infiltration. Figure 3-3 depicts all three unit hydrographs combined into one that can be used to approximate RDII flows in a sewer system.

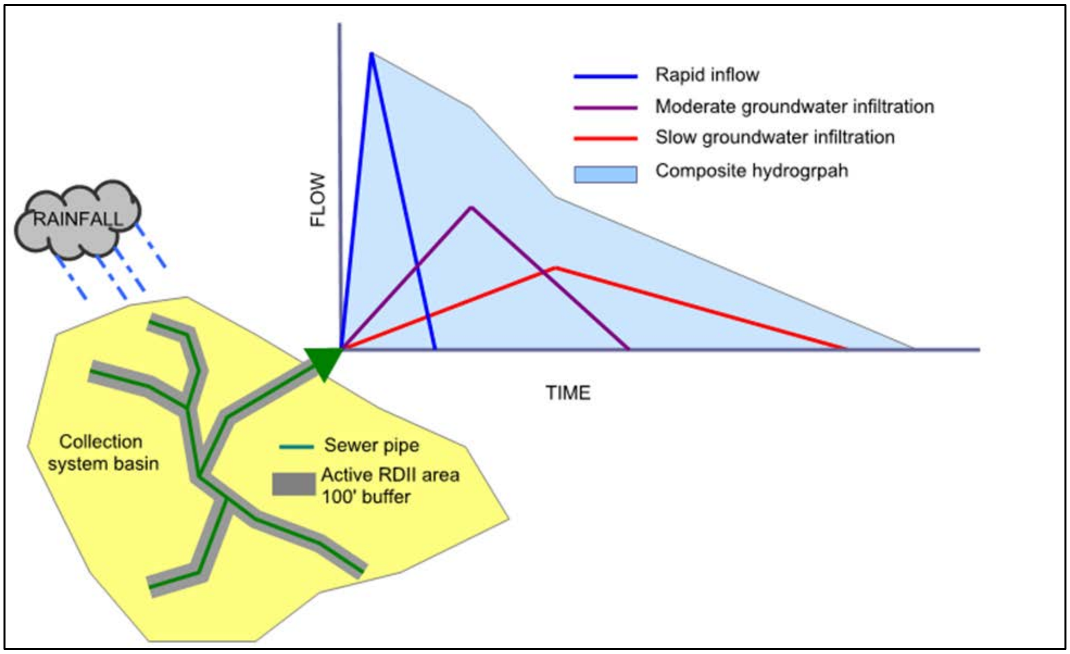



Figure 3-3. RTK method schematic

### 3.4.2 Precipitation Data

To calculate the R parameter for the RTK analysis, precipitation data representative of the sewer system are required. Rainfall data sets were obtained from the following sources and compared. Figure 3-4 includes rain gauge locations.

- *Rain Gauge 1 (RG-1):* This rain gauge was installed in Oregon City during the flow metering period, January 17, 2012 through early April 10, 2012. The data provided for this gauge are in 5-minute increments.
- *USGS Willamette River below Falls at Oregon City Rain Gauge*: The U. S. Geological Survey (USGS) rain gauge is operated in cooperation with the U.S. Army Corps of Engineers and funded by the National Streamflow Information Program (NSIP). Uncorrected provisional 15-minute data from August 2009 to present can be obtained at the following website:

  http://www.nwd-wc.usace.army.mil/cgi-bin/dataquery.pl?k=id:ORCO

The Rain Gauge 1 data, with USGS data added to the beginning of the time series (from January 1 to 17, 2012), were used for model calibration.

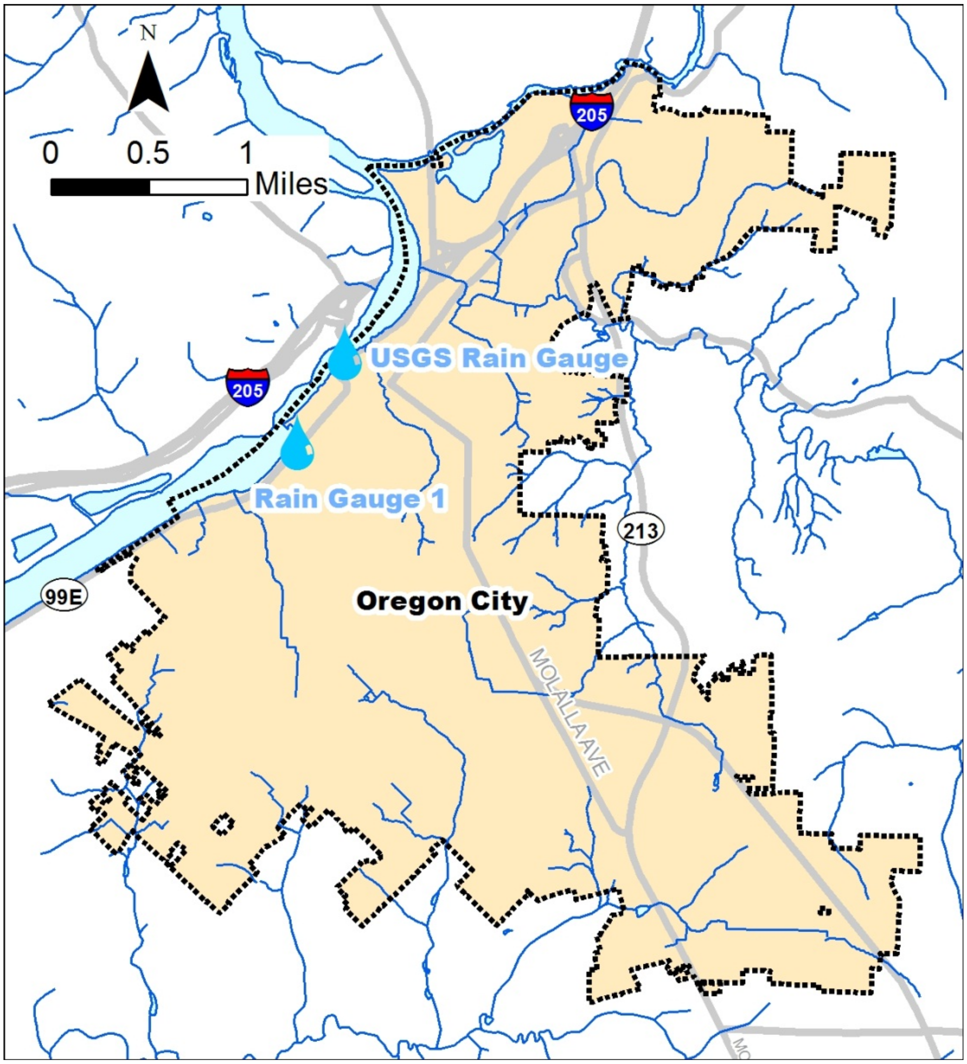



Figure 3-4. Rain gauge locations

### 3.4.3 Area Contributing to RDII

As shown in Figure 3-3, only a portion of a sewer basin was assumed to contribute to RDII in the sewer system. This portion of the overall area was estimated by applying a 100-foot buffer to all active sanitary mainline sewers in the system. This buffer area was distributed among all of the active model manholes based on upstream pipe length using GIS.

### 3.4.4 Wet Weather Model Calibration

The wet weather flow prediction capabilities of the model were verified against actual recorded flows to calibrate the model for wet weather conditions. Calibration of a model involves applying base flows and selecting RTK parameters that match RDII occurring during an observed storm event. Confidence in the prediction capabilities of the model are then increased by applying the parameters to other storm events in the flow record.

Calibration was completed for each flow meter location, and each pumping station with recorded data. The results for the three most downstream flow meters in each model zone are shown in Figure 3-5, Figure 3-6, and Figure 3-7. Results for the remaining flow meters are located in Appendix A.

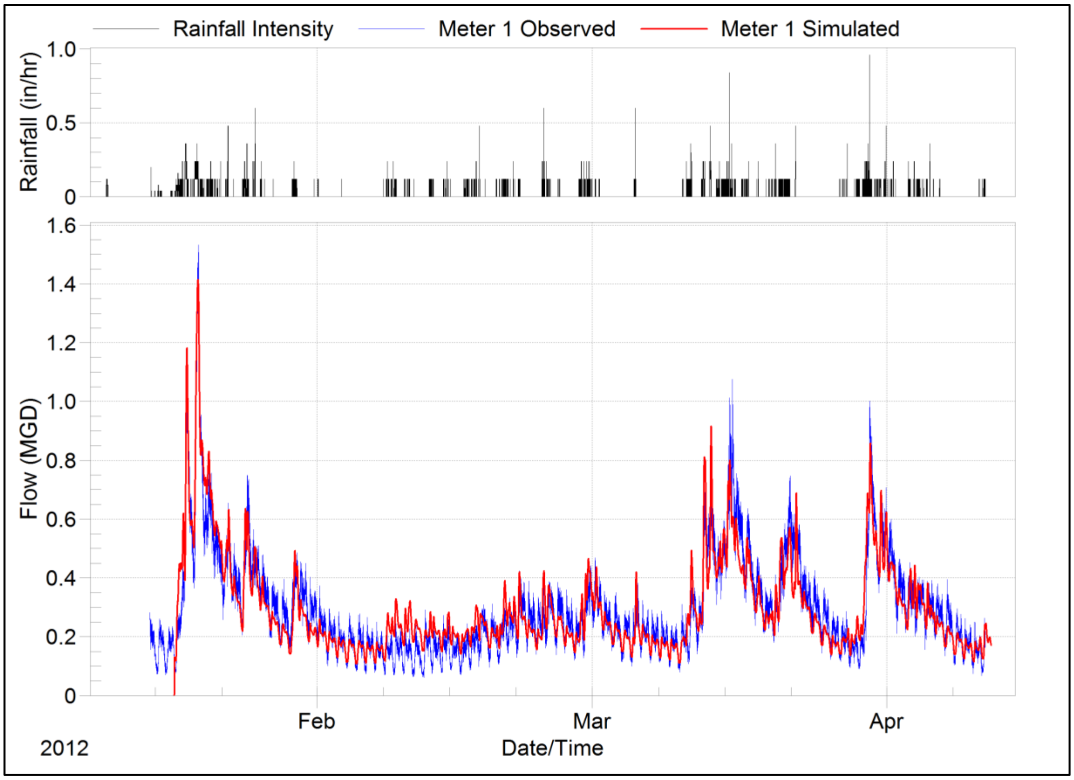



**Figure 3-5. Meter 1 (North Zone) calibration**

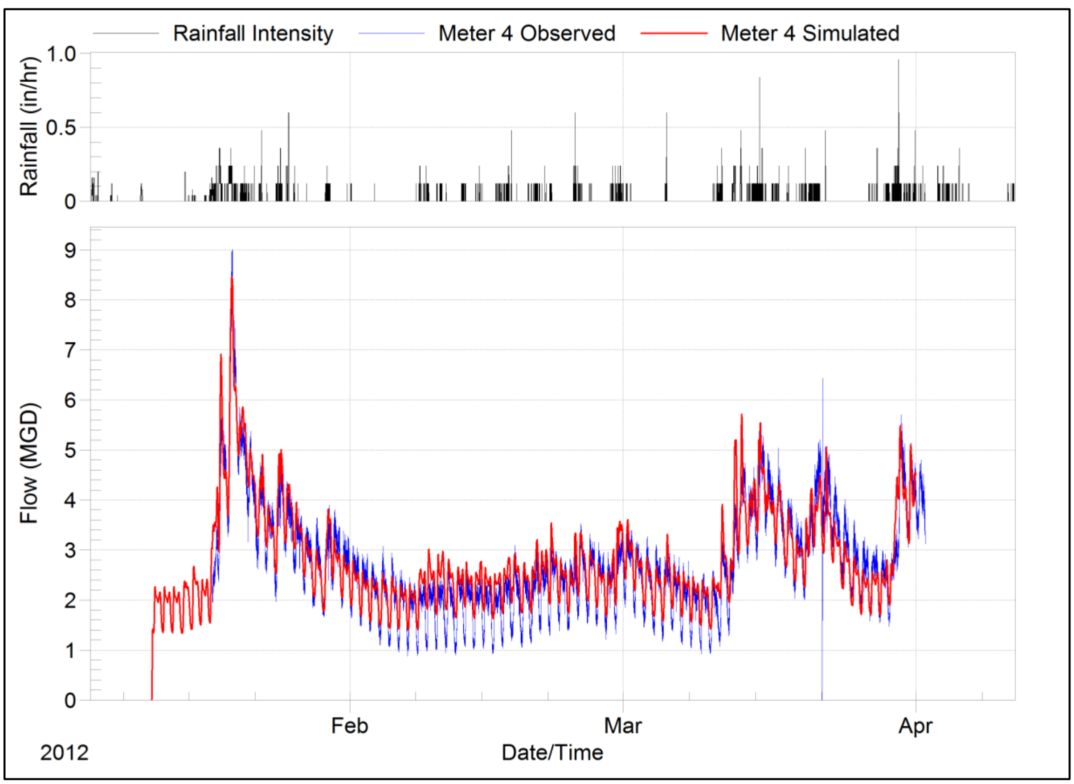



**Figure 3-6. Meter 4 (Central Zone) calibration**

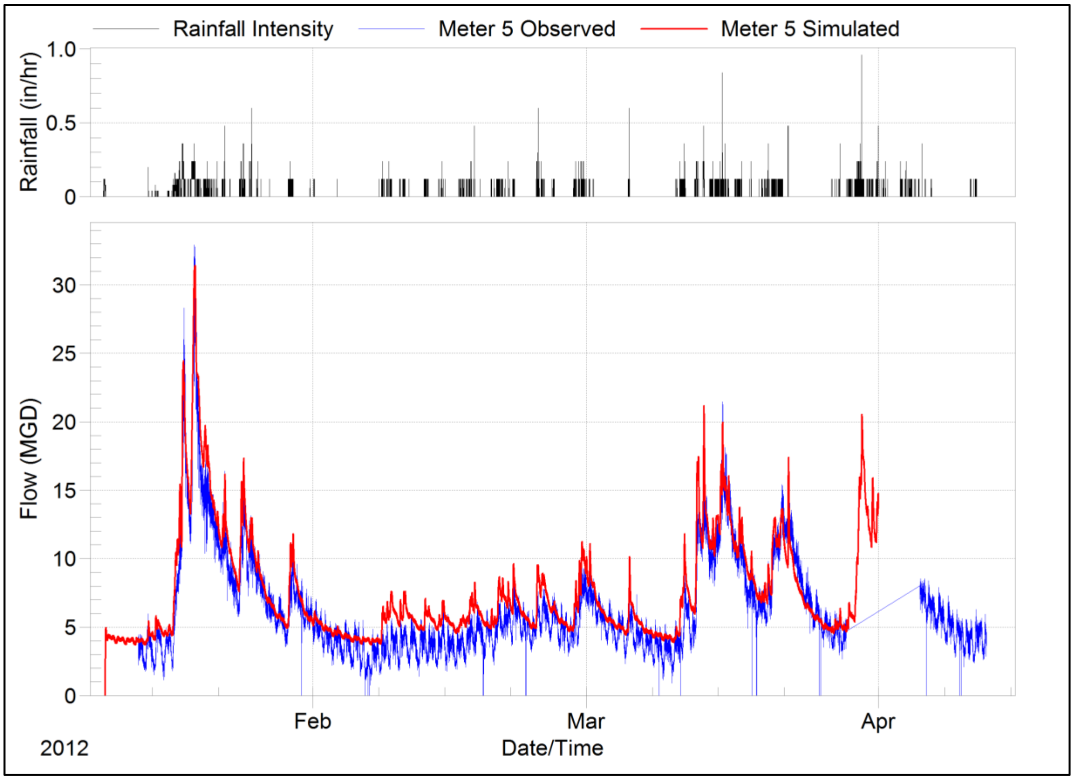



**Figure 3-7. Meter 5 (South Zone) calibration**

### 3.4.5 Design Storm

To evaluate the ability of the system to handle wet weather flows under both current and future flow scenarios, a design storm was loaded and run through the calibrated model. The size of the storm event is the responsibility of the owner with some minimum guidance provided by the Oregon Department of Environmental Quality (DEQ). DEQ's *Internal Management Directive for Sanitary Sewer Overflows (SSOs)* (November 2010) (IMD) cites the bacteria standard [Oregon Administrative Rules 340-041-0009 (6) and (7)] that prohibits discharge of raw sewage except during a winter storm event greater than the 1- in 5-year, 24-hour duration storm. In addition, the U.S. Environmental Protection Agency recommends that municipalities evaluate a range of storm events (i.e., 5- through 20-year is typical) and to select a storm event that provides a level of protection against SSOs that is in accordance with community values.

According to the IMD, the 5-year, 24-hour storm event is equal to 3.5 inches of rainfall (see IMD, Appendix C, Table 1). However, the IMD states that when the city is located between isopluvials, the higher rainfall values were selected to represent the 5-year, 24-hour event. The IMD Table 1 is based on an interpretation of the rainfall amounts found in the "Precipitation-Frequency Atlas of the Western United States, Volume X – Oregon," National Oceanic and Atmospheric Administration (NOAA) Atlas 2 (1973). Upon examination of this document, we find the rainfall amounts as listed in Table 3.1. Consequently, Brown and Caldwell's (BC) interpretation of the NOAA data is that the 3.5-inch rain event is more closely aligned with the 10-year, 24-hour event than it is with the 5-year event.

| Table 3-1. Design Storm Flow Volumes | |
|---|---|
| Storm event | Flow volume (inches) |
| 5-year, 24-hour | 3.0 |
| 10-year, 24-hour | 3.5 |

BC ran the hydraulic model with both the 3.0- and 3.5-inch storm events to determine the impacts to the collection system. As suspected, the larger storm event produced more surcharged pipes than did the smaller event. City staff approved the 10-year, 24-hour event (3.5 inches) for use as the design storm. Designing new and replacement sewers around this storm event will provide an added level of protection against SSOs than will the smaller storm event.

Typically a Soil Conservation Service (SCS) Type 1A storm is used as the design event hyetograph shape. This high-intensity, short-duration storm is not representative of the storms that typically occur during the winter months in the Pacific Northwest. An alternative to the SCS Type 1A storm was developed for the Portland area that is more representative of typical storms experienced by the city and will produce more realistic modeled flow predictions. The design storm and the SCS Type 1A are compared in Figure 3-8.

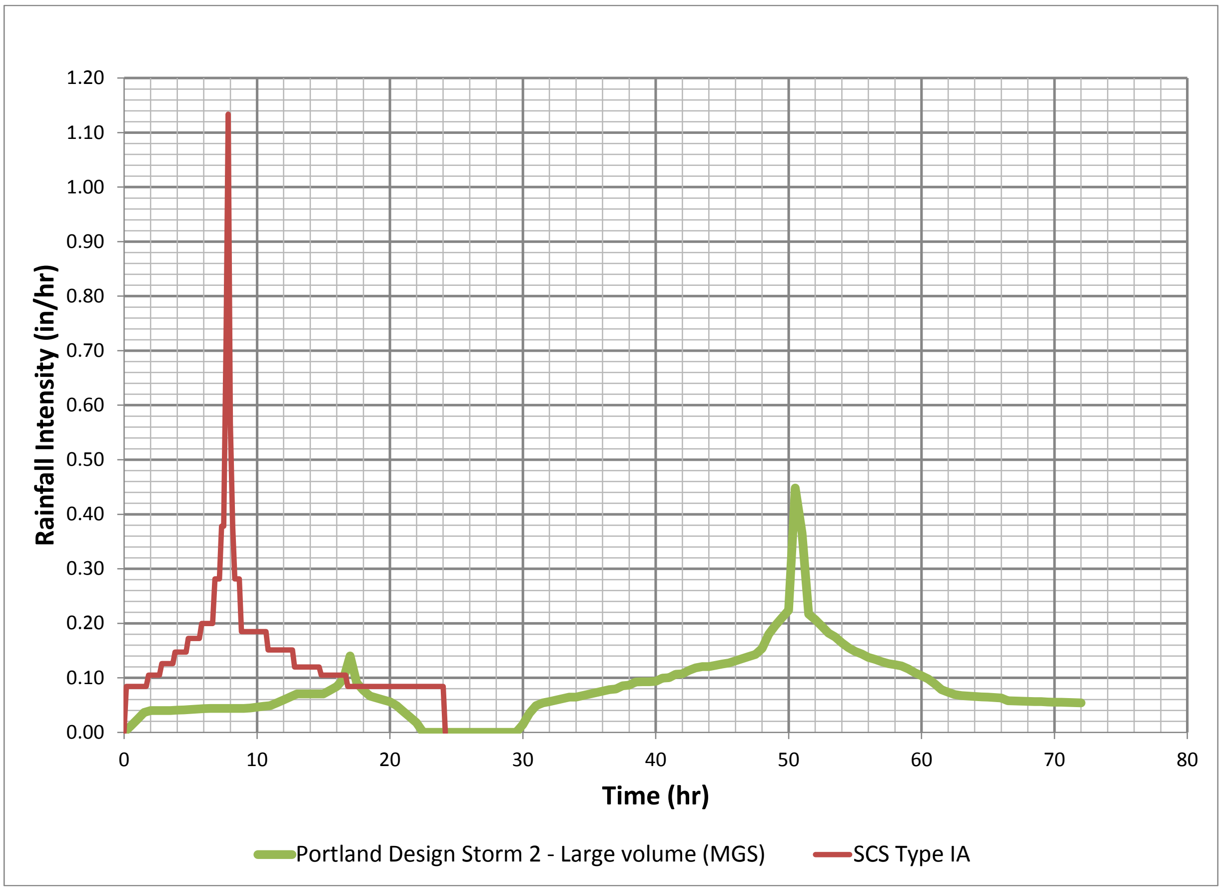



**Figure 3-8. Portland design storm and SCS Type 1A storm comparison for 3.5-inch event**

## 3.5 Future Flows

Base flows and RDII from future developments were estimated and routed through the model to estimate future capacity deficiencies in the trunk sewer system. Three types of future development areas were included in the analysis:

- Large future development areas at the boundaries of the City's urban growth area: South End Road, Park Place, and Beavercreek Road.
- Expected development areas within the city limits. This category includes all parcels identified by the City excluding those considered to be un-developable (e.g., existing parks) and lots considered not to have future development potential (e.g., small single residential lots with existing connections to the sewer system).
- Individual land parcels within the city limits with redevelopment potential. These consist of both vacant parcels and parcels where the existing land use is less dense than the parcel zoning. This category also includes individual parcels in unincorporated areas (within the urban growth area) with single family residential land use. It was assumed these parcels are currently serviced by onsite septic systems and will connect to the sanitary sewer system in the future.

### 3.5.1 Future Base Flows

Future average daily base flows were estimated from industry standard rates for each land use designation. For the large development areas, the proposed gross acreage for each land use designation was provided by the City. For parcels with areas greater than 1 acre, the net acreage was calculated assuming that 20 percent of the gross acreage would be used for local roads, easements, and other utilities. Table 3-2 lists the rates used to develop future base flows.

**Table 3-2. Future Sewer Base Flow Unit Rates**

| Land use | Unit type | Unit flow |
|---|---|---|
| Residential[a,b] | Gallons per capita per day | 80 |
| Commercial[c] | Gallons per acre per day (gpad) | 1,000 |
| Industrial[c] | gpad | 2,000 |

*[a] An average of 2.5 people per household was assumed.*

*[b] Development densities specified in the 2004 Oregon City Comprehensive Plan were used to determine the number of dwellings per acre. LDR = 5 dwellings per acre, MDR = 10 dwellings per acre, HDR = 22 dwellings per acre.*

*[c] Unit flow rates for commercial and industrial areas were based on industry standard.*

### 3.5.2 Future Wet Weather Flows

RDII from future areas was calculated by estimating the amount of future sewered areas and applying an infiltration/inflow (I/I) rate of 1,000 gpad. I/I was not applied to parcels within the city limits that are already developed, because it was assumed the I/I contribution from these parcels already would be accounted for in the existing conditions model.

# Section 4
# Hydraulic Analysis

This section documents the results of the hydraulic analysis used to evaluate the collection system under existing and future planning scenarios.

## 4.1 Assessment Criteria

This section discusses the criteria used to determine the adequacy of existing and future collection system infrastructure.

### 4.1.1 Gravity Sewer Pipelines

Two criteria are used to evaluate whether pipes are too small to convey the design flow. The first criterion is percent capacity, which is a ratio of maximum predicted flow (Q) to pipe capacity (Qm) expressed as a percentage. The maximum predicted flow, Q, is the calculated peak flow in each pipe from the model. The pipe capacity, Qm, is the theoretical pipe capacity according to Manning's equation, which assumes unpressurized flow (no surcharging). A percentage greater than 100 indicates the pipe is carrying more flow than is theoretically possible for unpressurized flow given a certain pipe slope, diameter, and internal roughness. A percent capacity greater than 100 is an indication of a surcharged pipe.

Unfortunately, the percent capacity alone cannot be used for determining pipe capacity due to the way that SWMM-based models report their data. In some situations, peak flows reported by the model exist for extremely short periods of time, sometimes only for seconds. Consequently, some of these peak flow values should not be used as the basis for pipe replacement. The second criterion, the ratio of depth of water to pipe diameter (d/D) is often more reliable. Use of the d/D ratio is described in more detail below.

In an unpressurized pipe, or a pipe with open-channel flow characteristics, the hydraulic grade line (HGL) is the elevation of the water surface within the pipe, or the d value. In a pipe that is surcharged (pressurized flow), the HGL is defined by the elevation to which water would rise in an open pipe, or manhole, as shown in Figure 4-1. In hydraulic terms, the HGL is equal to the pressure head measured above the invert of the pipe.

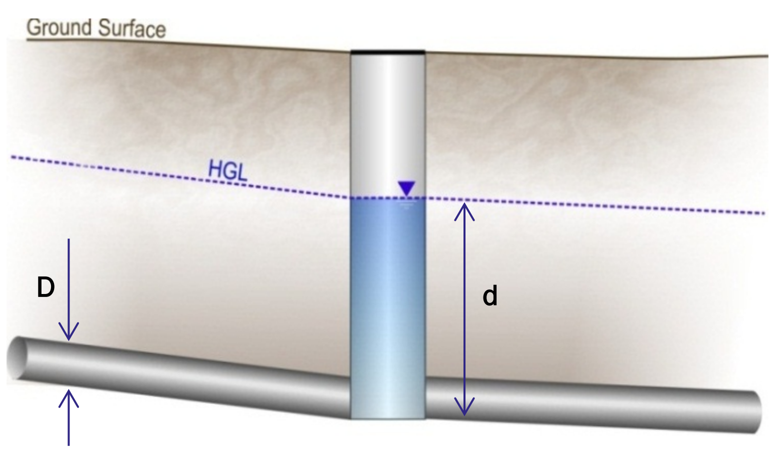



**Figure 4-1. HGL for surcharged condition**

The recommended approach for determining which pipes need to be upsized is to consider the amount and frequency of surcharging. For example, if minor surcharging (less than 1 to 2 feet) were to occur only during large storm events (i.e., the 1- in 10-year storm) and the surcharging did not impact property or create a sanitary sewer overflow (SSO), City staff should not consider upsizing this pipe. However, if the frequency or amount of surcharging were to increase and endanger property or overflow, then the pipe should be upsized (or capacity reclaimed through reduction of infiltration/inflow).

Pipes that surcharge frequently should be upsized (or tributary I/I reduced) since frequent surcharging has the potential to reduce their structural stability due to loss of pipe support from fine-grain soils washing into the sewer. Similarly, if the amount of surcharging is more than 1 or 2 feet, City staff should consider the amount of remaining freeboard (i.e., the distance between water surface in manhole and ground surface, or to the elevation of basements in the area) with regard to the risk of SSOs or basement backups. The amount of freeboard for the upstream manhole in each pipe is included in the model output table in Appendix E. As flows increase in the future, City staff will need to monitor water surface elevations throughout the system to determine when pipes should be upsized. This approach will help to ensure that the City has adequate capacity for conveying the design flows without spending more capital dollars than necessary.

In general, most sewers with d/D ratios of between 1 and 3 are not identified for replacement. City staff should monitor these sewers during large storm events to quantify the amount of surcharging that actually occurs. If the observed surcharging increases to the point of risking property or becoming an SSO, then the pipe or pipes should be upsized (or I/I reduction sought). Some pipes with minor surcharging are identified for replacement even though their d/D ratio is less than 1. Upsizing of these pipes will help to reduce more significant surcharging in the upstream system.

### 4.1.2 Pumping Stations

The existing capacities of the pumping stations are based on the available wet well and pump operational data. Recommendations to upsize capacity are made when influent flows to the wet well exceed existing stated capacities of the pumps. A fixed percentage of existing capacity is not used to trigger upgrades to pump stations since each pump station has unique influent flow characteristics. Several of the pump stations are within areas either fully built-out or with limited growth potential. Consequently, these stations do not need upgrades when the influent flows near the maximum design flows. If the observed flows exceed the capacity of the pump station, then City staff should consider if increased pumping capacity is warranted.

The Oregon Department of Environmental Quality's (DEQ) *Oregon Standards for Design and Construction of Wastewater Pump Stations* (May 2001), recommends force main velocities be between 3.5 to 8 feet per second (fps). Some cities have opted for lower maximum velocities to save pumping costs. For example, the City of Gresham limits the maximum velocity to 5 fps. Brown and Caldwell recommends force main velocities not exceed 7 fps. Force mains can be operated at higher velocities, but this will result in dramatic increases in pump power consumption due to high headloss.

## 4.2 Existing Conditions Planning Scenario – Modeling Results

The existing conditions modeling scenario represents the existing collection system under current flow conditions. This modeling scenario identifies the hydraulic deficiencies that are currently within the system. Based on discussions with City staff, the model predictions generally support their observations. Staff could not confirm every location identified by the model as potentially overflowing or surcharging but acknowledged that they were not usually looking for these occurrences during large storm events due to other responsibilities.

In general, this modeling scenario provides an initial priority ranking of required sewer improvements (or I/I reduction) since sewers that are currently undersized should be upsized prior to addressing problems associated with future flows.

Highlights of the modeling results are discussed below. The detailed results (i.e., modeled sewer statistics) for the current (existing) conditions planning scenario are shown in Appendix E.

### 4.2.1 Gravity Sewers

The modeling of the current planning scenario revealed surcharging throughout the collection system with approximately 70 sewers showing minor to severe surcharging. Surcharged sewers include all sewers with a modeled d/D ratio of greater than 1.0. The locations of the surcharged sewers are shown in Figure 4-2 and listed in Appendix E. City staff should note the remaining freeboard predicted by the model. Sewers with limited freeboard should be monitored to determine if, and when, improvements may be required to prevent basement backups or SSOs.

A number of Tri-City Service District (TCSD) sewers were included in the modeling to better understand the response of the City sewer system during wet weather flow events. As shown in Figure 4-2, several of the TCSD sewers are predicted to surcharge during the existing conditions planning scenario.

Not all of the identified sewers would need to be replaced to eliminate or reduce the surcharging. The upsizing of a number of strategically-located downstream sewers will significantly reduce the number of sewers that need to be replaced since many sewers are surcharged due to downstream restrictions in the collection system. In addition, the implementation of an infiltration and inflow (I/I) reduction program may reduce the number of pipes that must be replaced.

The detailed results (i.e., modeled sewers) for both existing and future planning scenarios are provided in Appendix E. The existing conditions planning scenario provides information on which sewers should be upsized first, but the flows shown for this scenario should not be used as the basis of upsizing the pipes. Rather, the future conditions planning scenario should be used for pipe sizing information (or for I/I reduction targets). Refer to Chapter 5 for capital improvement recommendations.

### 4.2.2 Pumping Stations and Force Mains

Two of the modeled pumping stations were found to lack firm capacity for conveying the existing peak flows. The Settler's Point Pumping Station has a projected peak flow of 931 gpm and a current rated capacity of 831 gpm. The Cook Street Pumping Station is barely undersized with a project peak flow of 647 gpm and a current rated pumping capacity of 620 gpm. Pumping station and force main flow statistics are listed in Table 4-1. The locations of the stations are shown in Figure 4-2.

| Table 4-1. Flows to Pumping Stations, Existing Conditions Planning Scenario | | | | | |
|---|---|---|---|---|---|
| Pumping station | Current pumping rated capacity[a], gallons per minute (gpm) | No. of pumps | Existing peak flow, gpm | Force main size, inches | Maximum force main velocity[c], fps |
| Amanda Court | 170 | 2 | 81 | 4 | 4.3/2.1 |
| Barclay Hills | 350 | 2 | 309 | 6 | 4.0/3.5 |
| Brendon Estates | 100 | 2 | 6 | 4 | 2.6/0.1 |
| Canemah | 1,200 | 2 | 360 | 10 | 4.9/1.5 |
| Cook Street | 620 | 2 | 647 | 6 | 7.0/7.3[d] |
| Hidden Creek | 404 | 2 | 231 | 6 | 4.6/2.6 |
| Hilltop | 95 | 2 | 70 | 4 | 2.4/1.8 |
| Newell Crest | 120 | 2 | 50 | 4 | 3.1/1.3 |
| Nobel Ridge | 140 | 2 | 53 | 4 | 3.6/1.3 |
| Parrish Road | 760 | 2 | 485 | 10 | 3.1/2 |
| Pease Road | 1,040/750[b] | 3 | 347 | 8 | 6.6/2.2 |
| Settler’s Point | 831 | 2 | 931 | 8 | 5.3/5.9[d] |

[a] *The rated pumping capacity, or firm capacity, is based on one-pump operation without the use of the second (redundant) pump. Use of all the pumps at a station does not provide pumping redundancy as per DEQ/U.S. EPA) requirements.*

[b] *The 1,040-gpm flow rate is based on two-pump operation and represents the firm capacity of the station. The 750-gpm flow rate is for one-pump operation.*

[c] *The first number is the maximum velocity based on firm pumping capacity, the second number is the velocity based on the actual flow that was modeled for this scenario assuming that pumped flow equals incoming flow. As per this SSMP, velocities exceeding 7 feet per second (fps) are generally to be avoided. Velocities in excess of 7 fps result in significant increases in pump power consumption.*

[d] *Would require larger pump or multiple pump operation to achieve the second value shown.*

The Cook Street Pumping Station force main has an existing condition force main velocity at the recommended upper velocity limit of 7 fps. All other existing condition force main velocities are less than 7 fps, which is acceptable according to the criteria defined in this SSMP.

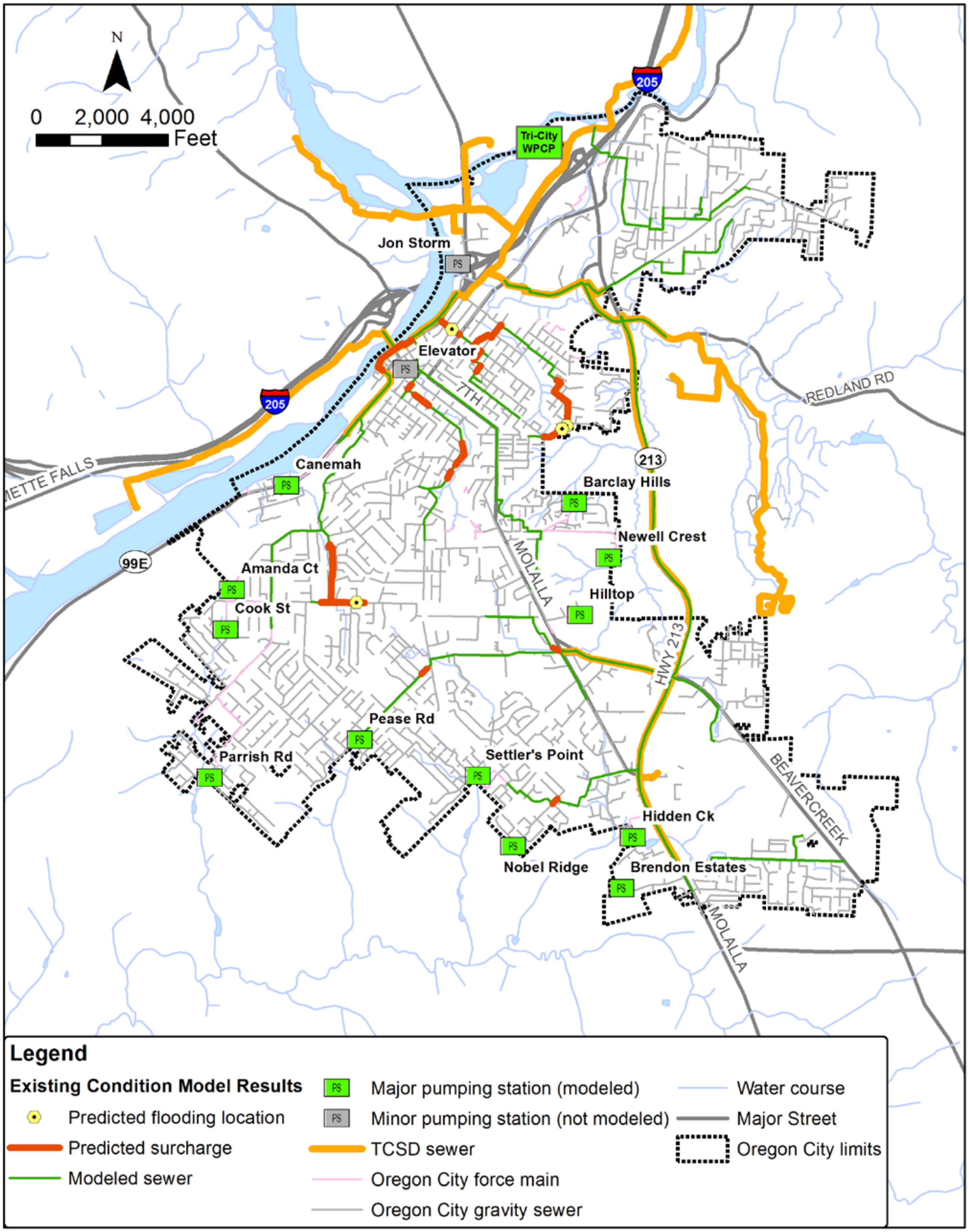



Figure 4-2. Surcharging gravity sewers (existing flows)

## 4.3 Future Conditions Planning Scenario – Modeling Results

The results of the future conditions planning scenario modeling are described in this section. The detailed results (i.e., modeled sewers) for the future conditions planning scenario are provided in Appendix E. Refer to Chapter 5 for capital improvement recommendations.

### 4.3.1 Gravity Sewers

Surcharged gravity sewers for the future conditions planning scenario are shown in Figure 4-3 along with the sewers that must be upsized to prevent excessive surcharging that could lead to basement backups and/or flooding [i.e., SSOs]. Flooding is predicted in two locations in the City system, at Warner Parrott Road and Division Street. Surcharging occurs at miscellaneous areas throughout the City as shown in Figure 4-3 and Appendix E.

Within the TCSD interceptor system that was included in the modeling, surcharging and flooding are predicted in the lower Highway 213 interceptor sewer. Surcharging is predicted along the Highway 99E interceptor sewer system, but as-built drawings show that the manhole covers are bolted down in the area predicted to surcharge so the potential for flooding is reduced. City staff observed flooding from two manholes (MH-10729 and MH-10671) along McLoughlin Boulevard during a large January 2009 storm event even though the covers are bolted down. It is assumed that flow was leaking from around the frame. City staff should discuss this situation with TCSD.

The flooding and surcharging predicted by the model for both the City and TCSD systems will increase in frequency and volume as growth increases unless pipes are upsized and/or, I/I reduction is achieved.

The detailed results are shown in Appendix E for the future conditions planning scenario. Future planning horizon results should be consulted for selecting pipe sizes rather than the results of the existing conditions modeling.

Some of the sewers shown in Figure 4-3 are not identified for replacement, but these are sewers for which the surcharging conditions should be monitored by City staff. In general, these are sewers constructed at shallow depth, or sewers with less than about 9 feet of freeboard. In the latter category, the surcharging of these sewers could present a risk of flooding for homes and businesses with basements. City staff should monitor flow levels in these sewers for frequent surcharging and surcharging that is too high in elevation.

### 4.3.2 Pumping Stations and Force Mains

Two of the modeled pumping stations were found to lack firm capacity for conveying the future peak flows. The Settler's Point Pumping Station has a projected peak flow of 1,092 gpm and a current rated capacity of 831 gpm. The Cook Street Pumping Station is barely undersized with a project peak flow of 648 gpm and a current rated pumping capacity of 620 gpm. Pumping station and force main flow statistics are listed in Table 4-2.

| Table 4-2. Flows to Pumping Stations, Future Conditions Planning Scenario | | | | | |
|---|---|---|---|---|---|
| Pumping station | Current pumping rated capacity[a], gpm | No. of pumps | Future peak flow, gpm | Force main size, inches | Maximum force main velocity[c], fps |
| Amanda Court | 170 | 2 | 81 | 4 | 4.3/2.1 |
| Barclay Hills | 350 | 2 | 310 | 6 | 4.0/3.5 |
| Brendon Estates | 100 | 2 | 7 | 4 | 2.6/0.2 |
| Canemah | 1,200 | 2 | 379 | 10 | 4.9/1.5 |
| Cook Street | 620 | 2 | 648 | 6 | 7.0/7.4[d] |
| Hidden Creek | 404 | 2 | 270 | 6 | 4.6/3.1 |
| Hilltop | 95 | 2 | 73 | 4 | 2.4/1.9 |
| Newell Crest | 120 | 2 | 51 | 4 | 3.1/1.3 |
| Nobel Ridge | 140 | 2 | 55 | 4 | 3.6/1.4 |
| Parrish Road | 760 | 2 | 535 (976)[e] | 10 | 3.1/2.2 |
| Pease Road | 1,040/750[b] | 3 | 430 | 8 | 6.6/2.7 |
| Settler's Point | 831 | 2 | 1,092 | 8 | 5.3/7.0[d] |

[a] *The rated pumping capacity, or firm capacity, is based on one-pump operation without the use of the second (redundant) pump. Use of all the pumps at a station does not provide pumping redundancy as per DEQ/USEPA requirements.*

[b] *The 1,040-gpm flow rate is based on two-pump operation and represents the firm capacity of the station. The 750-gpm flow rate is for one-pump operation.*

[c] *The first number is the maximum velocity based on firm pumping capacity, the second number is the velocity based on the actual flow that was modeled for this scenario assuming that pumped flow equals incoming flow. As per this SSMP, velocities exceeding 7 fps are generally to be avoided. Velocities in excess of 7 fps result in significant increases in pump power consumption.*

[d] *Would require larger pump or multiple pump operation to achieve the second value shown.*

[e] *Flow rate in parenthesis is the required flow rate with study areas S1 through S4 (see Section 5.2.2.2) routed to the Parrish Road Pumping station. Maximum force main velocity for the 976 gpm is about 4 fps.*

Note that the two pumping stations lacking firm capacity to convey future peak flows have also been identified with pumping deficiencies for the existing flow. A third station, Parrish Road, could become undersized depending on the areas and resulting flows routed to it. See the discussion under Section 5.3.3 on sewer extensions for more information regarding how the routing of flows within the South End Road Concept area affects the capacity of this station.

Timing for required station upgrades depends on the timing and type of future development. The City should monitor the flows to these stations and periodically assess the need to provide the increased pumping capacity (or achieve I/I reduction).

As listed in Table 4-1, the velocities in most force mains are well within acceptable limits as defined by the acceptance criteria. Two pumping stations, Cook Street and Settler's Point, show future flows near or exceeding velocities of 7 fps in the force main which violates the criteria defined in this SSMP. City staff should carefully evaluate the efficacy of using the existing force mains should the pumping capacity be expanded to meet the future demand. Staff may find through a life-cycle cost evaluation that it is more cost-effective to install a larger force main along with the larger pumping equipment than to use the smaller force main.

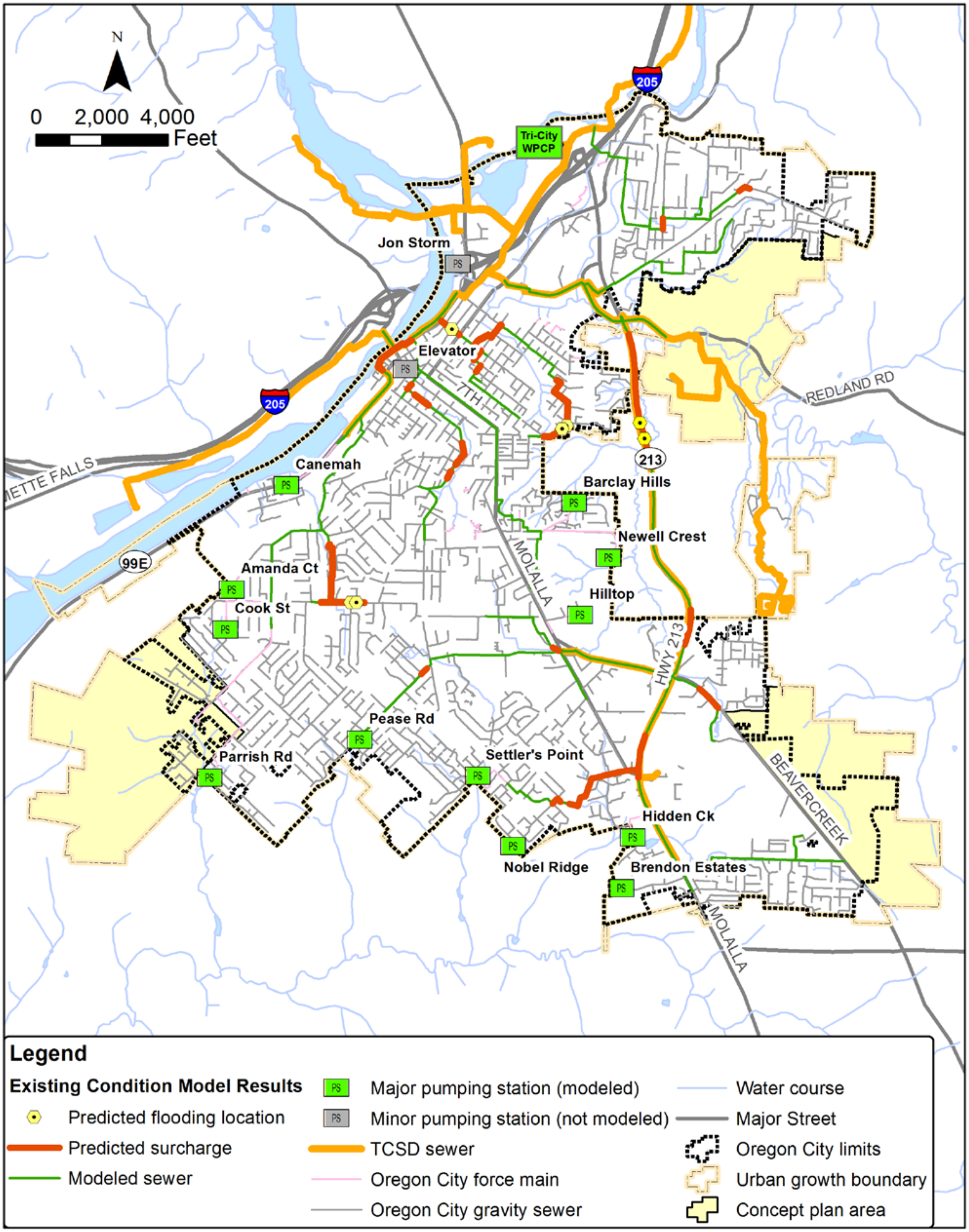



**Figure 4-3. Surcharging gravity sewers (future flows)**

Section 5

# Capital Improvement Plan (CIP)

This section presents the recommended CIP for the City of Oregon City's (City) sanitary sewer collection system. The plan addresses existing and predicted future deficiencies in the system and provides guidance for expanding the system to meet the City's future growth needs.

Capital improvements have been developed based on the future conditions planning scenario. These include sewer replacements that will be required to convey future flows and sewer extensions and pumping stations that will be required to service new areas to be brought into the City's boundary.

The recommendations contained herein should be updated as required to address future conditions that may differ from conditions used to develop this Sanitary Sewer Master Plan (SSMP).

## 5.1 Existing Conditions Planning Scenario

The existing conditions planning scenario serves two general purposes:

- *Project prioritization*—This scenario identifies existing deficiencies in the sanitary collection system. In general, existing deficiencies should be addressed before those associated with future conditions. See Appendix E for information identifying undersized existing condition sewers.
- *Rate/system development charges (SDCs)*—Upon acceptance of this SSMP, it is anticipated that the City will have a financial analysis performed to determine future sewer rates and SDCs. The financial analysis will depend, in part, on the excess capacity in the existing collection system that is available to serve growth. This information can be derived from the modeled flow data included in Appendix E.

Specific improvements to address existing collection system deficiencies are not identified since all improvements must be based on the predicted future condition flows. The existing condition scenario modeling did reveal a number of surcharged sewers and two undersized pumping stations. Improvements to these sewers and pumping stations should be performed prior to those that must be improved to provide future capacity. See Section 5.3 for the appropriate sizing of replacement sewers and pumping stations required to convey the future condition planning scenario.

## 5.2 Capital Improvement Recommendations

This section describes the improvements recommended to address the capacity and known condition deficiency needs of the City-owned sanitary sewer system for the future conditions planning scenario and to provide new sewer service to areas of the city without sewer service and to areas that may be annexed by the City in the foreseeable future. The City's implementation of an infiltration/inflow (I/I) reduction program may be sufficient to address the capacity needs of many of the sewers identified for replacement. Further analysis is required to determine where I/I reduction may be implemented cost-effectively.

### 5.2.1 Gravity Sewer Replacements

Gravity sewer replacements are largely confined to older areas of the city, within the south zone model. Individual sewer replacements were grouped into projects to expedite design- and construction-related activities. Typically, each project consists of several replacements. The projects were limited in size so that no single project would be too large for funding and bidding purposes.

Table 5-1 names the specific projects, defines the sewers to be replaced, and identifies the estimated project costs. Figures 5-1a and 5-1b provide an overview of recommended pipe replacements. This information is shown in detail in the Capital Improvements Summary sheet inserted at the end of this SSMP). Appendix H includes detailed project summary sheets with a figure and table for each project.

**Table 5-1. Recommended CIPs: Sewer Capacity Improvements**

| Pipe ID | Length, linear feet (LF) | Existing diameter, inches | Required diameter, inches | Estimated cost, dollars[a] | Project number/ name | Estimated project cost, dollars |
|---|---|---|---|---|---|---|
| 11402_11396 | 250 | 12 | 15 | 110,616 | (1) 12th Street | 407,000 |
| 10259_10157 | 346 | 8 | 10 | 128,789 | (1) 12th Street | |
| 12402_12401 | 367 | 12 | 15 | 86,858 | (1) 12th Street | |
| 12401_10273 | 184 | 12 | 15 | 81,202 | (1) 12th Street | |
| 10057_10172 | 142 | 8 | 10 | 72,918 | (2) 13th Street | 460,000 |
| 10171_10057 | 339 | 8 | 10 | 126,350 | (2) 13th Street | |
| 10170_10171 | 203 | 8 | 10 | 75,618 | (2) 13th Street | |
| 10060_10170 | 216 | 8 | 10 | 111,222 | (2) 13th Street | |
| 10064_10060 | 110 | 8 | 10 | 74,337 | (2) 13th Street | |
| 10063_10064 | 144 | 8 | 10 | 97,388 | (3) Division Street | 424,000 |
| 10071_10063 | 167 | 8 | 10 | 112,880 | (3) Division Street | |
| 10056_10071 | 287 | 8 | 10 | 194,127 | (3) Division Street | |
| 11444_10056 | 39 | 8 | 10 | 19,941 | (3) Division Street | |
| 11845_11564 | 315 | 12 | 15 | 139,464 | (4) Linn Avenue | 470,000 |
| 11832_11845 | 41 | 12 | 15 | 24,341 | (4) Linn Avenue | |
| 11569_11832 | 343 | 12 | 15 | 204,517 | (4) Linn Avenue | |
| 11546_11547 | 230 | 12 | 15 | 101,788 | (4) Linn Avenue | |
| 10928_10927 | 261 | 10 | 12 | 103,447 | (5) Hazelwood Drive | 1,319,000 |
| 10930_10928 | 89 | 10 | 12 | 35,100 | (5) Hazelwood Drive | |
| 11857_11856 | 23 | 10 | 12 | 18,052 | (5) Hazelwood Drive | |
| 11858_11857 | 132 | 10 | 12 | 83,522 | (5) Hazelwood Drive | |
| 11859_11858 | 105 | 10 | 12 | 51,370 | (5) Hazelwood Drive | |
| 10312_11859 | 260 | 10 | 12 | 127,524 | (5) Hazelwood Drive | |
| 11862_10312 | 355 | 10 | 12 | 173,929 | (5) Hazelwood Drive | |
| 11863_11862 | 30 | 10 | 12 | 14,549 | (5) Hazelwood Drive | |
| 10918_11863 | 120 | 10 | 12 | 75,758 | (5) Hazelwood Drive | |
| 13051_10918 | 331 | 10 | 12 | 162,156 | (5) Hazelwood Drive | |
| 10991_13051 | 218 | 10 | 12 | 106,766 | (5) Hazelwood Drive | |
| 10992_10991 | 109 | 10 | 12 | 53,202 | (5) Hazelwood Drive | |
| 11044_10992 | 179 | 8 | 10 | 92,088 | (5) Hazelwood Drive | |
| 11046_11044 | 431 | 8 | 10 | 221,253 | (5) Hazelwood Drive | |
| 10505_12992 | 161 | 8 | 10 | 60,107 | (6) Holcomb Boulevard | 60,000 |
| Total all sewer improvements (rounded to nearest $10,000) | | | | | | 3,140,000 |

[a] *Estimated costs include a 50 percent allowance for construction contingencies, engineering, and overhead. Costs are rounded to the nearest $10,000. Costs assume an average depth of 10 feet using cost condition 2. See Appendix C for unit cost tables and Appendix H for a detailed description of each project.*

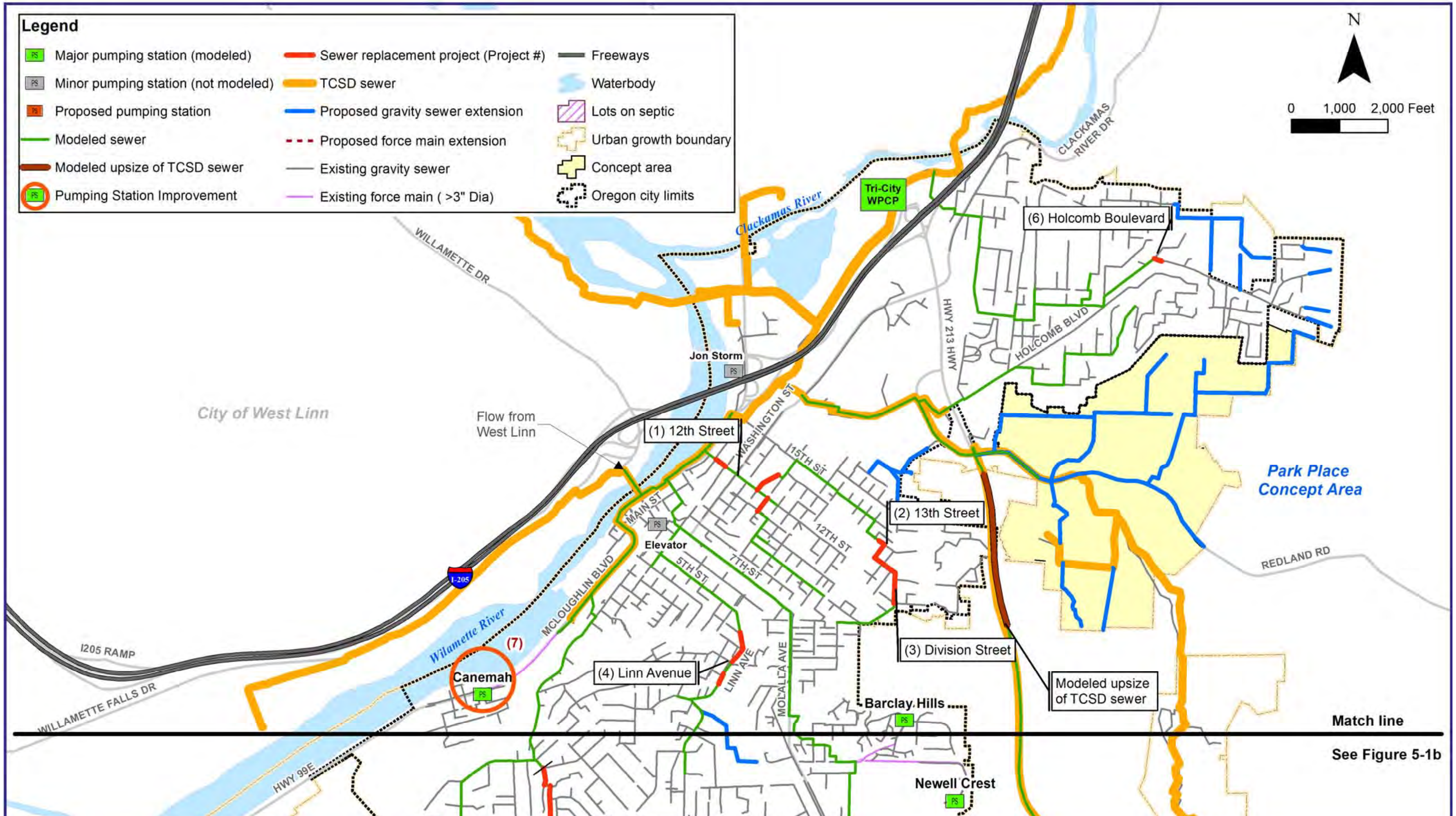



Figure 5-1a. Capital Improvements summary

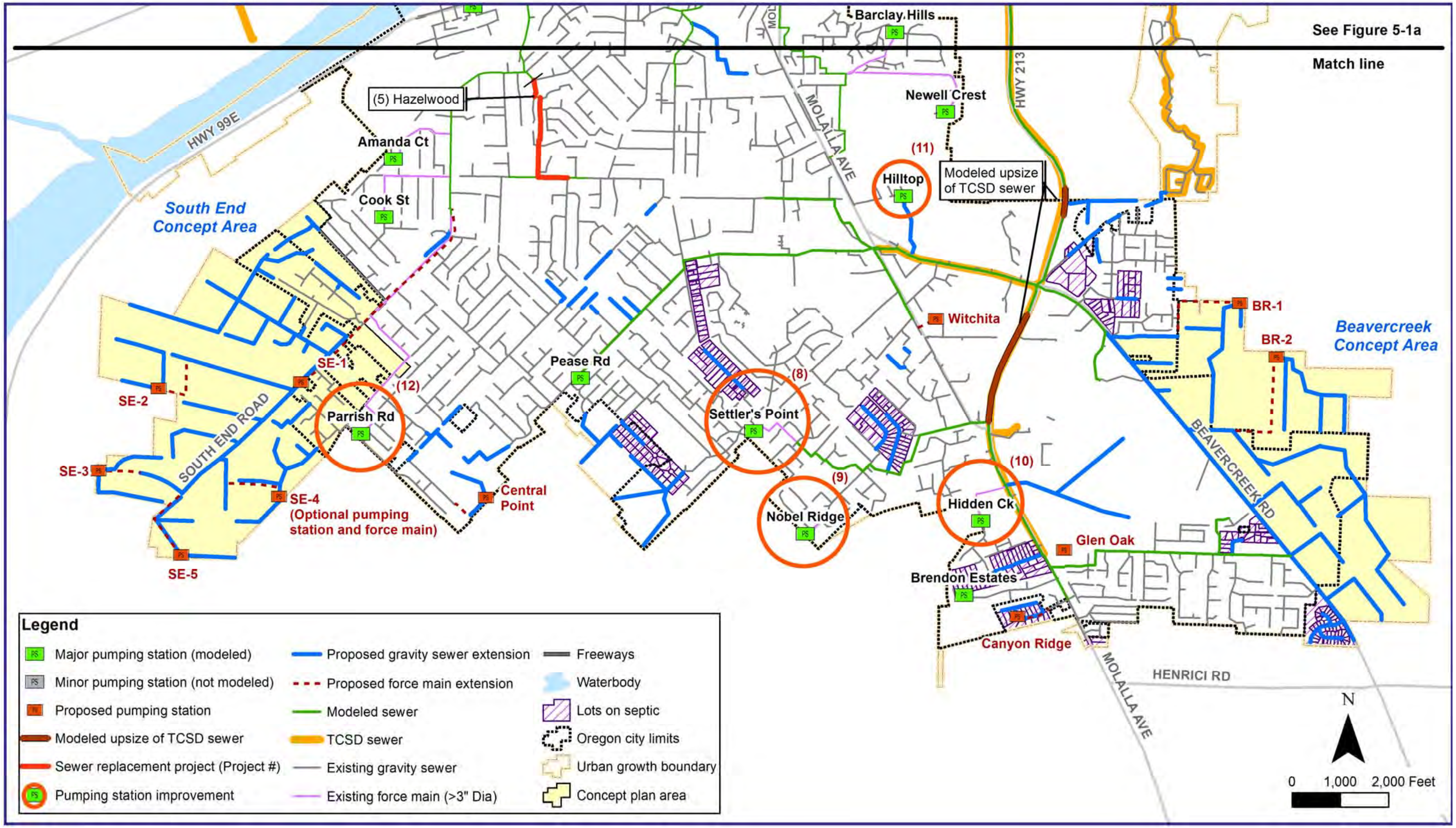



Figure 5-1b. Capital Improvements summary

A number of Tri-City Service District (TCSD) sewers along Highway (Hwy) 99E/McLoughlin Boulevard were found to be surcharging under both existing and future conditions. As-built drawings for this sewer show that these sewers have bolt-down manhole covers. This is corroborated by TCSD staff. This means that the manholes for these sewers should not flood if the hydraulic grade line (HGL) rises to higher than the rim elevation. The surcharging is more significant under the future conditions planning scenario such that the HGL approaches the rim elevations of several of the adjacent City sewers. City staff should monitor the City manholes in this area to determine actual water surface elevations (and to ensure that high water levels will not impact basements) during large storm events and to track how the HGL increases with future growth in the contributing basins.

Portions of the TCSD interceptor along Hwy 213 and Newell Creek were upsized in the model to convey modeled flows without excessive surcharging. The upsizing of five of these sewers just south of the Beavercreek Road and Hwy 213 intersection relieve surcharging to the south of this area such that upsizing of City pipes is not required. Alternatively, future analyses may show that I/I reductions in the area may relieve the need for upsizing of the TCSD sewers. The sewers that were upsized are not included in the City's CIP. These sewers are identified in Figures 5-1a and 5-1b, and more information on the projected flows for these sewers can be found in Appendix E. Discussions with TCSD should be initiated to determine whether I/I reduction in portions of Oregon City is more cost-effective than upsizing TCSD conveyance and treatment facilities to handle these capacity issues.

### 5.2.2 Pumping Station Improvements

The future conditions planning scenario revealed two pumping stations that are potentially undersized for conveying future flows. Interviews with City operation and maintenance staff have identified other improvements needed in addition to capacity improvements. A description of each major station and recommended improvements are provided in Appendix B.

A summary of the costs required to provide the necessary improvements is listed in Table 5-2. Modeled design flow rates for sizing the pump stations and force mains (FMs) are listed in Table 4-2.

**Table 5-2. Recommended CIPs: Existing Pumping Station and FM Improvements**

| Pumping station | Description of improvement | Project number/name | Estimated cost of improvements, dollars[a] |
|---|---|---|---|
| Canemah | Refurbish wet well and update controls | (7) Canemah | 360,000 |
| Settler's Point[b] | Upgrade pumping station | (8) Settler's Point | 300,000 |
| Nobel Ridge | Upgrade pumps and control systems | (9) Nobel Ridge | 260,000 |
| Hidden Creek | Upgrade control systems | (10) Hidden Creek | 60,000 |
| Hilltop[c] | Decommission existing pumping station and replace with 8-inch, 1,300–foot-long gravity sewer | (11) Hilltop | 440,000 |
| Parrish Road[d] | Upgrade pumps and control systems | (12) Parrish Road | 750,000 |
| Total all pumping station and FM improvements | | | 2,170,000 |

[a] *Estimated costs include a 50 percent allowance for construction contingencies, engineering, and overhead. Costs are rounded to the nearest $10,000.*

[b] *The City has commissioned a study to determine a more comprehensive assessment of this station's condition and future needs.*

[c] *This gravity line is planned to serve future development and a portion for the installation costs will be SDC-reimbursable to the future developer for this new gravity sewer line. The cost of this gravity sewer is not repeated in Section 5.2.3 on sewer extensions.*

[d] *See Section 5.2.2.2 for South End Road Concept Area flow routing concepts and impact on Parrish Road Pumping Station.*

The City has four pump stations that use FMs constructed partially or totally of asbestos cement. The U.S. Environmental Protection Agency (USEPA) has identified asbestos as a hazardous material that requires special precautionary handling and disposal procedures. USEPA is studying the problem (specifically with regard to asbestos cement pipe used in municipal water and sewer systems) but has not completed the study or released preliminary recommendations on how best to handle this material. The City should commission a study to evaluate the best course of action for replacing or de-commissioning the existing asbestos cement FMs. Projects and costs for replacing asbestos cement pipe are not specifically identified at this time but should be included as part of the City-wide sewer rehabilitation and replacement program should they be found to be in poor condition.

### 5.2.3 Sewer Extensions

Sewer extensions are required to provide service to those areas that do not have City sewer service. Areas without sewer service include homes on septic systems, areas within the current urban growth boundary (UGB) to be brought into the city limits within the foreseeable future (concept areas), and miscellaneous properties inside the city boundary that are not located near existing sewers.

Sewer extensions in this SSMP include primarily gravity sewers but also include new FMs and pumping stations where the topography precludes construction of a gravity system. This section provides one layout concept for the sewers and pumping stations. Many variations on these initial concepts could be developed that would serve the area equally well. In addition, pipe slopes for the sewer extensions were based on an assumed minimum slope. Actual slopes may allow for use of smaller pipe than shown in figures and tables.

Generally, sewer extensions are not funded by rates. Instead, most sewer extensions are funded by developers with potentially some of the costs being SDC-reimbursable. In areas of the city not currently connected to the sewer, Local Improvement Districts and special assessment districts may need to be formed to fund the projects. Developers and the general public who want more information on funding options should contact the City.

The following sections describe three types of projects based on funding mechanisms: Priority 1 CIPs that may be funded by the City through SDCs reimbursements, Priority 2 CIPs that are unlikely to be funded by the City, and concept area extensions that are most likely to be paid for directly by development except for some unique circumstances that may require City funding assistance to promote economic development.

#### 5.2.3.1 Recommended CIPs: Priority 1 Sewer Extensions

Many of the Priority 1 sewer extensions include areas currently on septic that may need City sewer service in the future and projects required to extend sewer service to areas currently without sewer service. The Priority 1 designation suggests that these are projects that are likely to be funded by the City through system development charge reimbursements.

There are several areas within the current city limits and one area within the UGB where homes are on private septic systems. In the future, these areas should be connected to the City's sanitary sewer system. The timing of these improvements will depend on several factors, including the age of the existing system and whether the City and the State of Oregon would allow expansion of the existing drain fields when they fail.

The locations of the Priority 1 CIPs are shown in Figures 5-1a and 5-1b. The individual projects are shown and named on the large fold-out figure at the back of this SSMP. The estimated cost of improvements for the Priority 1 CIPs is listed in Table 5-3.

| Table 5-3. Recommended CIPs: Priority 1 Sewer Extensions | |
|---|---|
| Description of improvement | Estimated cost of improvements, dollars[a,b] |
| Anchor Way, 2,529 LF of 8-inch sewer | 890,000 |
| Canyon Ridge Pumping Station and 714 LF of 4-inch FM | 580,000 |
| Canyon Ridge Drive, 1,579 LF of 8-inch sewer | 560,000 |
| Caufield Road, 1,405 LF of 8-inch sewer | 490,000 |
| Connie Court, 448 LF of 8-inch sewer | 160,000 |
| Gaffney Lane, 2,371 LF of 8-inch sewer | 830,000 |
| Kalal Court A, 637 LF of 8-inch sewer | 220,000 |
| Meyers Road A: | |
| • 550 LF of 12-inch sewer | 220,000 |
| • 2,127 LF of 15-inch sewer | 940,000 |
| Meyers Road C, 1,124 LF of 8-inch sewer | 400,000 |
| Singer Creek, 1,873 LF of 8-inch sewer | 660,000 |
| Thayer Road, 393 LF of 8-inch sewer | 140,000 |
| Total | 6,090,000 |

*[a] Estimated costs include a 50 percent allowance for construction contingencies, engineering, and overhead.*

*[b] Estimated costs assume cost condition 2 and a 10-foot depth. Unit costs are documented in Appendix C.*

### 5.2.3.2 Recommended CIPs: Priority 2 Sewer Extensions

Priority 2 sewer extensions include many of the same type of projects as the Priority 1 CIPs but these projects are unlikely to be funded by the City through system development charge reimbursements. Instead, it is expected that these projects would be paid directly by development.

Many of these projects extend the reach of the existing sanitary sewer so that areas currently without sewer service can be served. At some locations, a small pumping station and FM may be required. Each general area that requires sewer extensions is provided a name based on its location. The locations of the Priority 2 CIPs are shown in Figure 5-1a and Figure 5-1b. The individual projects are shown and named on the large fold-out figure at the back of this SSMP. The estimated cost of improvements for the Priority 2 CIPs is listed in Table 5-4.

| Table 5-4. Recommended CIPs: Priority 2 Sewer Extensions | |
|---|---|
| Description of improvement | Estimated cost of improvements, dollars[a, b] |
| Central Point Pumping Station and 915 LF of 4-inch FM | 750,000 |
| Central Point Road North, 3,841 LF of 8-inch sewer | 1,350,000 |
| Central Point Road South, 4,439 LF of 8-inch sewer | 1,560,000 |
| Clackamas Heights, 2,041 LF of 8-inch sewer | 720,000 |
| Holcomb Boulevard: | |
| • 3,082 LF of 8-inch sewer | 1,080,000 |
| • 611 LF of 10-inch sewer | 230,000 |
| • 1,087 LF of 12-inch sewer | 430,000 |

| Table 5-4. Recommended CIPs: Priority 2 Sewer Extensions | |
|---|---|
| Description of improvement | Estimated cost of improvements, dollars[a, b] |
| Kalal Court B, 1,584 LF of 8-inch sewer | 550,000 |
| Leland Road, 4,613 LF of 8-inch sewer | 1,620,000 |
| Lodgepole Way, 543 LF of 8-inch sewer | 190,000 |
| Maplelane A, 829 LF of 8-inch sewer | 290,000 |
| Maplelane B, 1,373 LF of 8-inch sewer | 480,000 |
| Meyers Road B, 1,790 LF of 10-inch sewer | 670,000 |
| Molalla Avenue, 516 LF of 8-inch sewer | 180,000 |
| Newell Creek, 1,932 LF of 8-inch sewer | 680,000 |
| Timbersky Way (Three Mountain), 1,821 LF of 8-inch sewer | 640,000 |
| Wichita Pumping Station and 422 LF of 4-inch FM | 440,000 |
| Glen Oak Road Pumping Station | 270,000 |
| Total | 12,130,000 |

[a] *Estimated costs include a 50 percent allowance for construction contingencies, engineering, and overhead. Costs are rounded to the nearest $10,000. Costs assume an average depth of 10 feet using cost condition 2. See Appendix C for unit cost tables.*

[b] *Some of the areas listed below are not currently within the city limits but are located inside the UGB.*

### 5.2.3.3 South End Concept Area

The South End Concept Area is one of three large areas expected to be brought into the City's service area in the near future. It consists of approximately 611 acres located in the southwest corner of the UGB along South End Road. Approximately 133 acres are currently within the city limits and the remainder of the land has not yet been annexed by the City. Approximately 290 acres were added to the UGB prior to 2002 and 188 acres were added in 2002. Figure 5-2 shows a conceptual layout for sewer extensions to serve this area.

Table 5-5 lists the major assumptions used in developing flows for this area. The areas in Table 5-5 do not include areas already connected to the City's sanitary collection system.

| Table 5-5. South End Concept Area Future Flows | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Area | Gross acres[a] | Net acres[b] | Dwelling units | Residents | Average sanitary flow[c,d], million gallons per day (mgd) | Peak factor | Peak flow, mgd | Peak flow, gallons per minute (gpm) |
| Pre-2002 UGB/R-8 | 241 | 193 | 1,542 | 3,856 | 0.386 | 2.8 | 1.270 | 882 |
| 2002 UGB expansion/R-10 | 168 | 134 | 1,344 | 3,360 | 0.336 | 2.8 | 1.086 | 754 |
| Existing low-density development | 69 | 55 | 156 | 390 | 0.039 | 3.5 | 0.193 | 134 |
| Total all areas | | | | | | | 2.548 | 1,769 |

[a] *Gross acres equal future planning boundary less existing rights-of-way (ROWs), according to geographic information system (GIS) parcel data.*

[b] *Net acres equals gross acres less 20 percent for new local roads and ROWs.*

[c] *Does not include flows from areas inside current city limits except for one large flag lot (24 acres) west of Shelby Rose Drive. This area cannot connect by gravity sewer to the existing City sanitary sewer collection system due to the adverse slope of the land.*

[d] *Flow generation is based on 2.5 residents per dwelling, 80 gallons per capita per day (gpcd), and 1,000 gallons per acre per day (gpad) of I/I.*

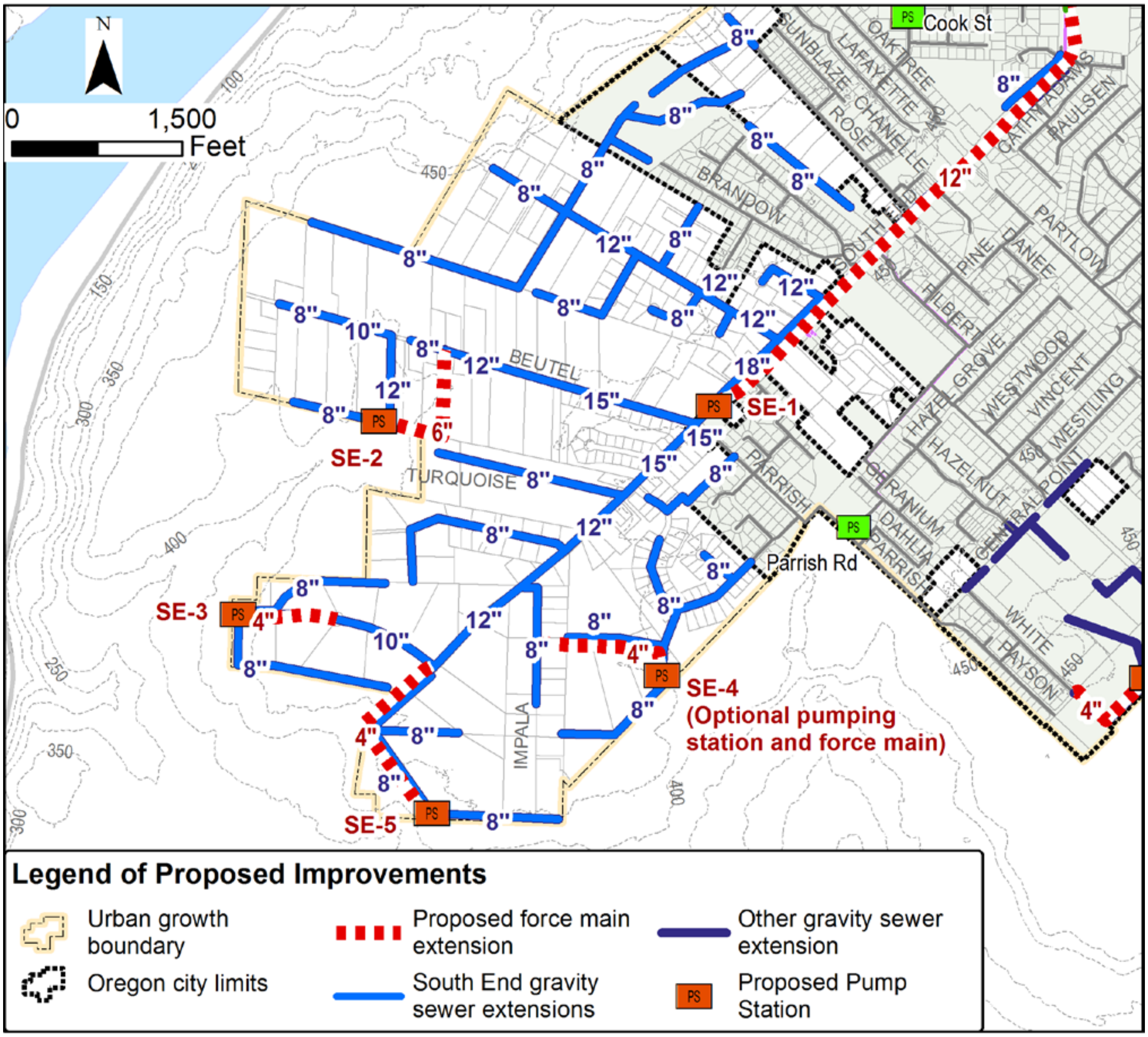



Figure 5-2. South End Concept Area improvements

The development of the South End Concept Area will require a number of new sewers and pumping stations. The new stations are required because much of the area slopes away from the existing sewer system connections. Figure 5-2 shows one layout concept for the sewers and pumping stations. Many variations on this initial concept could be developed that would serve the area equally well.

It is feasible for flows from portions of the South End Concept Area to be routed to the existing Parrish Road Pumping Station. The four most likely areas are shown in Figure 5-3. Unfortunately, this station does not have capacity to receive the flows from all four areas. The Parrish Road Pumping Station has a firm capacity of 760 gpm. Predicted future flows to the station are 535 gpm, resulting in available capacity of 225 gpm. Flows from all four areas total 441 gpm and are listed in Table 5-6.

| Table 5-6. South End Concept Area, Parrish Road Pumping Station Flows | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Area/land use | Gross acres[a] | Net acres | Dwelling units | Residents | Average sanitary flow, million gallons per day (mgd) | Peak factor | Peak flow, mgd | Peak flow, gpm |
| S1/R-8 | 26 | 21 | 166 | 414 | 0.041 | 3.5 | 0.166 | 115 |
| S2/R-8 | 2 | 2 | 15 | 38 | 0.004 | 4.5 | 0.019 | 13 |
| S3/R-8 | 36 | 29 | 230 | 575 | 0.057 | 3.4 | 0.223 | 155 |
| S4/R-8 | 37 | 29 | 234 | 586 | 0.059 | 3.4 | 0.227 | 158 |
| Total all areas | | | | | | | 0.635 | 441 |

[a] *Flow generation based on 2.5 residents per dwelling, 80 gpcd, and 1,000 gpad of I/I.*

Four potential scenarios have been identified for routing the flows listed in Table 5-6:

- Scenario No. 1–Areas S1 and S2 are located such that they could be connected readily to existing sewers that drain to the Parrish Road Pumping Station. The station has capacity for both of these areas. For this scenario, Areas S3 and S4 would drain to a new pumping station at their east boundary and flows would be discharged via a new FM that would connect to a new gravity sewer in South End Road.
- Scenario No. 2–Area S3 is an area of existing homes on septic systems. At some point, it is likely that these homes will need to be connected to the sanitary sewer system. An initial review of this area shows that it could be connected to the Parrish Road Pumping Station through gravity sewers. Areas S3 and S2 could be connected to the station without exceeding its existing capacity.
- Scenario No. 3–Area S4 drains to a low point on its east boundary that abuts the southerly most tip of Area S3. Area S4 could be connected to a new sewer system in Area S3, thereby connecting to the Parrish Road Pumping Station. However, connecting both Areas S3 and S4 to the station would exceed its current capacity. Connecting Area S4 to the Parrish Road Pumping Station eliminates the need to build a new pump station and FM to serve Area S4.
- Scenario No. 4–Upgrades to Parrish Road Pumping Station could be made so that flow from all areas listed in Table 5-5 could be connected. At a minimum, the extent of the upgrades would require larger pumps and new control systems and potentially could require a larger or expanded wet well. However, it is estimated that such improvements would be less than or equal to the cost of building a new pump station and FM in Area S4. The existing 10-inch-diameter FM would be adequate to convey these higher flows.

The recommended approach is Scenario No. 4, route areas S1 through S4 to the Parrish Road Pumping Station. The remainder of the South End Concept Area will require substantial improvements, as shown in Figure 5-2, and all remaining new development in the area should be routed to the new improvements so that all growth participates in the cost of the improvements.

Ultimately, the final layout of new sewers to serve the area will depend on how the land is to be developed and when. The location of planned development and the timing for those improvements are important since land to be developed farther away from existing sanitary sewer connections will require more improvements to connect to the existing system. A unique aspect of the South End Concept Area is that substantial capital investment is required prior to development of this area. The pump station identified as SE- 1 in Table 5-6, also requires a 4,830 LF FM, and approximately 4,700 LF of 12- to 18-inch-diameter sewer to be built before the area can be developed at an approximate cost of $5.83 million. The City may need to create a special assessment district or use other means to fund the up-front costs so that development can occur in this area since it is unlikely that a developer will fund such a project. To ensure that the overall needs are met, the City may want to take the lead on planning, designing, and constructing the backbone of this system.

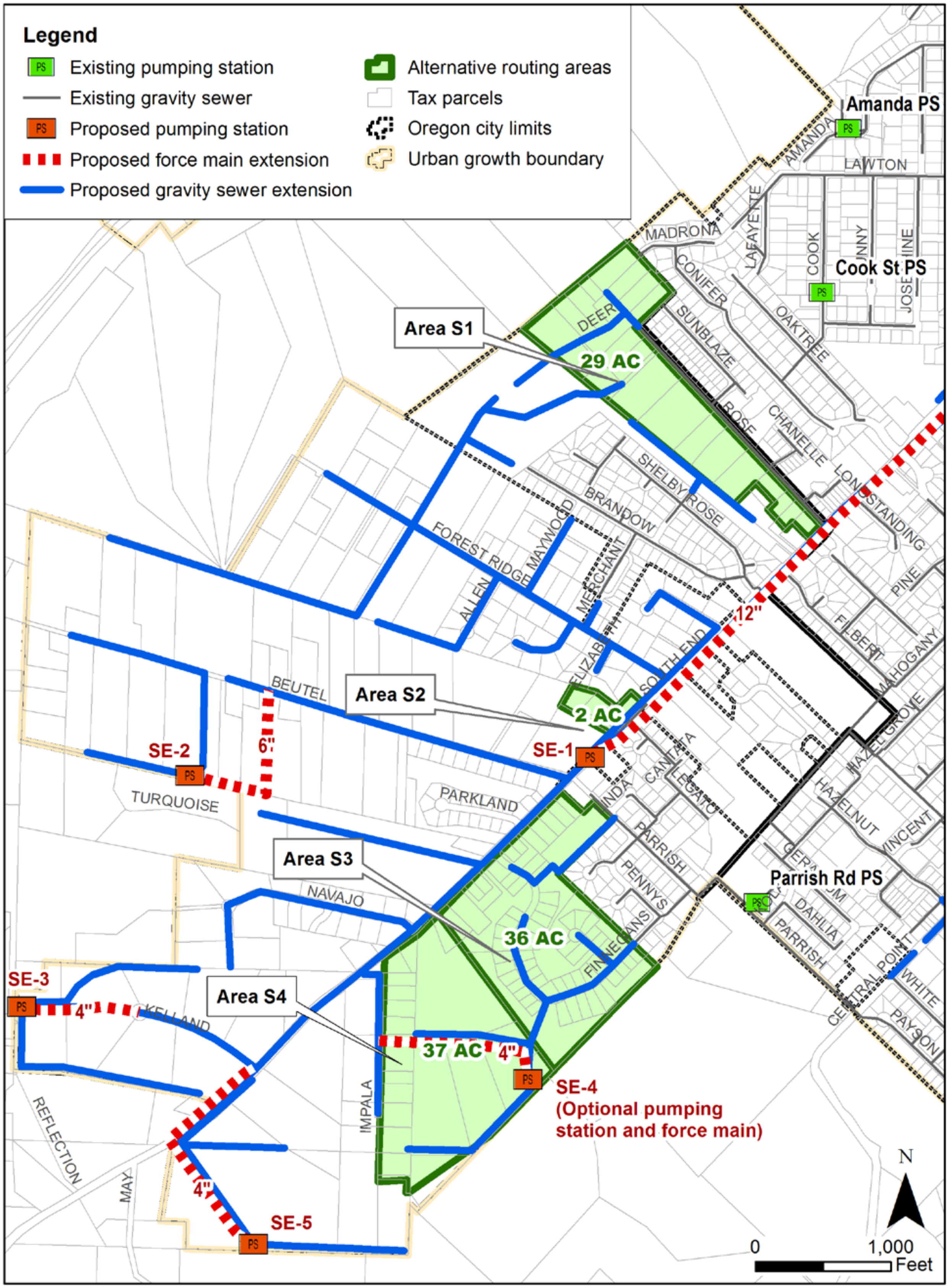



Figure 5-3. South End Concept Area, Parrish Road Pumping Station options

The estimated cost of improvements for the South End Concept Area is listed in Table 5-7. It is assumed that areas S1, S2, S3, and S4 will be routed through the Parrish Road Pumping Station, so the SE-4 pumping station is listed as optional with no costs assigned. In addition, if this (gravity sewer) scenario is implemented, then the size of the SE-1 pumping station and FM could be reduced by the flow that would have been provided by the SE-4 pumping station.

**Table 5-7. South End Area, Estimated Improvement Costs**

| Description of improvement | | | | Cost estimate, dollars[a] |
|---|---|---|---|---|
| Gravity sewer extensions[b] | | | | |
| 8-inch-diameter sewers, 30,556 LF | | | | 10,760,000 |
| 10-inch-diameter sewers, 1,492 LF | | | | 560,000 |
| 12-inch-diameter sewers, 7,025 LF | | | | 2,780,000 |
| 15-inch-diameter sewers, 2,860 LF | | | | 1,260,000 |
| 18-inch-diameter sewers, 823 LF | | | | 400,000 |
| Gravity sewer extension subtotal | | | | 15,760,000 |
| Pumping stations and FMs | | | | |
| Pumping station number[c] | Pumping station capacity, gpm | FM, diameter, inches | FM length, LF | |
| SE-1[c] | 1,766 | 12 | 4,830 | 3,770,000 |
| SE-2 | 210 | 4 | 1,343 | 1,090,000 |
| SE-3 | 70 | 4 | 896 | 640,000 |
| SE-4 (optional) | 119 | 4 | 1,285 | - |
| SE-5 | 157 | 4 | 1,706 | 1,050,000 |
| Pumping station and FM subtotal | | | | 6,550,000 |
| Total | | | | 22,310,000 |

[a] *Estimated costs include a 50 percent allowance for construction contingencies, engineering, and overhead. Costs are rounded to the nearest $10,000. Costs assume an average depth of 10 feet using cost condition 2. See Appendix C for unit cost tables.*

[b] *Pipes sizes are based on an assumed minimum slope. Actual slope may permit smaller size pipes.*

[c] *If the gravity sewer solution is preferred by the City for areas S1 through S4, then the SE-4 pumping station and FM need not be constructed and the flows coming into SE-1 pumping station can be reduced by the flow listed for SE-4.*

### 5.2.3.4 Beavercreek Road Concept Area

The *Beavercreek Road Concept Area Plan, Summary and Recommendations,* (OTAK, June 30, 2007), calls for this area to be developed as a diverse mix of uses that will include an employment campus, mixed use (employment and transit) districts, and two mixed use neighborhoods that will be woven together by open space, trails, and a network of green streets that are all constructed using sustainable development practices. The total area consists of approximately 453 acres located along the east side of Beavercreek Road, as shown in Figure 5-4. Approximately 284 acres will be developed or redeveloped, as listed in Table 5-8. Approximately 113 acres are defined as parks, open space, and natural areas and 56 acres are defined as ROWs.

| Table 5-8. Beavercreek Road Concept Area Future Flows | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Area/land use | Gross acres[a] | Net acres[b] | Dwelling units | Residents | Average sanitary flow[d], mgd | Peak factor | Peak flow, mgd | Peak flow, gpm |
| North Employment Campus | 149 | 127 | | | 0.158 | 3.1 | 0.610 | 424 |
| Mixed Employment Village | 26 | 21 | | | 0.026 | 3.7 | 0.116 | 81 |
| Main Street (mixed use)[c] | 10 | 8 | 100 | 250 | 0.030 | 3.6 | 0.117 | 81 |
| West mixed use neighborhood | 22 | 18 | 387 | 968 | 0.097 | 3.2 | 0.329 | 228 |
| East mixed use neighborhood | 77 | 62 | 536 | 1,340 | 0.134 | 3.1 | 0.478 | 332 |
| Total all areas | | | | | | | 1.650 | 1,146 |

[a] *Gross acres equal future planning boundary less existing ROWs, according to GIS parcel data.*

[b] *Net acres equal gross acres less 15 percent for employment use and 20 percent for mixed employment, mixed use, and residential areas to account for local roads and easements.*

[c] *Mixed use land use assumes 50 percent of acreage devoted to commercial uses and the remaining 50 percent devoted to vertical mixed use.*

[d] *Flow generation based on 2.5 residents per dwelling, 80 gpcd, 1,000 gpad for commercial areas, and 1,000 gpad of I/I.*

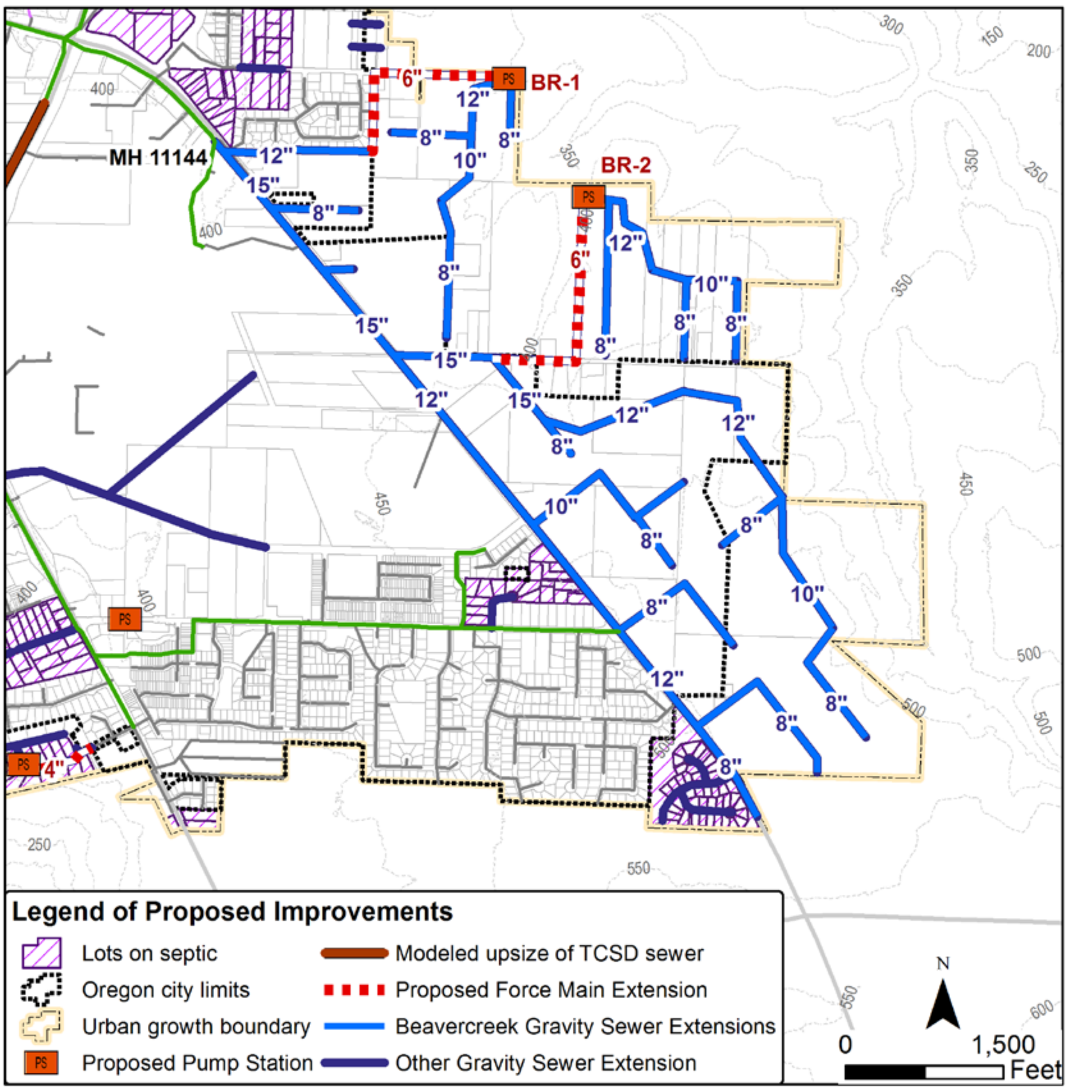



**Figure 5-4. Beavercreek Road Concept Area improvements**

A more in-depth analysis was performed for the City that considered routing alternatives for the southern end of the concept area. The alternatives included routing flows through the existing sewer in Glen Oak Road. The analysis, *Glen Oak Road Sewer Extensions Technical Memorandum*, is included as Appendix I.

The estimated cost of improvements for the Beavercreek Road Concept Area is listed in Table 5-9. These costs are based on all flows generated within the concept area being routed to a downstream discharge manhole (MH) 11144 in Beavercreek Road. If the City decides to route flow from any portion of the concept area to a different manhole, then some of the required improvements shown in Figure 5-4 could be reduced in size accordingly.

**Table 5-9. Beavercreek Road Concept Area, Estimated Improvement Costs**

| Description of improvement | | | | Estimated cost of improvements, dollars[a] |
|---|---|---|---|---|
| Gravity sewer extensions[b] | | | | |
| 8-inch diameter sewers, 14,356 LF | | | | 5,050,000 |
| 10-inch diameter sewers, 4,317 LF | | | | 1,610,000 |
| 12-inch diameter sewers, 10,683 LF | | | | 4,230,000 |
| 15-inch diameter sewers, 4,372 LF | | | | 1,930,000 |
| Gravity sewer extension subtotal | | | | 12,820,000 |
| Pumping stations and FMs | | | | |
| Pumping station number | Pumping station capacity, gpm | FM, diameter, inches | FM, length, LF | |
| BR-1 | 272 | 4 | 2,080 | 1,390,000 |
| BR-2 | 217 | 4 | 2,333 | 1,370,000 |
| Pumping station and FM subtotal | | | | 2,760,000 |
| Total | | | | 15,580,000 |

[a] *Estimated costs include a 50 percent allowance for construction contingencies, engineering, and overhead. Costs are rounded to the nearest $10,000. Costs assume an average depth of 10 feet using cost condition 2. See Appendix C for unit cost tables.*

[b] *Pipes sizes shown are based on an assumed minimum slope. Actual slope may permit smaller size pipes. For example, the modeling did not predict the need to upsize the existing City sewer downstream of MH 11144.*

### 5.2.3.5 Park Place Concept Area

The *Park Place Concept Plan,* (City of Oregon City, March 12, 2008) was prepared to create a common vision for how the area is to be developed. The plan identifies a development framework that "respects and augments the area's context, history, and natural systems." The plan calls for this area to be developed in a way that emphasizes good urban design, promotes multi-modal connectivity, enhances community, expands diversity, and provides for sustainable growth. The total area consists of nearly 500 acres located along the city's northeast boundary, as shown in Figure 5-5. Approximately 272 acres will be developed or redeveloped, as listed in Table 5-10. Approximately 166 acres are defined as parks, open space, and natural areas.

| Table 5-10. Park Place Concept Area Future Flows | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Area/land use | Gross acres[a] | Net acres[b] | Dwelling units | Residents | Average sanitary flow[d], mgd | Peak factor | Peak flow, mgd | Peak flow, gpm |
| Low/medium-density residential | 203 | 173 | 1,033 | 2,583 | 0.258 | 2.9 | 0.924 | 641 |
| Medium/high-density residential | 57 | 46 | 426 | 1,065 | 0.107 | 3.2 | 0.384 | 267 |
| Mixed-use commercial[c] | 8 | 6 | 0 | 0 | 0.008 | 4.1 | 0.039 | 27 |
| Retail | 3.6 | 3 | 0 | 0 | 0.004 | 4.5 | 0.019 | 13 |
| Civic | 28.7 | 29 | 0 | 0 | - | - | - | - |
| Park | 11.2 | 11 | 0 | 0 | - | - | - | - |
| Constrained land (buffers, etc.) | 166.1 | 166 | 0 | 0 | - | - | - | - |
| Total all areas | | | | | | | 1.367 | 949 |

[a] *Gross acres equal future planning boundary less existing ROWs, according to GIS parcel data.*

[b] *Net acres equal gross acres less 15 percent for low/medium density residential and 20 percent for medium/high density residential, and 25 percent for mixed-use commercial.*

[c] *Mixed use land use assumes 100 percent of acreage devoted to commercial use.*

[d] *Flow generation based on 2.5 residents per dwelling, 80 gpcd, 1,000 gpad for commercial areas, and 1,000 gpad of I/I.*

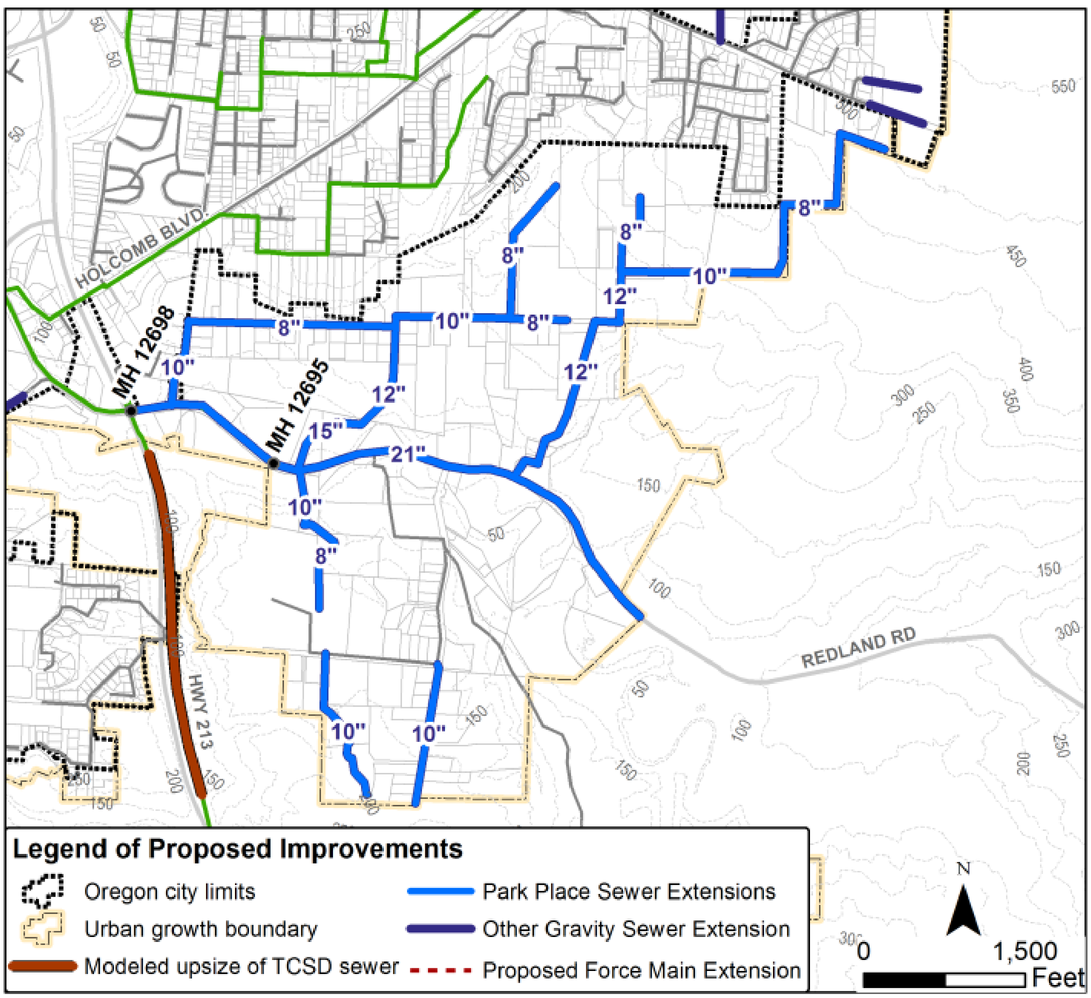



Figure 5-5. Park Place Concept Area improvements

The estimated cost of improvements for the Park Place Concept Area is listed in Table 5-11. These costs are based on all flows generated within the concept area being routed to a downstream discharge manhole (MH 12698) in Redland Road. If the City decides to route flow from any portion of the concept area to a different manhole, then some of the required improvements shown in Figure 5-4 could be reduced in size accordingly.

**Table 5-11. Park Place Concept Area, Estimated Improvement Costs**

| Description of improvement[c] | Estimated cost of improvements, dollars[a] |
|---|---|
| 8-inch-diameter sewers, 7,831 LF | 2,760,000 |
| 10-inch-diameter sewers, 6,740 LF | 2,510,000 |
| 12-inch-diameter sewers, 3,282 LF | 1,300,000 |
| 15-inch-diameter sewers, 1,116 LF | 490,000 |
| 21-inch-diameter sewers, 5,143 LF | 2,760,000[b] |
| Total | 9,820,000 |

[a] *Estimated costs include a 50 percent allowance for construction contingencies, engineering, and overhead. Costs are rounded to the nearest $10,000. Costs assume an average depth of 10 feet using cost condition 2. See Appendix C for unit cost tables.*

[b] *The topography of this area, existing bridges and the elevation of the existing TCSD sewer should be reviewed during preliminary design to determine the feasibility of the 21-inch FM on Redland Road. The cost of this sewer extension is listed as a cost to TCSD in the Park Place Concept Area Plan and sized as a 36 inches. This sewer extension was sized to convey flow from the Park Place Concept Areas only.*

[c] *Pipes sizes shown are based on an assumed minimum slope. Actual slope may permit smaller size pipes. For example, the modeling did not predict the need to upsize the existing TCSD sewer downstream of MH 12698.*

## 5.3 Continued Observation

The modeling identified sewers that are predicted to surcharge during the design storm event for both the existing and future planning scenarios. The sewers experiencing surcharging are identified in Section 4 with a detailed list of all surcharged pipes included in Appendix E. Pipes shown in Appendix E with the ratios of depth of water to pipe diameter of greater than 1.0 are considered surcharged pipes since the depth of the water is greater than the diameter of the pipe. In some locations, pipes were identified for upsizing so that excessive surcharging and/or flooding could be mitigated. At a number of locations, pipe upsizing of one or more sewers relieved the surcharging in the immediate upstream sewers. Also, at a number of other locations pipe upsizing is not recommended since the amount of surcharging was not deemed to be excessive. In these latter cases, the surcharging predicted by the model is considered acceptable since it does not appear to result in basement backups or manhole flooding. However, it is recommended that some of these sewers be observed during large wet weather events to establish the maximum depth of water that actually occurs. If City staff observe water surface elevations that are higher than predicted by this SSMP, or deemed excessive by staff, then additional actions to alleviate the surcharging should be considered by the City.

Criteria used to develop the list of sewers listed in Appendix E, Table E2 include the following:

- Upstream manhole depth of less than 8 feet and surcharging of at least 1 foot above crown of pipe (could impact basements if located in vicinity)
- Freeboard of less than 5 feet (priority sewers to observe)

It is recommended that the sewers listed in Table E-2 be observed during large wet weather events to establish actual water surface elevations. This information, along with the calculated freeboard should be considered with regard to the potential to flood manholes or backup flow into basements. Many of the sewers identified for observation are associated with a named project. The determination of the actual maximum water surface elevations will help establish a priority for implementing these projects.

## 5.4 Rehabilitation and Replacement (R&R) Program

As a collection system ages, the structural and operational condition of the sewer system will decline as the number and type of defects in the piped system increase. If unattended, the severity and number of defects will increase along with an increased potential of sewer failure. Sewer failure is defined as an inability of the sewer to convey the design flow. It is manifested by hydraulic and/or structural failure modes. Hydraulic failures can result from inadequate hydraulic capacity in the sewer. Loss of hydraulic capacity can result from a reduction of pipe area due to accumulations of sediment, gravel, debris, roots, fats, oil, and grease, and structural failure. Also, a major loss of hydraulic capacity can be the result of excessive I/I or inappropriate planning for future growth that results in flows in excess of pipe capacity. Structural defects left unattended can lead to catastrophic failures such as pipe collapses and sanitary sewer overflows (SSOs). Structural failures may start from common structural defects such as cracks, fractures, holes, corrosion, and joint separations. Both hydraulic and structural failures can have a significant negative impact on the community and the environment.

An R&R program is required to reduce the potential for sewer failures and to extend the useful life of the collection system. A proactive R&R program rehabilitates sewers prior to failure. Such a program extends the useful life of assets at minimum cost since the cost of rehabilitation is typically half the cost of pipe replacement, and is even more economical when compared with the cost of repairing a failed sewer. The most frequently used sewer rehabilitation technologies are discussed in Appendix G.

The City should develop and implement an R&R program. It should be based on a sewer inspection and condition assessment program that assesses sewer and manhole condition. Sewer condition and other risk factors should be identified such that a priority ranking system be established for identifying the order in which sewers should be rehabilitated. The recommended system would be a risk-based approach for identifying when sewers should be rehabilitated. The risk-based approach considers the likelihood and consequences of sewer failure. The likelihood of sewer failure is based on the sewer's structural and hydraulic condition. The consequences of sewer failure are based on several factors, including emergency sewer repair costs, sewer location, environmental, and health impacts that could be realized should the sewer fail. A risk-based approach to implementing a R&R program helps ensure that capital dollars are spent where they will provide the greatest benefit.

The program should be coordinated with the results of prioritized basins for I/I reduction (Appendix D) and the capacity analysis and recommended sewer upsizing recommendations in this section.

### 5.4.1 Inspection/Condition Assessment Program

The foundation of an R&R program is built on knowing the structural and operational condition of the collection system. The USEPA's proposed Capacity, Management, Operation, and Maintenance requirements identify a sewer inspection program as being an essential element of a proactive maintenance program and its complementary R&R program.

The City has recently implemented a sewer inspection program. To date, nearly 103,000 LF of sewer have been inspected which represents approximately 16 percent of the total sewer system. This SSMP recommends that the City increase the annual inspection goal to align more closely with the business practices of the industry.

In the Northwest, many cities and utilities have a 7- to 10-year goal for inspecting their entire sewer systems the first time. After that, cycle time for inspections are often determined by initial findings and consequence of failure. The City has approximately 779,000 LF of sanitary sewer. To inspect the entire collection system on a 7-year cycle, approximately 111,000 LF of sewer would need to be inspected annually. The cost of labor for a 7-year inspection cycle is approximately $90,000 per year (based on production of 1,000 LF per day, two-person crew, and $50 per hour loaded costs). A 10-year cycle translates into 77,900 LF of inspection per year at $62,000 annual cost.

Although there are a number of inspection and investigative technologies currently on the market, closed-circuit television (CCTV) inspection is still the most economic and versatile inspection technology available. Many of the other investigative technologies are best applied for specialized conditions not addressed by basic CCTV inspection.

### 5.4.2 Condition Assessment

Once a sewer has been inspected, the observed defect information is used to assess both the structural and operational condition of the sewer. Both categories are important since a failure in either category can lead to sewer failure if the proper maintenance, repairs, and/or rehabilitation are not performed in a timely manner. For most sewer inspection and condition assessment processes, each observed defect is given a score or grade. A widely accepted grading system is presented by the National Association of Sewer Service Companies' Pipeline Assessment and Certification Program (PACP), each defect is assigned a grade ranging from 1 to 5, with 5 being the worst grade, as listed in Table 5-12. Then, PACP offers several ways of rating the condition of a sewer:

- *Defect grade*–the worst defect observed is used to grade the entire pipe. A pipe with one Grade 5 defect would be given a Grade 5 for either the structural or operational condition.
- *Segment grade*–the number of occurrences of each defect grade is multiplied by the value of the defect grade. For example, a sewer with two Grade 5 defects, and four Grade 4 defects, and no other defects would have a segment grade of 26. Some municipalities would then create a look-up table to convert the total conditional grade score into a 1 to 5 scale. Total grades would be established for both the structural condition and operational condition.
- *Pipe Rating Index (PRI)*–the segment grade is divided by the number of defect occurrences. Using the above example, the PRI would be 4.3 (26 divided by 6).

**Table 5-12. Structural and Operational Condition Grades for Sewers**

| Condition grade | Grade description | Defect description | Structural condition grade implication | Operational condition grade implication |
|---|---|---|---|---|
| 5 | Immediate attention | Sewers requiring immediate attention | Collapsed or collapse imminent | Unacceptable infiltration or blockages; surcharging of pipe during high flow with possible overflows |
| 4 | Poor | Severe defects that will continue to degrade with likely failure in 5 to 10 years | Collapse likely in 5 to 10 years | Pipe at near surcharge condition during high flow; overflows still possible at high flows |
| 3 | Fair | Moderate defects that will continue to deteriorate | Collapse unlikely in near future; further deterioration likely | Surcharge or overflows unlikely but increased maintenance required |
| 2 | Good | Minor and few moderate defects | Minimal near-term risk of collapse, potential for further deterioration | Routine maintenance only |
| 1 | Excellent | No defects, condition like new | Good structural condition | Good operational condition |

The City currently uses a 0 to 5 scale for assessing condition grade with Grade 5 being a sewer requiring immediate attention. Figure 5-6 shows the sewers that have been inspected to date (approximately 12 percent by length) along with the sewers assigned Grade 4 and Grade 5 condition grades. Grade 4 and 5 sewers should be the focus of the R&R program.

As additional inspections are performed and condition grades assigned, the City will develop a more complete and accurate understanding of existing pipe conditions. This information should be managed by the City's computerized maintenance management system, GIS, or other software tools so that the inspection information can be readily available to both engineering and maintenance staff. This condition information should be used for making informed decisions on the amount and type of maintenance that may be required and for identifying when to rehabilitate sewers and the type of rehabilitation such that the performance and condition of the collection system are maintained.

### 5.4.3 I/I Abatement

As shown in Appendix D, several areas of the city have high I/I. Reducing the amount of I/I in the collection system can improve the hydraulic capacity of the existing system such that some pipes may not need to be replaced to convey future flows. In addition, I/I reduction can help prevent some types of structural failures. Some cracked and broken sewers are the result of a condition called soil piping. Soil piping in this context is a loss of pipe bedding and backfill support due to small grain soil particles washing out of the supporting soils into the sewer as a result of infiltration at sewer cracks and separated joints. If these conditions are not addressed, sewers can fail, resulting in sinkholes, basement backups, and SSOs.

Appendix D describes the primary components of an I/I abatement program. The I/I projects that come from the investigative work will include sewer rehabilitation and replacement, service lateral replacement, and potentially, the construction of new sanitary sewers. It is known that some small areas of the city do not have a storm drain system and that in these areas roof leaders and footing drains may be connected to the sanitary sewer. The City may find that converting the existing sanitary sewer into a storm drain and constructing a new sanitary sewer may be the most cost-effective means of eliminating these sources of inflow.

The City has approximately 10,400 service laterals. These must be addressed both for I/I control and to preserve structural integrity. In a program that addresses mains and laterals, laterals account for about 25 to 50 percent of the overall project cost depending on density of development. The City will need to determine how to fund lateral replacements that are on private property. Many different lateral funding strategies are in use throughout the Northwest.

In addition, the City should consider developing new City codes to augment implementation of some of the recommended I/I reduction activities. Code should be developed that requires the disconnection of roof leaders and footing drains where alternatives to the sanitary sewer are available. New code is required to support the rehabilitation of service laterals. Since the most effective I/I abatement programs include rehabilitation of the service laterals, the City needs the authority to have this work performed. Factors to be considered in developing new code language for service lateral rehabilitation include the following:

- Will the homeowner or the City perform the required upgrades?
- Who will pay for the upgrades, or what will be the cost sharing mechanism?
- At what point will the improvements be required?
- How long will the homeowner have to perform the improvements if they are required to perform them?

In March 2014, TCSD initiated a multi-year I/I investigation that will evaluate I/I contributions from throughout the service district. The purpose of the investigation is to determine if and where I/I can be removed from the system cost-effectively. For definition purposes, cost-effective I/I reduction is achieved when the cost of eliminating I/I from within a portion of a sanitary drainage basin is less expensive than improvements to the downstream conveyance and treatment systems. The results of this investigation will not be known for several years, but it is recommended that the City move forward with some of the recommended first steps of an I/I abatement program to improve an understanding of I/I sources from within the city limits.

### 5.4.4 R&R Program Implementation

I/I abatement projects are part of the overall R&R program. While the focus of many R&R programs is to restore the structural integrity of existing sewers, such activities will also help reduce the amount of infiltration that finds its way into the collection system.

The City's GIS database identifies approximately 779,000 LF of sanitary sewer including FMs. A simplified R&R program would be to rehabilitate 1 percent of the collection system annually to keep it in good structural and operational condition. This assumes that the useful life of a sanitary sewer is 100 years . Based on this, the City should be rehabilitating approximately 7,800 LF of sewer a year. Most sewer rehabilitation technologies, including cured-in-place-pipe and pipe-bursting, are less expensive than complete replacement costs. Based on an assumed $300 per LF (assuming a mix of open-cut replacement and trenchless technologies), the City should budget approximately $2.34 million per year in 2013 dollars to the R&R program based on the simplified approach.

Alternatively, the City has performed sewer inspections on approximately 12 percent of the collection system. This information can be used as a starting point for developing an R&R program. Of the pipe inspected, approximately 8 percent has been assessed as Grade 4 or Grade 5 based on the City's grading system. Assuming that the condition grades for the inspected pipe are representative of the overall system, approximately 64,000 feet of sewers eventually will require maintenance, replacement, or rehabilitation.

Table 5-13 lists a recommended R&R implementation strategy based on the existing condition grade information. Years 1 through 8 should focus on the most severely deteriorated sewers, the Grade 5 sewers identified by the CCTV inspections. The less deteriorated Grade 4 sewers should be addressed during years 5 through 8. As future inspections are conducted, additional Grade 4 and Grade 5 sewers will be identified. The LF listed in Table 5-13 for the unknown (i.e., yet to be inspected) Grade 4 and 5 sewers are estimated based on the distribution of grades for sewers inspected to date. These sewers are identified for R&R during years 5 through 16. The future inspections may find that the actual LF for each grade may vary from these projections. Also, the City should anticipate that additional R&R will be required in the future as the collection system ages.

**Table 5-13. Per Annum Costs for Recommended R&R Program Activities**

| Work item | Total LF or quantity | Cost per year for years 1 – 16 | | | |
|---|---|---|---|---|---|
| | | 1 – 4 | 5 - 8 | 9 - 12 | 13 - 16 |
| Grade 5 (known) | 4,095 | $154,000 | $154,000 | | |
| Grade 4 (known) | 4,348 | | $326,000 | | |
| Grade 5 (unknown) | 26,892 | | $500,000 | $758,000 | $758,000 |
| Grade 4 (unknown) | 28,557 | | $350,000 | $895,000 | $895,000 |
| Total | 63,892 | $154,000 | $1,330,000 | $1,653,000 | $1,653,000 |

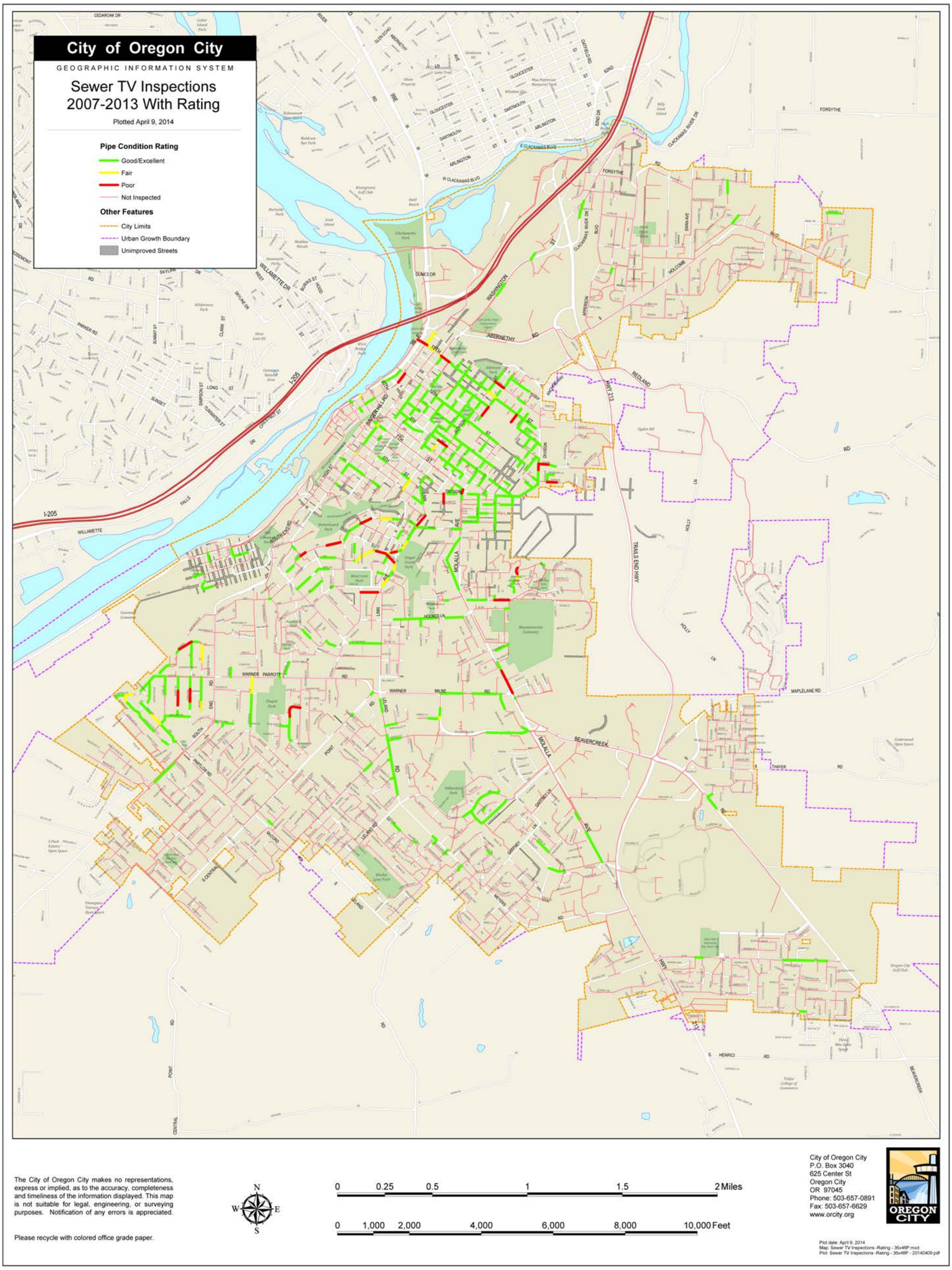



Figure 5-6. Sewer CCTV inspections with ratings (2007 through 2013)

Some of the pipe R&R projects may overlap with the sewers recommended for replacement due to hydraulic deficiencies. In addition, the R&R program should be structured to address the structurally- and operationally-deficient sewers including those sewers with excessive I/I. Table 5-13 does not include costs to construct new sanitary sewers to support downspout and foundation drain disconnects nor does it include the costs for R&R of privately owned service laterals. The annual costs for sewer I/I investigative activities can vary significantly depending on how aggressively the City pursues I/I reduction.

Other factors that affect cost include level of data analysis to be performed, time of year that inspections are performed, and how much work is done in-house versus use of outside consultants. Based on the overall approach presented in Appendix D, the costs for sample I/I investigative activities are outlined in Table 5-14. Note that the City's existing CCTV program is included in this category.

**Table 5-14. Per Annum Costs for Recommended I&I Investigative Activities**

| Work item | Annual LF or quantity | Assumptions | Annual cost, dollars |
|---|---|---|---|
| Flow monitoring and modeling | 4 | Four flow meters, 3 months, hydrologic regression models, updates to hydraulic models | 40,000 |
| CCTV inspections | 77,900 | 10-year inspection cycle | 62,000 |
| Dye and/or smoke testing | 40,000 | Focus on the oldest sewers in city | 80,000 |
| Total | | | 182,000 |

## 5.5 Capital Improvement Project Summary

The improvement projects recommended in the previous sections are summarized in Tables 5-15, 5-16, and 5-17. The project locations are shown in Figure 5-5. Also shown in the recommended CIP Tables 5-16 and 5-17 are the anticipated years for performing the work. The City reserves the right to modify the priority based on flow conditions and funding.

**Table 5-15. Recommended CIPs: Sewer Improvements**

| Project number/name | Year completed | Estimated project cost, dollars |
|---|---|---|
| (1) 12th Street | 3 | 407,000 |
| (2) 13th Street | 4 | 460,000 |
| (3) Division Street | 5 | 424,000 |
| (4) Linn Avenue | 1 | 470,000 |
| (5) Hazelwood Drive | 2 | 1,319,000 |
| (6) Holcomb Boulevard | 6 -10 | 60,000 |
| Total all sewer improvements | | 3,140,000 |

[a] *Estimated costs include a 50 percent allowance for construction contingencies, engineering, and overhead. Costs are rounded to the nearest $10,000. Costs assume an average depth of 10 feet using cost condition 2. See Appendix C for unit cost tables and Appendix H for more detailed description of each project.*

| Table 5-16. Recommended Existing Pumping Station and FM Improvements | | | | |
|---|---|---|---|---|
| Pumping station | Description of improvement | Project number/name | Year completed | Estimated cost of improvements, dollars[a] |
| Canemah | Wet well refurbishment and update of controls | (7) Canemah | 4 | 360,000 |
| Settler's Point | Pumping station upgrades | (8) Settler's Point | 1 | 300,000 |
| Nobel Ridge | Upgrade pumps and control systems | (9) Nobel Ridge | 3 | 260,000 |
| Hidden Creek | Upgrade controls | (10) Hidden Creek | 2 | 60,000 |
| Hilltop[b] | Decommission existing pumping station and replace with 8-inch, 1,300–foot-long gravity sewer | (11) Hilltop | 5 | 440,000 |
| Parrish Road[c] | Pumping station upgrades | (12) Parrish Road | 6 - 10 | 750,000 |
| Total all pumping station and FM improvements | | | | 2,170,000 |

[a] *Estimated costs include a 50 percent allowance for construction contingencies, engineering, and overhead. Costs are rounded to the nearest $10,000. Costs assume an average depth of 10 feet using cost condition 2. See Appendix C for unit cost tables.*

[b] *This gravity line is planned to serve future development and a portion for the installation costs will be SDC-reimbursable to the developer for this new gravity sewer line. The cost of this gravity sewer is not repeated in Section 5.2.3 on sewer extensions.*

[c] *See Section 5.2.2.2 for South End Road Concept Area flow routing concepts and impact on Parrish Road Pumping Station.*

| Table 5-17. Recommended CIPs: Sewer Extensions | |
|---|---|
| Description of improvement | Estimated cost of improvements, dollars[a] |
| Priority 1 CIPs | 6,090,000 |
| South End Road Concept Area | 22,310,000 |
| Beavercreek Road Concept Area | 15,580,000 |
| Park Place Concept Area | 9,820,000 |
| Priority 2 CIPs[b] | 12,130,000 |
| Total all sewer extensions | 65,930,000 |

[a] *Estimated costs include a 50 percent allowance for construction contingencies, engineering, and overhead. Costs are rounded to the nearest $10,000. Costs assume an average depth of 10 feet using cost condition 2. See Appendix C for unit cost tables.*

[b] *Some areas requiring sewer extensions will also require small pumping stations due to the topography.*

## Section 6

# Limitations

This document was prepared solely for the City of Oregon City, Oregon (City) in accordance with professional standards at the time the services were performed and in accordance with the original contract between City and Brown and Caldwell dated October 25, 2011 and as amended thereafter. This document is governed by the specific scope of work authorized by City; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by City and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

# Appendix A: Wastewater Conveyance System Model Development

## Appendix A

# Wastewater Conveyance System Model Development



Brown AND Caldwell

# List of Figures

# List of Tables

# Introduction

Appendix A describes the City of Oregon City's (City) hydrologic and hydraulic (H/H) wastewater conveyance model (model). The model was developed by Brown and Caldwell to estimate wet weather flows and assess capacity of the conveyance system. Recent flow monitoring conducted on behalf of the City was used for calibration of the model.

The document is organized into the following sections:

1. **System Characterization:** The City's wastewater conveyance system is described in this section. Specifically, the portion of the wastewater conveyance system included in the model is discussed.
2. **Data Collection:** This section describes the data used in development and calibration of the model, including the recently collected flow monitoring data.
3. **Model Development:** The method for constructing the model is discussed in this section.
4. **Model Calibration:** The model was calibrated using recently-collected observations. The calibration details are provided in this section.
5. **System Evaluation:** This section discusses how the model was used to estimate existing and future wet weather flows.
6. **Summary:** This section summarizes the work described in this Appendix

# Section 1 System Characterization

The City's conveyance system collects wastewater within the city limits and transports it to the regional collection system, owned by Tri-City Service District (TCSD). TCSD operates and maintains the interceptors and the Tri-City Water Pollution Control Plant in Oregon City.

The model includes flow contributions from the entire Oregon City wastewater conveyance system, which was organized (for modeling) into three zones. The zones, identified as North, Central, and South, correspond to distinct TCSD tributary basins.

The pipes included in the model represent a backbone of the City's conveyance system, consisting of larger diameter pipes. The model also includes TCSD-owned pipes located within the city limits. The City's conveyance system and the pipes included in the model are shown in Figure 1.

The 14 pumping stations maintained by the City, and part of the wastewater conveyance system, are also shown in the figure. The pumping stations with existing capacities of greater than 0.6 million gallons per day (mgd) were explicitly represented in the model. The remaining pumping stations are accounted for in the model as described in more detail in Section 3 of this Appendix.

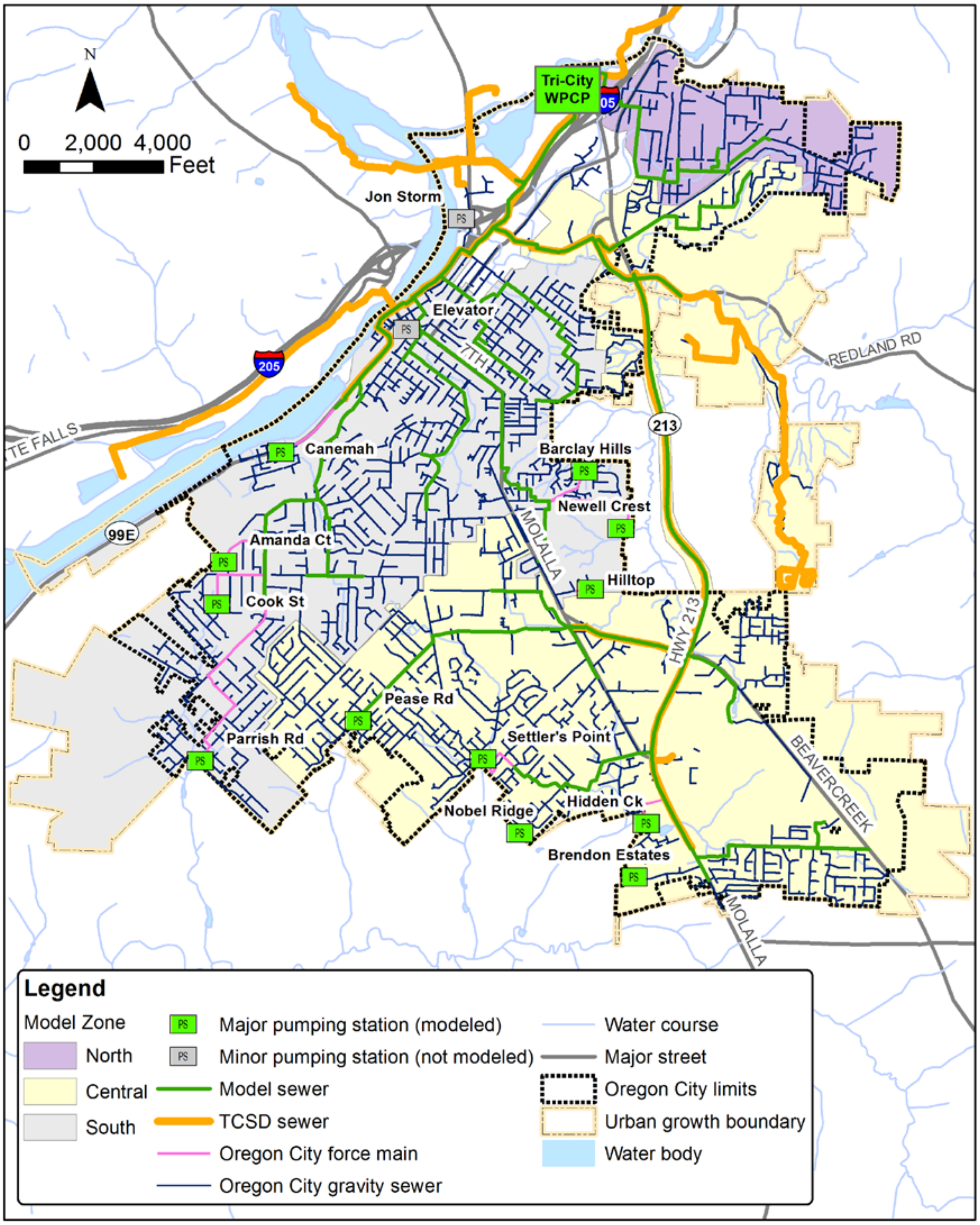



Figure 1. Oregon City wastewater conveyance system

# Section 2 Data Collection

This section describes the sources of data used to develop and calibrate the model. Table 1 lists these data, the sources of the data, and names of specific files where the data can be located (if applicable).

**Table 1. Data Sources**

| Data description | Data source | File name(s) |
|---|---|---|
| Pipe and manhole attributes (e.g., inverts, ground elevation, length, diameter) | Geographic information system (GIS) files (from City) | Manhole, pump, and pipe feature classes provided by the City in a geodatabase. |
| | City field survey | The City had approximately 62 structures surveyed by AKS. The survey elevations were in North American Vertical Datum of 1988 (NAVD88). |
| | City record drawings | Various record drawings detailing pipe and manhole elevations (rim and invert) were provided. |
| | Previous hydraulic model | The City provided a hydraulic model, in spreadsheet format, developed by Tetra Tech. This model file name is "TT Hydraulic Model.xls." The model contains manhole rim and invert elevations, which were used in development of the current model. Vertical datum of the elevations was assumed to be National Geodetic Vertical Datum of 1929 (NGVD29), based on comparisons to City field survey information for common locations. |
| Pump operation curves and set points | City record drawings | Record drawings were provided for the following pumping stations: Canemah, Pease Road, Parrish Road, Settler's Point, Cook Street, Hilltop, Brendon Estates, Newell Crest, and Nobel Ridge. |
| Precipitation time series | USGS | Rainfall data were retrieved for the U.S. Geological Survey (USGS) gauge named Willamette River Below Falls At Oregon City (crohms#361). Data were retrieved from August 2009 through January 2013. The time step of the rainfall data is 15 minutes (USGS-ID: 14207770) The USGS also has a page for this station online at: http://or.waterdata.usgs.gov/nwis/uv?14207770 |
| | SFE Global (SFE) RG01 | Rainfall data collected during flow monitoring were provided in 5-minute time steps from January 17, 2012 through June 12, 2012. Data were collected with a tipping bucket and an Isco 2105 logger. |
| Flow monitoring data | SFE observations | Data were collected 5-minute time steps at 12 sites from January 2012 to early April 2012. Level, velocity, and estimate flow were provided in each data file. More details are provided below. |
| | City SCADA data | Supervisory control and data acquisition (SCADA) data were provided in 1-minute time steps for all pumping stations for the period January through March 2012. |
| Surface elevation | City GIS | City GIS feature class named "TERRAIN_Contours_2ft" was used for ground elevations during model development. The data were 2-foot contours. Elevation datum is NGVD29. |

## 2.1 Horizontal and Vertical Datum

The horizontal and vertical datum of the hydraulic model are consistent with the City's GIS datum as follows:

- Horizontal: North American Datum of 1983 State Plane Oregon North FIPS 3601 Feet HARN
- Vertical: NAVD88

Development of the model required conversion of elevations from NGVD29 to NAVD88. In these situations, 3.5 feet was added to the NGVD29 elevation for conversion to NAVD88. This conversion is based on the National Oceanic and Atmospheric Administration's (NOAA) Vertcon for latitude of 45.347393 and longitude of 122.597879.

## 2.2 Flow Monitoring Data

SFE Global, Inc. installed 12 flow meters in January 2012, which were used for calibration of the City's wastewater flows in the conveyance system. Detailed information regarding SFE's monitoring is available in the final flow monitoring report (SFE Global Inc., 2012).

The flow monitoring location, type of meter, purpose for monitoring, and dates that were collected for each meter are provided in Table 2. The meter locations are shown in Figure 2.

**Table 2. Flow Monitoring Summary**

| Meter basin | Meter no. | Period of record | Downstream manhole ID |
|---|---|---|---|
| Park Place-West | 1 | 1/17 – 4/1/2012 | 10652 |
| Park Place-East | 2 | 1/14 – 4/11/2012 | 18032 |
| Holcomb Boulevard | 3 | 1/24 – 4/12/2012 | 10787 |
| Abernethy | 4 | 1/17 – 4/1/2012 | 11347 |
| Downtown | 5 | 1/13 – 4/12/2012 | 11387 |
| 9th Street-West | 8 | 1/20 – 4/12/2012 | 10206 |
| 9th Street-West | 10 | 1/17 – 4/11/2012 | 10869 |
| South End-East | 12 | 1/20 – 4/11/2012 | 13207 |
| Hilltop-East | 13 | 1/20 – 4/12/2012 | 11290 |
| Community College | 14 | 1/20 – 4/12/2012 | 11140 |
| Molalla Highway-East | 15 | 1/18 – 4/4/2012 | 11782 |
| Molalla Highway-West | 16 | 1/14 – 4/11/2012 | 10383 |

*Note: ISCO 2150 level and velocity meters were used for the purpose of providing hydrology calibration at all locations. All meters were set to a 5-minute time step.*

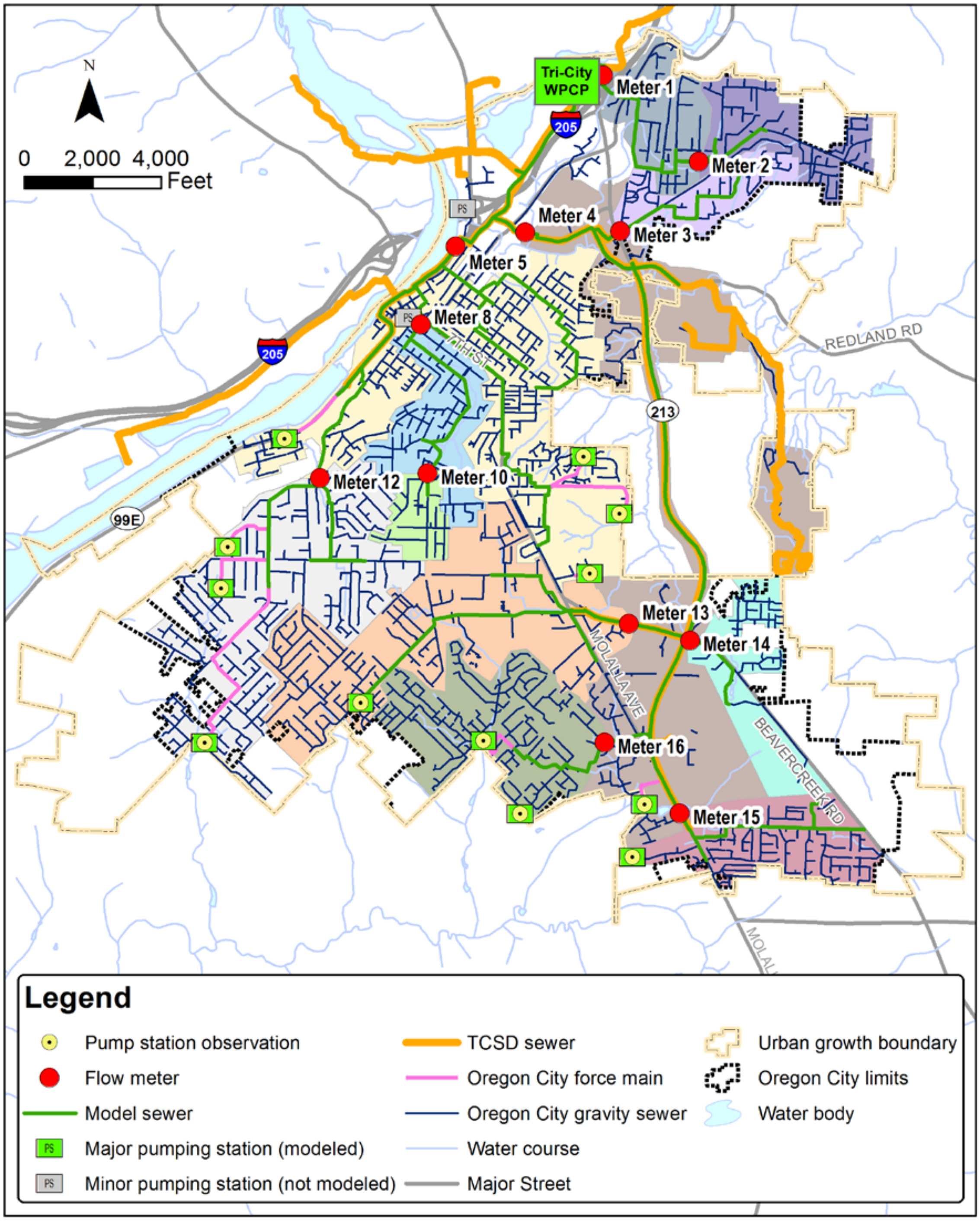



**Figure 2. City flow monitoring locations**

In addition to the flow monitoring data, the City provided 1-minute SCADA data from each pumping station. The SCADA data included start and run time information for each pump in the station. In addition, some stations had SCADA data for pumped flow from the station. A summary of the pumping stations with SCADA data and the type of information provided is presented in Table 3.

| Table 3. City SCADA Data Summary | | | |
|---|---|---|---|
| Pumping station | SCADA Cal no. | Pump start and run time data | Pump flow data |
| Amanda Court | LS12 | X | |
| Barclay Hills | LS01 | X | |
| Brendon Estates | LS02 | X | |
| Canemah | LS03 | X | |
| Cook Street | LS04 | X | X |
| Hidden Creek | LS05 | X | |
| Hilltop | LS11 | X | |
| Newell Crest | LS06 | X | |
| Nobel Ridge | LS07 | X | |
| Parrish Road | LS08 | X | X |
| Pease Road | LS09 | X | X |
| Settler's Point | LS10 | X | |

## 2.3 Rainfall Data

Wet weather flows in the wastewater conveyance system are derived from rainfall, most generally described as a direct contribution (i.e., inflow) or delayed infiltration. Therefore, rainfall data are necessary for simulation of the wastewater conveyance system. The rainfall used in calibration and evaluation is discussed below.

### 2.3.1 Calibration Rainfall Data

A rain gauge (RG01) was installed in January 2012 by SFE. Rainfall data were collected in 5-minute increments from January 15 through April 11, 2012, to coincide with the period when flow monitoring in the conveyance system occurred. The rain gauge location is shown in Figure 3. This rainfall data were used for model calibration.

The SFE rainfall gauge began collecting data at the same time flow monitoring began. However, rainfall data prior to the beginning of flow monitoring were needed to simulate the hydrologic conditions adequately, which is a function of antecedent rainfall. Therefore, additional rainfall data were retrieved from a USGS gauge located in Oregon City. Data were available in 15-minute time steps for the period before flow monitoring occurred (January 1 through 15, 2012).

The data summarized in Table 4 were combined to create a 5-minute rainfall data set for the period of January 1 to April 11, 2012. The native time step of the USGS data was greater than 5 minutes, so the data were evenly disaggregated to a 5-minute time step.

| Table 4. Calibration Rainfall Data Summary | | | |
|---|---|---|---|
| Gauge ID | Rainfall period | Gauge location | Native data time step (min.) |
| RG01 | 1/14/2012 10:40 – 4/11/2012 9:40 | 198 South 2nd Street, Oregon City | 5 |
| USGS | 1/1/2012 0:00 – 1/14/2012 10:30 | McLoughlin Boulevard near 6th Street, Oregon City | 15 |

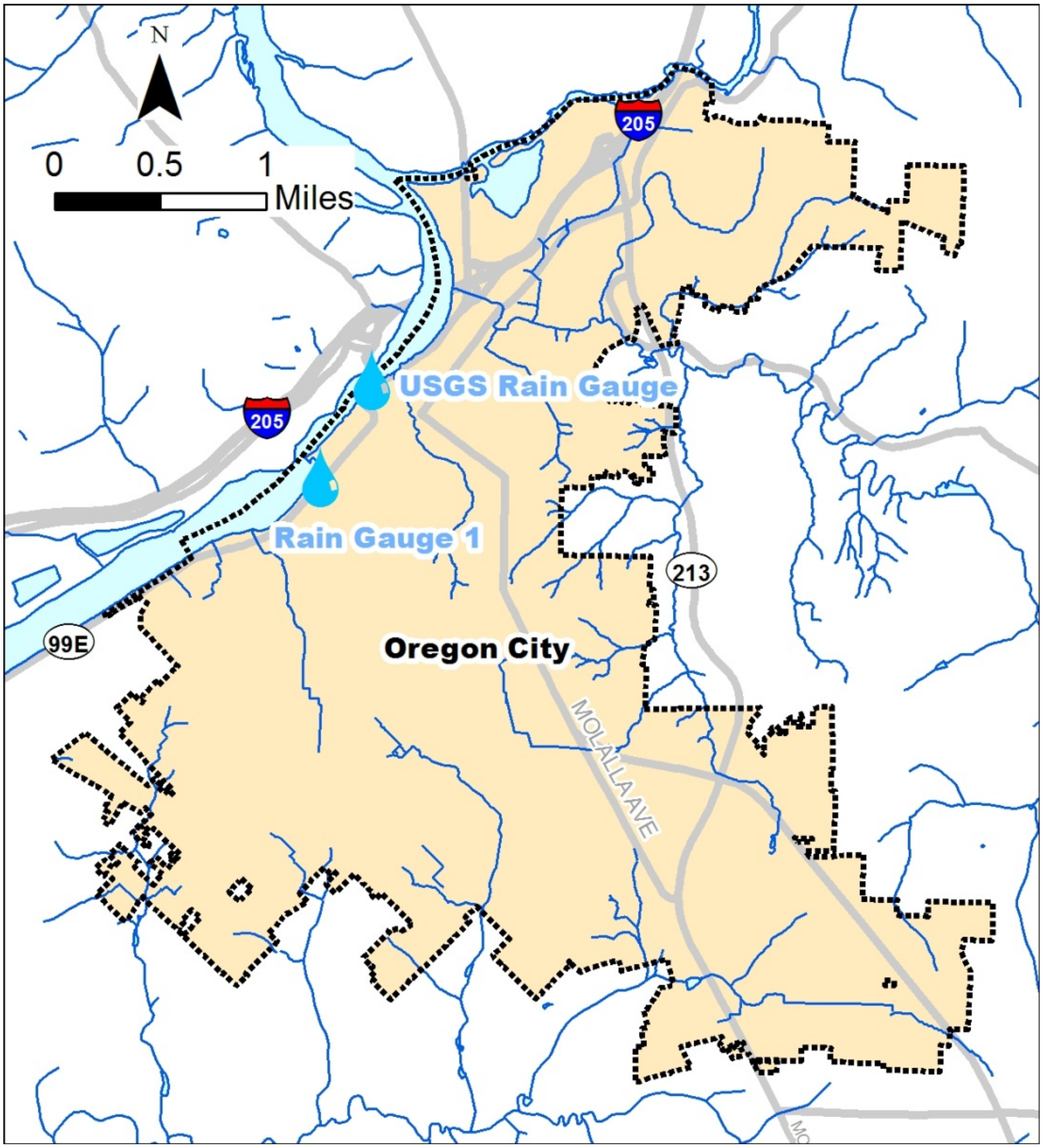



**Figure 3. Rainfall gauge locations**

The RG01 rainfall data set was analyzed by selecting periods of rainfall with a minimum inter-event period of 12 hours and by summarizing the observed depths. The events with more than 0.4 inch of total rainfall are provided in Table 5 in chronological order. The five largest rainfall events are highlighted.

| Table 5. Rainfall Event Summary[a] | | | | | | | |
|---|---|---|---|---|---|---|---|
| Event start date/time | Event duration, hours | Event total depth, inches | Max 15-min depth, inches | Max 1-hour depth, inches | Max 6-hour depth, inches | Max 12-hour depth, inches | Max 24-hour depth, inches |
| 1/17/2012 13:40 | 122.83 | 5.22 | 0.04 | 0.29 | 1.28 | 2.03 | 2.23 |
| 1/24/2012 4:30 | 32.17 | 1.24 | 0.05 | 0.2 | 0.5 | 0.88 | 0.96 |
| 1/29/2012 9:45 | 12.25 | 0.69 | 0.02 | 0.13 | 0.42 | 0.68 | NA |
| 2/8/2012 0:20 | 32.75 | 0.45 | 0.01 | 0.07 | 0.16 | 0.22 | 0.39 |
| 2/16/2012 11:10 | 41.00 | 0.43 | 0.02 | 0.06 | 0.14 | 0.21 | 0.3 |
| 2/19/2012 21:25 | 60.17 | 0.81 | 0.01 | 0.09 | 0.25 | 0.32 | 0.42 |
| 2/24/2012 16:35 | 21.42 | 0.49 | 0.01 | 0.1 | 0.26 | 0.32 | NA |
| 2/28/2012 14:30 | 52.75 | 1.01 | 0.01 | 0.09 | 0.29 | 0.46 | 0.7 |
| 3/10/2012 11:45 | 24.17 | 0.57 | 0.01 | 0.08 | 0.28 | 0.49 | 0.56 |
| 3/12/2012 11:45 | 24.83 | 1.22 | 0.01 | 0.12 | 0.66 | 0.84 | 1.21 |
| 3/14/2012 1:50 | 48.33 | 1.48 | 0.02 | 0.13 | 0.46 | 0.6 | 1 |
| 3/16/2012 17:30 | 18.00 | 0.44 | 0.01 | 0.09 | 0.27 | 0.38 | NA |
| 4/15/2012 20:55 | 11.08 | 0.56 | 0.01 | 0.08 | 0.35 | NA | NA |
| 4/17/2012 19:00 | 18.17 | 0.4 | 0.01 | 0.11 | 0.31 | 0.38 | NA |
| 4/25/2012 17:30 | 27.25 | 0.66 | 0.01 | 0.08 | 0.34 | 0.54 | 0.64 |
| 4/29/2012 21:05 | 14.75 | 0.51 | 0.02 | 0.11 | 0.26 | 0.46 | NA |
| 5/2/2012 16:50 | 18.42 | 0.62 | 0.01 | 0.08 | 0.36 | 0.56 | NA |
| 5/21/2012 2:30 | 14.00 | 0.51 | 0.02 | 0.1 | 0.28 | 0.48 | NA |
| 6/3/2012 22:25 | 36.75 | 0.71 | 0.02 | 0.1 | 0.4 | 0.47 | 0.59 |

*[a]The highlighted events are the five largest, based on total event depth.*

### 2.3.2 Evaluation Rainfall Data

The calibrated model was evaluated with a design storm event. The rainfall depths used in the evaluation were associated with 5- and 10-year recurrence intervals for a 24-hour duration. These rainfall depths were retrieved from NOAA, which analyzed historical rainfall in Oregon to develop rainfall frequency estimates (NOAA, 1973). The evaluation rainfall depths are listed in Table 6.

| Table 6. Evaluation Rainfall Summary | |
|---|---|
| Recurrence interval, years | 24-hour rainfall depth, inches |
| 5 | 3.0 |
| 10 | 3.5 |

A Soil Conservation Service (SCS) Type 1A storm is typically used as the design event hyetograph. However, this high-intensity, short-duration storm is not representative of the storms that occur regularly during the winter months in the Pacific Northwest.

An alternative to the SCS Type 1A storm was developed for the Portland area (MGS Engineering Consultants, 2001). This hyetograph is more representative of storms in Oregon City, and will produce more realistic simulated flow predictions. A comparison of the SCS rainfall distribution and the hyetograph used in modeling (Portland Design Storm 2) is shown in Figure 4.

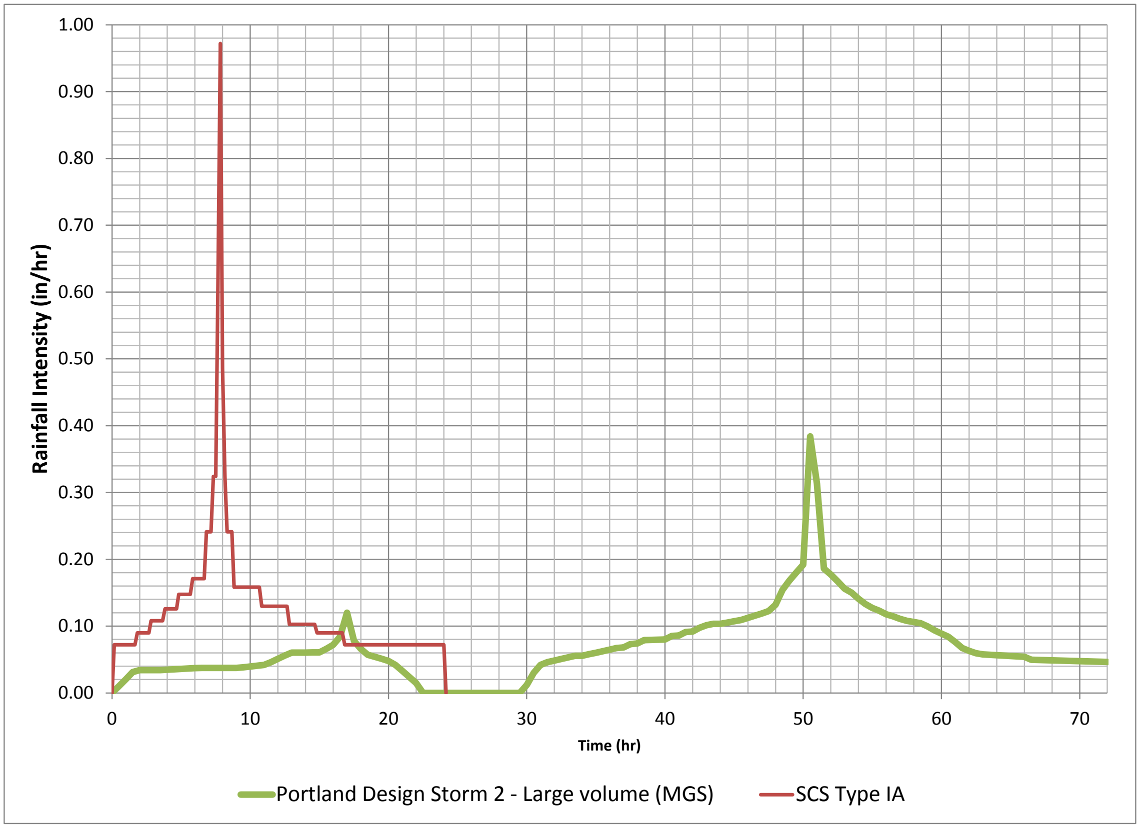



**Figure 4. Comparison of evaluation rainfall distributions**

# Section 3 Model Development

The hydraulic model was developed using the U.S. Environmental Protection Agency's SWMM5 (Version 5.0.022). The model was configured to reflect existing conditions in the wastewater conveyance system based on data collected from the City and others (as discussed previously). This section describes the model development.

## 3.1 Model Network

The hydraulic model pipe network was defined to allow for the estimation of flows in the City's wastewater conveyance system. The extent of the City's system included in the model was shown previously in Figure 1. The City's GIS was the source of the manholes, pipes, and pumping stations imported to the model.

The GIS attributes provided the initial set of manhole invert and rim elevation data used in constructing the model. This was updated with elevation data collected by the City during a recent field survey of about 62 manholes. Manhole inverts with no elevation from the survey or GIS were assigned values from a previous hydraulic model developed by Tetra Tech, or by interpolating elevations from neighboring manholes. Missing rim elevations were interpolated using GIS contour data provided by the City.

The logic followed in assigned elevations to the model network is as follows:

1. Incorporate AKS Survey data into GIS attribute data. This addressed about 10 percent of model structures.
2. Apply difference between a common AKS Survey and GIS elevation to structures identified as being constructed within the same project as the surveyed structure (i.e., the structures are in the same record drawing set). This addressed about 65 percent of model structures.

3. Use elevation as shown in the previous Tetra Tech hydraulic model.
4. Use Oregon City GIS data attributes for elevation.
5. Address rim elevation data gaps with GIS 2-foot contour data provided by the City.
6. Fill remaining data gaps by interpolating between structures with known elevations.

The source of rim and invert elevation data was provided in the Description field within SWMM, where applicable.

The Name attribute in SWMM was set to the Oregon City GIS OBJECTID attribute for all manhole and pipe features in the model.

### 3.1.1 Pumping Stations, Diversions, and TCSD Inflow

Pumping stations are both explicitly and implicitly represented in the model. Pumping stations with larger capacities (~>0.6 mgd) were explicitly modeled, which simulates the pumping station flow rate using attributes of the wet well and pumps. The implicit approach simply assumes the pump flow rate equals the inflow rate at its inlet node (with no capacity limitations).

A summary of the attributes for the explicitly modeled pumping stations is provided in Table 7.

**Table 7. Summary of Explicit Model Pumping Stations**

| Pumping station name | Firm capacity, mgd | Wet well operating depth, feet | Wet well unit surface area, square feet per foot | Notes |
|---|---|---|---|---|
| Canemah | 1.7 | 1.0 | 144.0 | Canemah as-builts, dwg no. 1259-2, Sheet C-1: wet well min/max elevations 57 (Pump 1 off) to 68 (overflow). Assume add +3.5-feet for datum conversion. |
| Cook Street | 0.9 | 1.3 | 78.5 | Cook St record dwg (94099.23): 10-foot-diameter circular wet well; pump off elevation 429.0; pump on elev 430.25; wet well bottom elev is 426.5; high water alarm 431.75; rim 449.7. Assume add +3.5-feet for datum conversion. Lag pump on elev = 430.75, off elev = 429.5. Assume sloped wet well as shown on record drawing - 4.5-foot bottom channel. |
| Parrish Road | 1.1 | 2.6 | 78.5 | Parrish Road record dwg (94003.01): 10-foot-diameter circular wet well; pump off elevation 393.05; pump on elev 395.6; wet well bottom elev is 390.35; high water alarm 408.35; rim 416.35. Assume add +3.5-feet for datum conversion. |
| Pease Road | 1.5 | 2.0 | 50.3 | Pease Road record dwg: 96-inch-diameter wet well; wet well inv is 412.25+3.5 = 415.75; rim elev is 437.25 + 3.5 = 440.75 |
| Settler's Point | 1.2 | 2.4 | 113.1 | Settler's Point record dwg (10083.05); 144-inch-diameter wet well; 15.6 feet deep; pump off elevation 400.08; pump on elev 402.48; wet well bottom elev is 395.58; high water alarm 408.48; rim 411.15. Need to add +3.5-feet for datum (Assume). Lag pump -- on elev = 403.43 |

A diversion located in Meter 5 basin was included in the model for calibration and existing conditions evaluation. A sketch from City staff showed the weir crest 3.5 inches above the outlet Manhole (MH) 12171 invert, which is how the diversion was represented in the model. The diversion location is shown in Figure 5. Results from the 10-year future modeling do not show any flow diverted out of the sanitary collection system. Regardless, City staff should investigate why the diversion was initially installed and if the diversion is still needed. Measures should be put into place such that the diversion can be removed since it is not a designated overflow point.

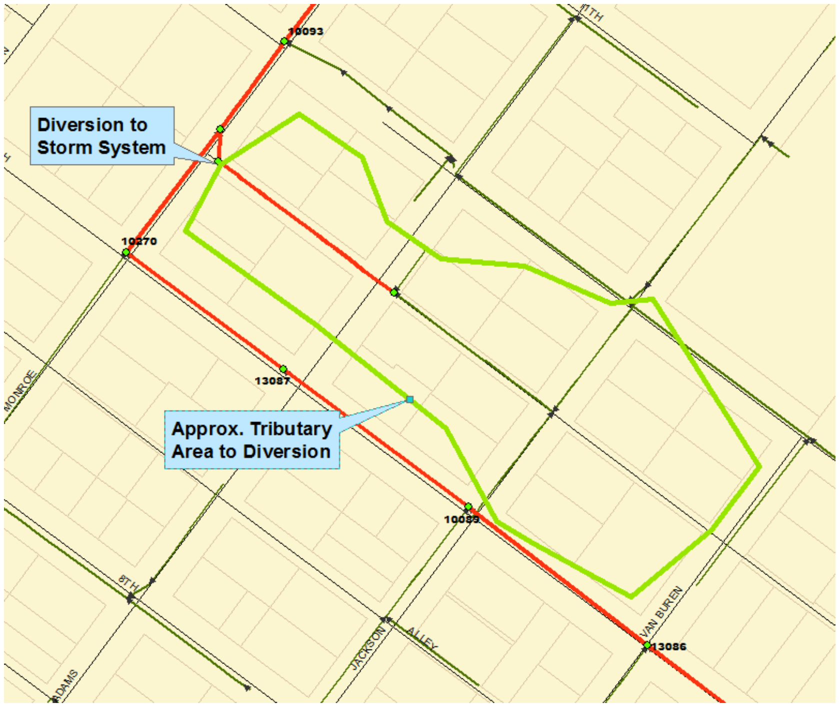



**Figure 5. Modeled diversion**

A TCSD sewer crosses the Clackamas river and contributes flow to the Meter 5 basin upstream of Meter 5. As part of this analysis, it was necessary to account for the TCSD flow contribution to Meter 5. A simple hydrologic model was constructed to simulate the TCSD flow contributing to Meter 5. The flows from this model were loaded into the model at MH 10267. The flow calibration for the TCSD contribution is discussed in more detail in the calibration section of this document.

## 3.2 Boundary Conditions

The model contains boundary conditions at the downstream outfall of each model zone (North, Central, and South). The boundary condition is set as a FREE outfall, in which the stage is determined by minimum of critical flow depth and normal flow depth in the connecting model pipe.

## 3.3 Dry Weather Flow

Base sanitary sewer flows in the existing sanitary sewer collection system were developed from February 2012 recorded flows. February rainfall was about 41 percent below average for the month with very little rain falling the first week. The flow monitoring record showed that after one week of drier weather the base flow rate stabilized. The base flow includes wastewater contributions from residential, commercial, and industrial sources and long term ground water infiltration that finds its way into sewers and manholes through cracks, joint separations, and other defects. Rainfall derived infiltration and inflow (I/I) is not included in the base flow; whereas, long-term groundwater is included. The groundwater contributions may include perched water sources that only contribute groundwater infiltration during the wet season. The flow monitoring record includes the groundwater sources so that with the addition of the wet weather I/I, the modeling portrays all of the wet weather flow regime.

The base flow in each meter basin was scaled to match the pattern observed by the flow meter during dry periods. Review of the flow monitoring data identified the period from early February as a dry period.

A summary of base sanitary flow for each meter is provided in Table 8.

| Table 8. Base Sanitary Flow Estimates | | |
|---|---|---|
| Meter basin | Meter no. | Base flow, mgd |
| Park Place-West | 1 | 0.07 |
| Park Place-East | 2 | 0.08 |
| Holcomb Blvd | 3 | 0.09 |
| Abernethy | 4 | 0.51 |
| Downtown | 5 | 1.00 |
| 9th Street-West | 8 | 0.96 |
| South End-East | 12 | 1.00 |
| Hilltop-East | 13 | 0.71 |
| Community College | 14 | 0.20 |
| Molalla Highway-East | 15 | 0.12 |
| Molalla Highway-West | 16 | 0.25 |

In addition to the base sanitary flows listed in Table 8, a base flow of 0.7 mgd was allocated to the TCSD inflow contributing to the Meter 5 basin. This value was estimated by assuming that base sanitary flows from Meters 8, 12, and 5 (local contributing area only) were 1 mgd each, and subtracting this total from the observed base sanitary flow measured at Meter 5 (total tributary area, including Meters 12 and 8 and TCSD) for early February (3.7 mgd).

The Meter 8 base sanitary flow was observed as 1 mgd, but the Meter 12 base sanitary flow was measured as 1.3 mgd. Therefore, this estimate of TCSD base sanitary flow reduces the Meter 12 base flow from what was observed to 1 mgd. This was considered to be acceptable considering that the Meters 12 and 8 tributary areas are each half of the local Meter 5 tributary area, but they contribute twice the base flow.

## 3.4 Wet Weather Flow

The simulation of wet weather hydrology affecting the City's wastewater conveyance system is presented below.

### 3.4.1 I/I

The model hydrology simulation employed unit hydrographs (UHs) for estimating infiltration to the wastewater conveyance system. A UH set contains three hydrographs, one for short-term response, one for intermediate-term response, and one for a long-term response.

Each unit hydrograph is defined by three parameters, known as RTK parameters:

- R: the fraction of rainfall volume that enters the wastewater conveyance system
- T: the time from the onset of rainfall to the peak of the UH in hours
- K: the ratio of time to recession of the UH to the time to peak

An example UH set, with three hydrographs, is shown in Figure 6.

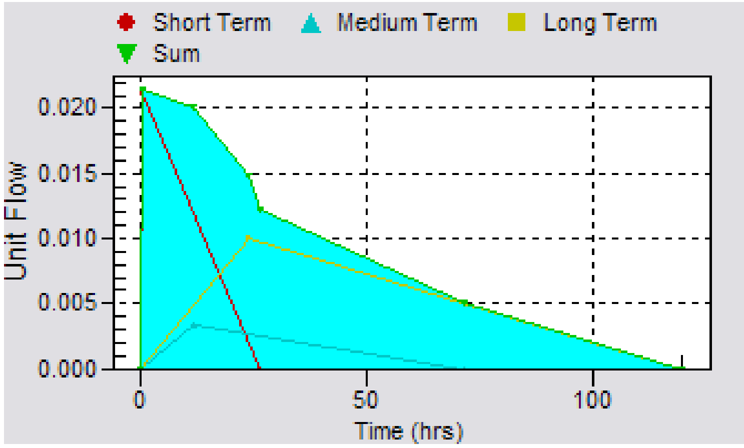



Figure 6. UH example

### 3.4.2 Sewershed

The area contributing wet weather flow (i.e., I/I) was assumed to be a 200-foot buffer (i.e., 100 feet on either side) along the length of the pipe. The sewershed for pipes in the City's conveyance system, but not included in the model, were represented in the model at the nearest downstream manhole.

| Table 9. Sewershed Summary | | | | |
|---|---|---|---|---|
| Meter Basin | Meter no. | Total pipe length, linear feet | Sewershed area, acres | Total basin area, acres |
| Park Place-West | 1 | 30,069 | 138 | 205 |
| Park Place-East | 2 | 31,394 | 144 | 217 |
| Holcomb Blvd | 3 | 23,308 | 107 | 168 |
| Abernethy | 4 | 80,652 | 370 | 1,236 |
| Downtown | 5 | 156,563 | 719 | 1,083 |
| 9th Street-West | 8 | 52,906 | 243 | 254 |
| South End-East | 12 | 111,325 | 511 | 774 |
| Hilltop-East | 13 | 89,870 | 413 | 783 |
| Community College | 14 | 21,793 | 100 | 335 |
| Molalla Highway-East | 15 | 45,594 | 209 | 337 |
| Molalla Highway-West | 16 | 66,169 | 304 | 458 |

## 3.5 Future Flows

The future conditions are defined as the flows in the City's wastewater conveyance system under buildout conditions. The change in flows from existing to future (i.e., buildout) conditions are attributed to four sources:

- Development of currently vacant land.
- Redevelopment of currently developed land, to a higher density (as prescribed by zoning).
- Extension of sewer service to existing development not served by the existing wastewater conveyance system.
- Development of concept plan areas.

### 3.5.1 Development of Vacant Land and Redevelopment

Estimate of future flow from development of vacant land and redevelopment was completed using GIS data provided by the City. The flow was estimated for each tax parcel according to logic developed by the City, which is presented below.

- If 100 percent vacant, residential, current land use code = future comp code → Develop to future comp code density
- If 100 percent vacant, residential, current land use code <> future comp code → Develop to future comp code density
- If 100 percent vacant, non-residential, current land use code = future comp code → Develop to future comp code density
- If 100 percent vacant, non-residential, current land use code <> future comp code → Develop to future comp code density
- If partially vacant, residential, current land use code = future comp code → No action
- If partially vacant, residential, current land use code <> future comp code → Redevelop to future comp code density
- If partially vacant, non-residential, current land use code = future comp code → Develop the vacant parts to future comp code density
- If partially vacant, non-residential, current land use code <> future comp code → Develop the vacant parts to future comp code density
- If 0 percent vacant, residential, current land use code = future comp code → No action
- If 0 percent vacant, residential, current land use code <> future comp code → Redevelop to future comp code density
- If 0 percent vacant, non-residential, current land use code = future comp code → No action
- If 0 percent vacant, non-residential, current land use code <> future comp code → Examine on case-by-case basis

Details of the analysis and assumptions to estimate additional flow from vacant lands is provided in Attachment A.

### 3.5.2 Extension of Sewer Service to Existing Development

Dry weather flow from existing development not currently connected to the wastewater conveyance system was estimated based on future zoning. The estimates were assigned to the appropriate manhole based on topography. It was assumed that all of these developments would be connected to the system in the future condition. New piping added to the conveyance system to serve the newly connected development was assumed to contribute wet weather flows by way of I/I. The future conditions model assumed the net developable area of the tax parcels currently on septic systems contributed 1,000 gallons per acre per day (gpad) of I/I.

Details of the analysis and assumptions to estimate additional flow from parcels currently served by septic systems is provided in Attachment A.

### 3.5.3 Concept Areas

The concept plan areas represent three significant developments located within the urban growth boundary (UGB), but mostly outside of the city. Existing planning efforts provided details on how these concept plan areas are expected to develop. The estimate of additional flow from each concept area is described below.

### Park Place

The estimated flow from the Park Place Concept Area is listed in Table 10. This additional flow was assumed to enter the TCSD conveyance system at MH 12698 for future model simulations.

**Table 10. Park Place Concept Area Flow Estimate**

| Land use | Gross acres | Net acres[a] | Floor area ratio (FAR), acre[b] | Jobs[c] | Dwelling units | Residents[d] | I/I, gpad | Average daily flow, mgd[e] | Peak factor | Peak flow, mgd |
|---|---|---|---|---|---|---|---|---|---|---|
| Low/med-density residential | 203 | 173 | NA | NA | 1033 | 2,583 | 1,000 | 0.26 | 2.9 | 0.92 |
| Med/high-density residential | 57 | 46 | NA | NA | 426 | 1,065 | 1,000 | 0.11 | 3.2 | 0.38 |
| Mixed-use commercial[f] | 8 | 6 | 0.44 | 175 | 0 | 0 | 1,000 | 0.01 | 4.1 | 0.04 |
| Retail | 3.6 | 3 | 0.44 | 79 | 0 | 0 | 1,000 | 0.004 | 4.5 | 0.02 |
| Civic | 28.7 | 29 | NA | NA | 0 | 0 | 0 | - | - | - |
| Park | 11.2 | 11 | NA | NA | 0 | 0 | 0 | - | - | - |
| Constrained land (buffers, etc.) | 166.1 | 166 | NA | NA | 0 | 0 | 0 | - | - | - |
| | | | | | | | | | Total | 1.37 |

[a]*Net acres equals gross acres minus a percentage for local roads and easements.*

[b]*Based on Metro 2002-2022 Urban Growth Report: An Employment Land Need Analysis. Includes total onsite employment (full and part time). Mixed employment FAR and job density reflects a mix of office, technical/flex, and ground floor retail.*

[c]*Number of jobs in mixed use and retail calculated by multiplying total acres by the FAR; converting to square feet; and dividing by number of jobs per square foot.*

[d]*Residents per dwelling unit assumed to be 2.5.*

[e]*Residential unit flow assumed to be 80 gallons per capita per day (gpcd) and commercial unit flow assumed to be 1,000 gpad.*

[f]*Mixed use land use assumes 100 percent of acreage devoted to commercial uses.*

### Beavercreek

The estimated flow from the Beavercreek Concept Area is listed in Table 11. This additional flow was assumed to enter the City's conveyance system at MH 11144 for future model simulations.

**Table 11. Beavercreek Concept Area Flow Estimate**

| Land use | Gross acres | Net acres[a] | FAR, acre[b] | Jobs[c] | Dwelling units | Residents[d] | I/I, gpad | Average daily flow, mgd[e] | Peak factor | Peak flow, mgd |
|---|---|---|---|---|---|---|---|---|---|---|
| North employment campus | 149 | 127 | 0.3 | 3,678 | | | 1,000 | 0.16 | 3.1 | 0.61 |
| Mixed employment village | 26 | 21 | 0.44 | 1,139 | | | 1,000 | 0.03 | 3.7 | 0.12 |
| Main Street (mixed use) | 10 | 8 | 0.44 | 219 | 100 | 250 | 1,000 | 0.03 | 3.6 | 0.12 |
| West mixed use neighborhood | 22 | 18 | | 15 | 387 | 968 | 1,000 | 0.10 | 3.2 | 0.33 |
| East mixed use neighborhood | 77 | 62 | | 21 | 536 | 1,340 | 1,000 | 0.13 | 3.1 | 0.48 |
| | | | | | | | | | TOTAL | 1.65 |

[a]*Net acres equals gross acres minus a percentage for local roads and easements.*

[b]*Based on Metro 2002-2022 Urban Growth Report: An Employment Land Need Analysis. Includes total onsite employment (full and part time). Mixed Employment FAR and job density reflects a mix of office, technical/flex, and ground floor retail.*

[c]*Number of jobs in Main Street mixed use, North employment campus and mixed employment village calculated by multiplying total acres by the FAR; converting to square feet; and dividing by number of jobs per square foot.*

[d]*Residents per dwelling unit assumed to be 2.5.*

[e]*Residential unit flow assumed to be 80 gpcd and Commercial unit flow assumed to be 1,000 gpad.*

### South End Road

The estimated flow from the South End Road Concept Area is listed in Table 12. This additional flow was assumed to enter the City's conveyance system at MH 11105 for future model simulations.

**Table 12. South End Road Concept Area Flow Estimate**

| Land use | Gross acres | Net acres[a] | FAR, acre | Jobs | Dwelling units | Residents[b] | I/I, gpad | Average daily flow, mgd[c] | Peak factor | Peak flow, mgd |
|---|---|---|---|---|---|---|---|---|---|---|
| Pre-2002 UGB | 241 | 193 | NA | NA | 1,542 | 3,856 | 1,000 | 0.39 | 2.8 | 1.27 |
| 2002 UGB expansion | 168 | 134 | NA | NA | 1,344 | 3,360 | 1,000 | 0.34 | 2.8 | 1.09 |
| Existing low-density residential | 69 | 55 | NA | NA | 156 | 390 | 1,000 | 0.04 | 3.5 | 0.19 |
| | | | | | | | | | Total | 2.55 |

[a]*Net acres equals gross acres minus a percentage for local roads and easements.*

[b]*Residents per dwelling unit assumed to be 2.5.*

[c]*Residential unit flow assumed to be 80 gpcd and commercial unit flow assumed to be 1,000 gpad.*

# Section 4 Model Calibration

Calibration is the process of adjusting model input parameters in an effort to match simulation results as closely as possible to accurately measured data or observed conditions within the conveyance system. The model was calibrated to existing conditions using the flow monitoring and pumping station SCADA data. This section describes the calibration process including methodology and results.

## 4.1 Calibration Process

The general approach to calibration included adjusting parameters for the hydrology upstream of the monitoring location to obtain a suitable match between observed and modeled flows. This involved adjusting RTK parameters. A set of parameters were applied to each flow meter basin.

The calibration period was January 13 to April 11, 2012, which is the date range in which flow meters were installed. Significant rainfall (and subsequent flow) events during the calibration period were identified for use in comparing model results to observations, as discussed in Section 2.3.1. The January 19th flow event was noteworthy because it contained the largest observed flow during the calibration period.

### Pumping Station SCADA

The pumping station SCADA data were interpreted for use in the model calibration. Specifically, SCADA data were used to develop estimates of wet well inflow and pump flow for comparison to model predictions.

The pump flow was estimated by multiplying the run time data (in 1-minute increments) by the published pump capacity. If more than one pump was running during a 1-minute period, then an estimate of flow from the pumps was multiplied by the run time data.

The wet well inflow was estimated using two methods. The first method is referred to as the wet well drain method and the inflow was estimated by dividing the wet well volume by the number of 1-minute increments needed to fill the wet well between the time step the pumps shut off and when the pumps turned on.

The second method is referred to as the pump run method and the inflow was estimated by averaging the volume pumped (SCADA run time multiplied by the published pump capacity) less the wet well volume for the time the pumps ran.

## 4.2 Calibration

The calibration was completed for each flow monitoring basin in the three model zones. A summary of the calibration results is provided below.

### 4.2.1 North Model Zone

The North Model Zone consists of Meters 1 and 2.

#### 4.2.1.1 Meter 2

The Meter 2 calibration is shown in Figure 7. Some difference between simulated and observed data is attributed to frequent velocity dropouts in the monitoring data in February and early March.

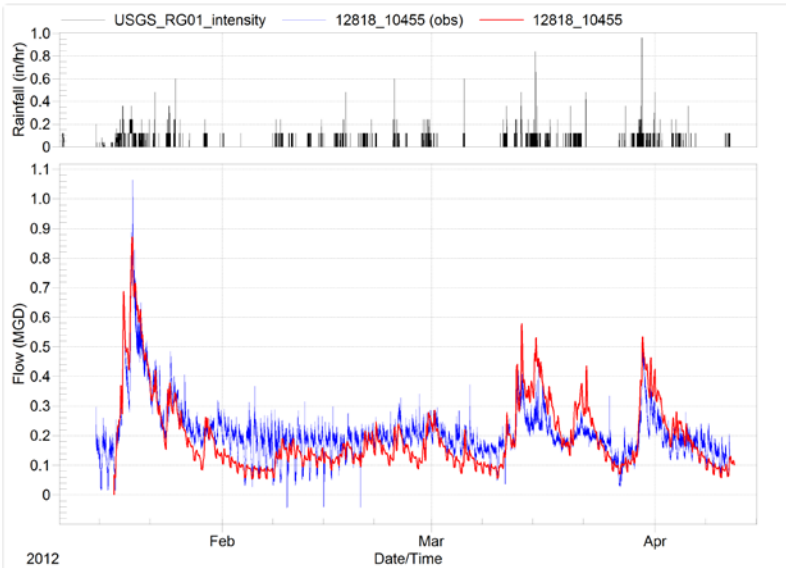



**Figure 7. Calibration of model to Meter 2**

*red = simulated; blue = observed*

#### 4.2.1.2 Meter 1

The Meter 1 calibration is shown in Figure 8. Meter 1 is the most downstream flow meter in the North Model Zone. The match between observed and simulated flow is suitable.

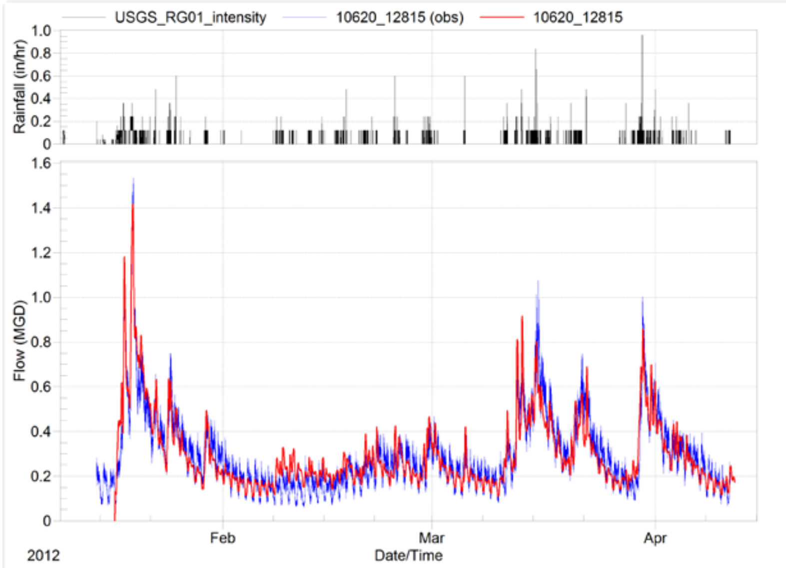



**Figure 8. Calibration of model to Meter 1**

*red = simulated; blue = observed*

### 4.2.2 Central Model Zone

The Central Model Zone consists of Meters 13, 14, 15, 16, 3, and 4.

#### 4.2.2.1 Meter 13

The Meter 13 calibration is shown in Figure 9. The Pease Road Pumping Station is located upstream of the flow meter (in the same meter basin), which is evident in the observed flow data. Observed data are not available for the peak flow event in January, but there is suitable agreement between observed and simulated flow for the remainder of the calibration period.

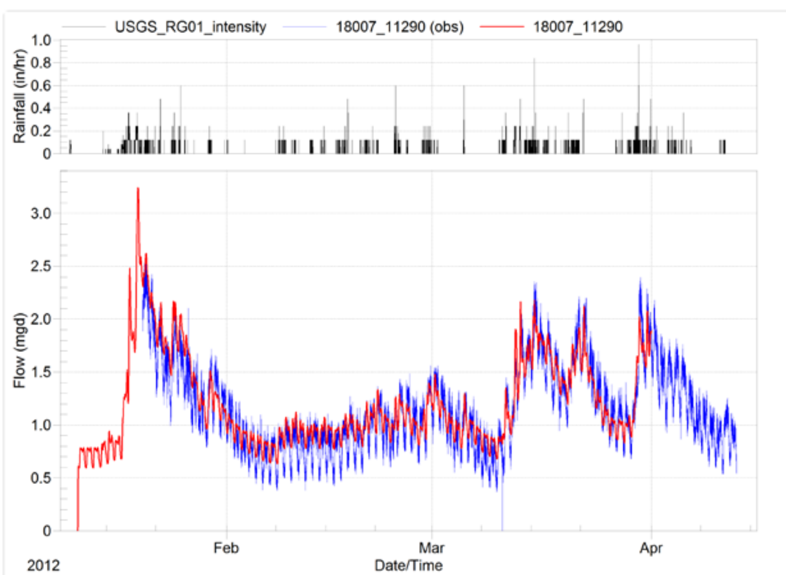



**Figure 9. Calibration of model to Meter 13**

*red = simulated; blue = observed*

### Pease Road Pumping Station

The wet well inflow calibration is shown in Figure 10. The simulated inflow value is significantly less than the inflow estimated using the pump run method. The simulated inflow was lowered after refining the calibration based on a comparison of total volume pumped for each flow event, as listed in Table 13. The SCADA pump volume is from the flow meter installed at the Pease Road Pumping Station.


**Figure 10. Pease Road Pumping Station wet well inflow calibration, January 19, 2012 event**

*red = simulated, blue = estimated (pump run), green = estimated (wet well drain)*

| Table 13. Pease Road Observed and Simulated Pump Volume for Calibration Flow Events | | | |
|---|---|---|---|
| Event start date | Event duration, hours | Simulated pump volume, million gallons (MG) | Observed pump volume, MG |
| 1/18/2012 3:20:00 AM | 70.5 | 0.95 | 0.88 |
| 1/23/2012 11:55:00 PM | 48.42 | 0.43 | 0.43 |
| 2/7/2012 12:00:00 AM | 24 | 0.10 | 0.12 |
| 3/12/2012 6:40:00 PM | 24.58 | 0.29 | 0.22 |
| 3/15/2012 5:55:00 AM | 38.08 | 0.43 | 0.41 |
| 3/21/2012 3:10:00 PM | 21.42 | 0.19 | 0.22 |
| 3/30/2012 2:15:00 AM | 45.08 | 0.49 | 0.45 |

### 4.2.2.2 Meter 14

The Meter 14 calibration is shown in Figure 11. Observed data are not available for the peak flow event in January, and the remaining data show little response to rainfall, yet have a significant base flow. There is suitable agreement between observed and simulated flow for the calibration period without the January event.

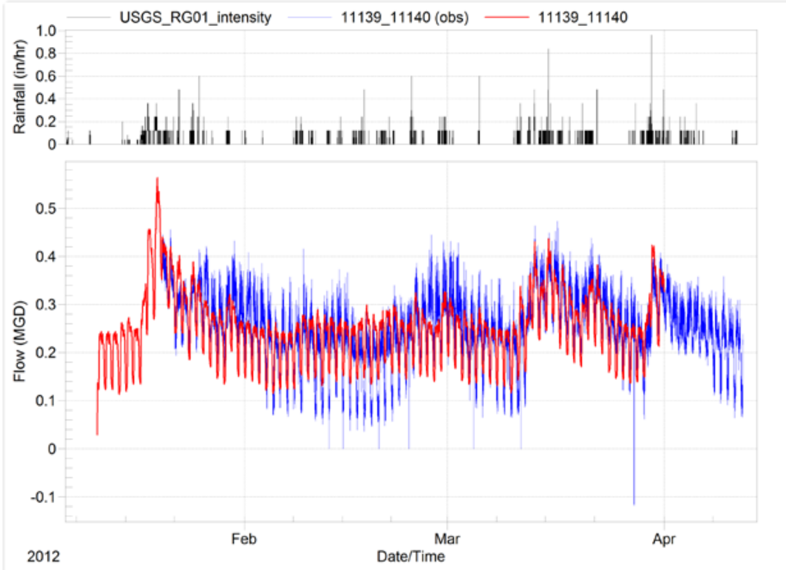



**Figure 11. Calibration of model to Meter 14**

*red = simulated; blue = observed*

### 4.2.2.3 Meter 15

The Meter 15 calibration is shown in Figure 12. Some difference between simulated and observed data is attributed to frequent velocity dropouts in the monitoring data from late February through April. The match of peak flow for the January event is suitable.

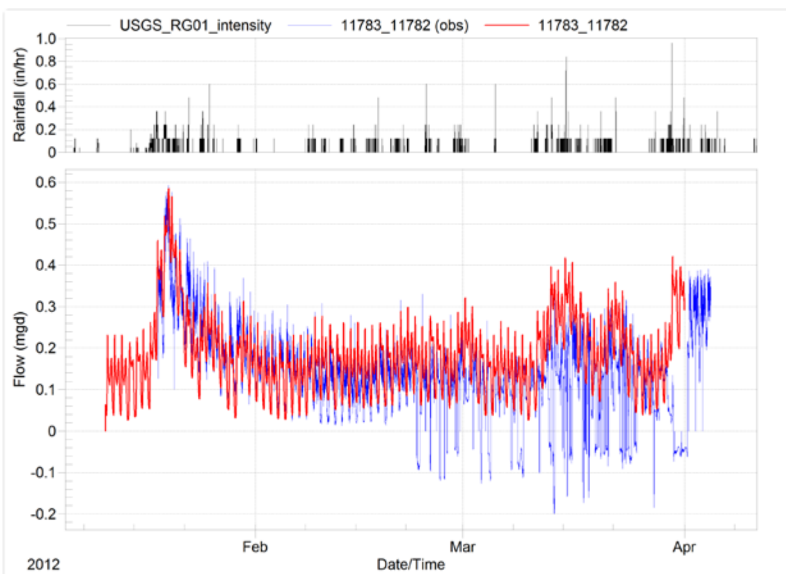



**Figure 12. Calibration of model to Meter 15**

*red = simulated; blue = observed*

### 4.2.2.4 Meter 16

The Meter 16 calibration is shown in Figure 13. Settler's Point Pumping Station is located upstream in this meter basin. The match between observed and simulated flow is suitable.

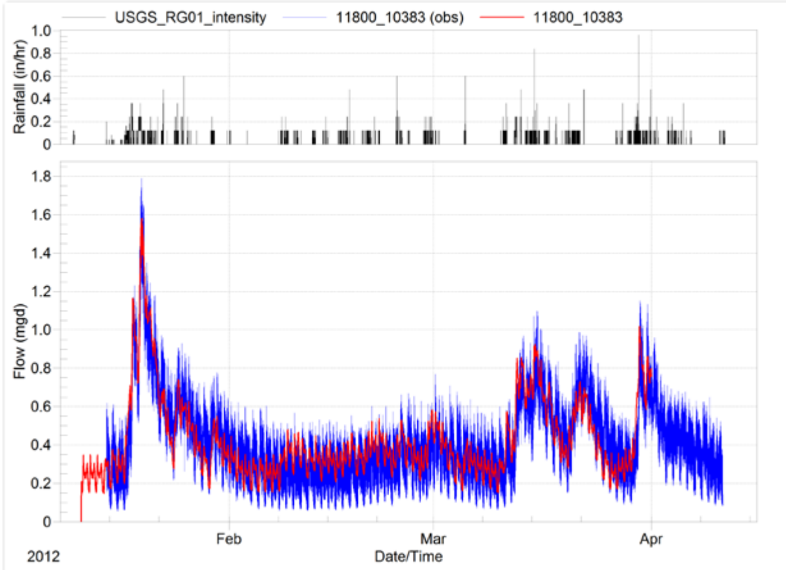



**Figure 13. Calibration of model to Meter 16**

*red = simulated; blue = observed*

## Settler's Point Pumping Station

The wet well inflow calibration is shown in Figure 10. The simulated inflow value agrees with observed inflow estimated by both methods. The comparison of total volume pumped for each flow event, as listed in Table 13, indicates suitable agreement between observed and simulated volume. The SCADA pump volume in the table is from the flow meter installed at the Settler's Point Pumping Station.

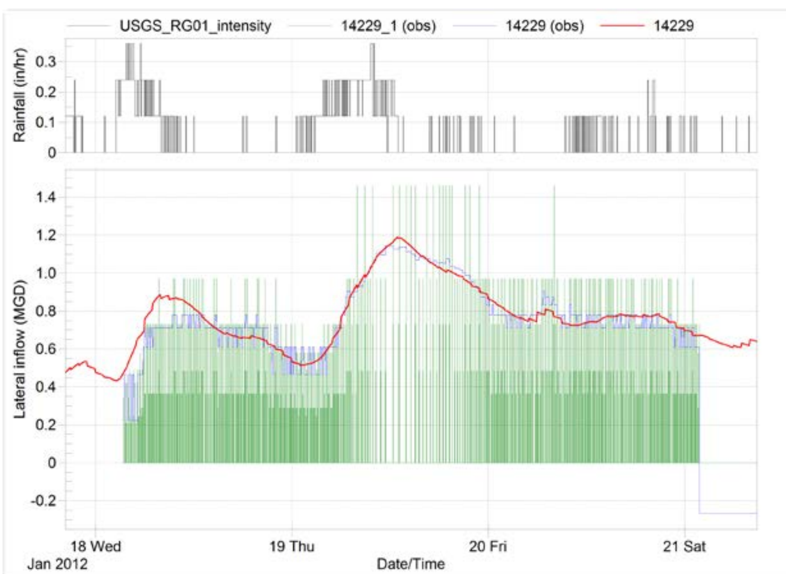



**Figure 14. Settler's Point Pumping Station wet well inflow calibration, January 19, 2012 event**

*red = simulated, blue = estimated (pump run), green = estimated (wet well drain)*

| Table 14. Settler's Point Observed and Simulated Pump Volume for Calibration Flow Events | | | |
|---|---|---|---|
| Event start date | Event duration, hours | Simulated pump volume, MG | Observed pump volume, MG |
| 1/18/2012 3:20:00 AM | 70.5 | 2.41 | 2.54 |
| 1/23/2012 11:55:00 PM | 48.42 | 0.89 | 1.10 |
| 2/7/2012 12:00:00 AM | 24 | 0.16 | 0.21 |
| 3/12/2012 6:40:00 PM | 24.58 | 0.54 | 0.54 |
| 3/15/2012 5:55:00 AM | 38.08 | 0.83 | 1.09 |
| 3/21/2012 3:10:00 PM | 21.42 | 0.41 | 0.61 |
| 3/30/2012 2:15:00 AM | 45.08 | 1.00 | 1.26 |

### Nobel Ridge Pumping Station

The wet well inflow calibration is shown in Figure 4-9. The simulated inflow value compares well with the observed inflow estimated by both the wet well drain and pump run method. This pumping station was simulated implicitly, so pump flow information is not available.

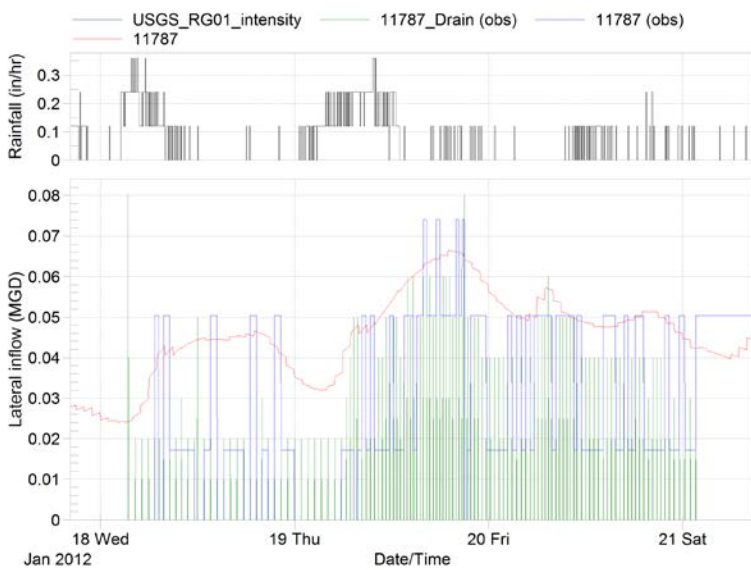



**Figure 15. Nobel Ridge Pumping Station wet well inflow calibration, January 19, 2012 event**

*red = simulated, blue = estimated (pump run), green = estimated (wet well drain)*

### 4.2.2.5 Meter 3

The Meter 3 calibration is shown in Figure 16. The January event is missing from the observed flow data, and velocity dropouts in late March are evident in the data. The match between observed and simulated flow is suitable for the remaining periods of the monitoring data.

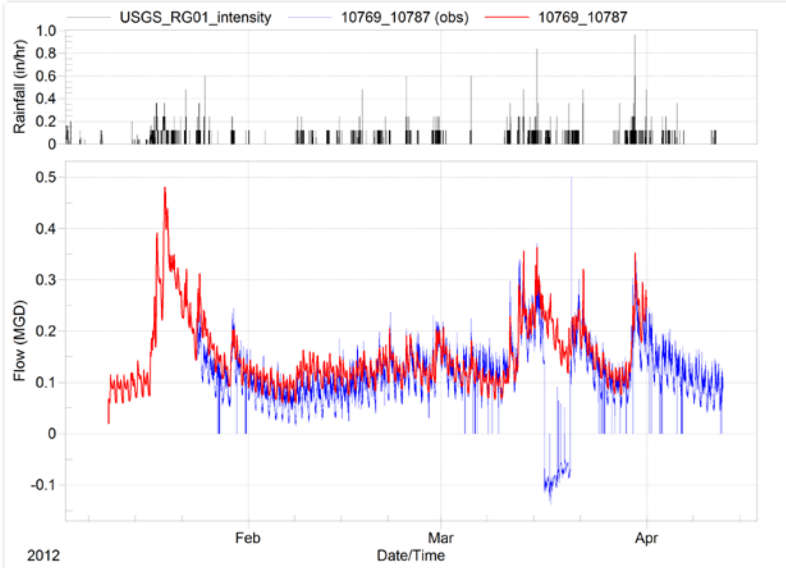



**Figure 16. Calibration of model to Meter 3**

*red = simulated; blue = observed*

### 4.2.2.6 Meter 4

The Meter 4 calibration is shown in Figure 17. Meter 4 is the most downstream meter in the Central Model Zone. The match between observed and simulated flow is suitable for this meter.

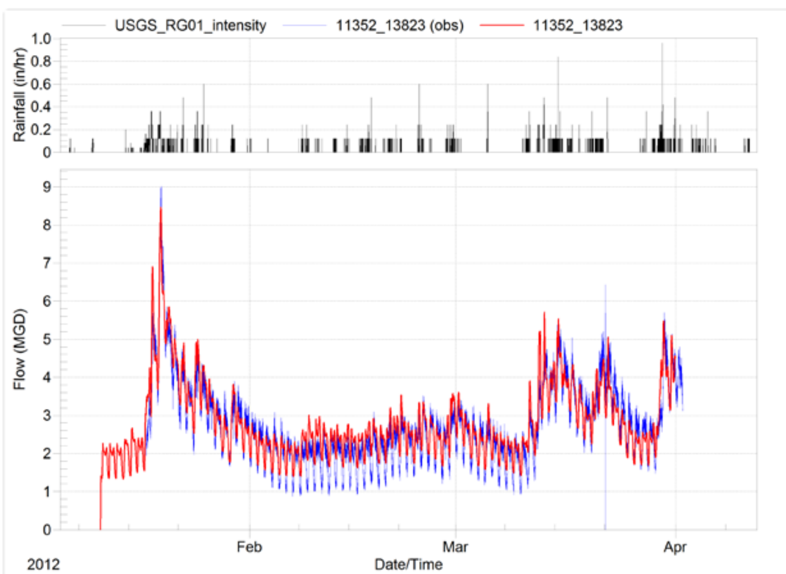



**Figure 17. Calibration of model to Meter 4**

*red = simulated; blue = observed*

#### Hidden Creek Pumping Station

The wet well inflow calibration is shown in Figure 18. The simulated inflow value compares well with the observed inflow estimated by both the wet well drain and pump run method. This pumping station was simulated implicitly, so pump flow information is not available.

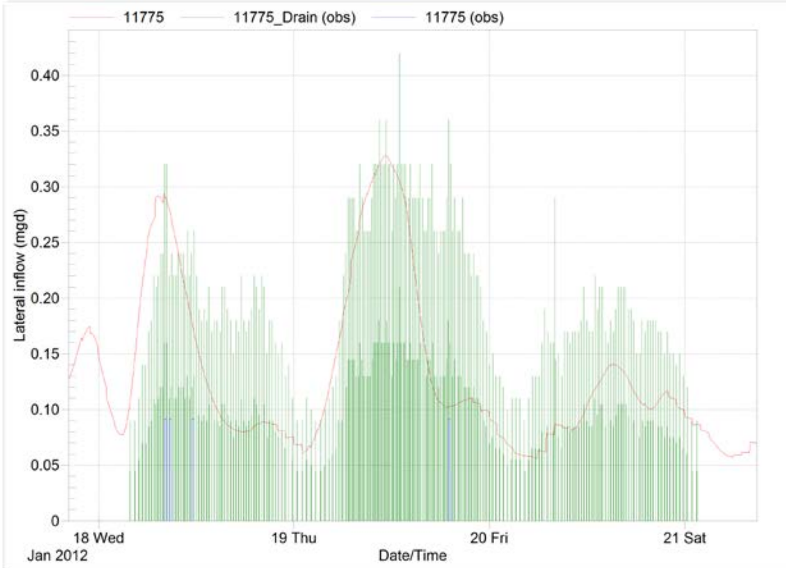



**Figure 18. Hidden Creek Pumping Station wet well inflow calibration, January 19, 2012 event**

*red = simulated, blue = estimated (pump run), green = estimated (wet well drain)*

### 4.2.3 South Model Zone

The South Model Zone includes Meters 12, 10, 8, and 5.

#### 4.2.3.1 Meter 12

The Meter 12 calibration is shown in Figure 19. Parrish Road and Cook Street Pumping Stations are located upstream of this meter in the basin. The calibration at Meter 12 shows a suitable match of peak observed and simulated flows.

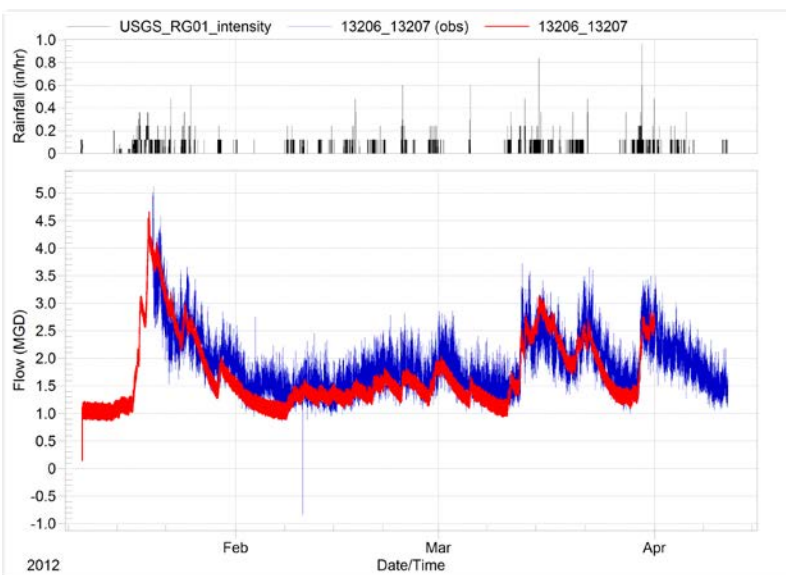



**Figure 19. Calibration of model to Meter 12**

*red = simulated; blue = observed*

### Parrish Road Pumping Station

The wet well inflow calibration is shown in Figure 20. The simulated inflow value is slightly less than the observed inflow estimated by the pump run method, but agrees with the wet well drain method estimate. The comparison of total volume pumped for each flow event, as listed in Table 15, indicates suitable agreement between observed and simulated volume. The SCADA pump volume in the table is from the flow meter installed at the station.

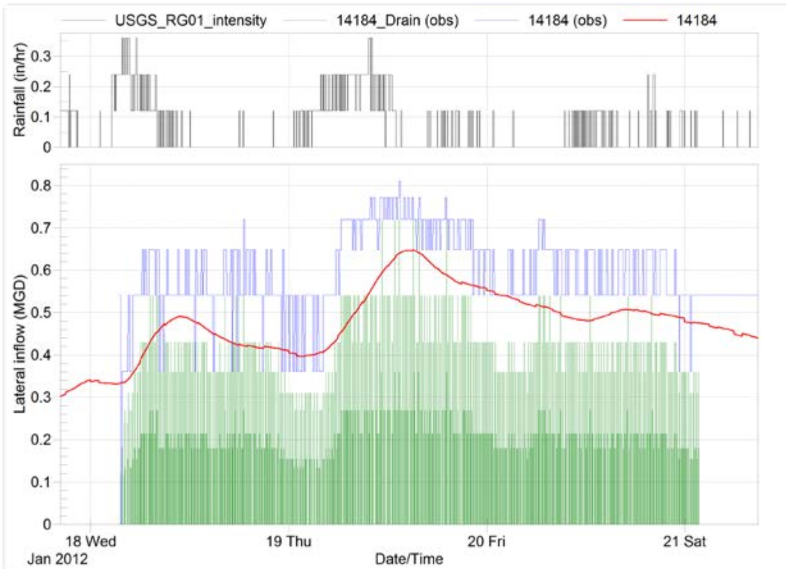



**Figure 20. Parrish Road Pumping Station wet well inflow calibration, January 19, 2012 event**

*red = simulated, blue = estimated (pump run), green = estimated (wet well drain)*

**Table 15. Parrish Road Observed and Simulated Pump Volume for Calibration Flow Events**

| Event start date | Event duration, hours | Simulated pump volume, MG | Observed pump volume, MG |
|---|---|---|---|
| 1/18/2012 3:20:00 AM | 70.5 | 1.44 | 1.33 |
| 1/23/2012 11:55:00 PM | 48.42 | 0.68 | 0.69 |
| 2/7/2012 12:00:00 AM | 24 | 0.18 | 0.18 |
| 3/12/2012 6:40:00 PM | 24.58 | 0.38 | 0.35 |
| 3/15/2012 5:55:00 AM | 38.08 | 0.62 | 0.62 |
| 3/21/2012 3:10:00 PM | 21.42 | 0.28 | 0.34 |
| 3/30/2012 2:15:00 AM | 45.08 | 0.72 | 0.70 |

### Cook Street Pumping Station

The wet well inflow calibration is shown in Figure 21. The simulated inflow value is slightly less than the peak observed inflow estimated by both the pump run and wet well drain method. However, the calibration shows good agreement of the comparison of total volume pumped for each flow event, as listed in Table 16. The high estimated inflows during the peak of the January event may be a result of the Cook Street SCADA data indicating that the pumps ran for long periods of time.

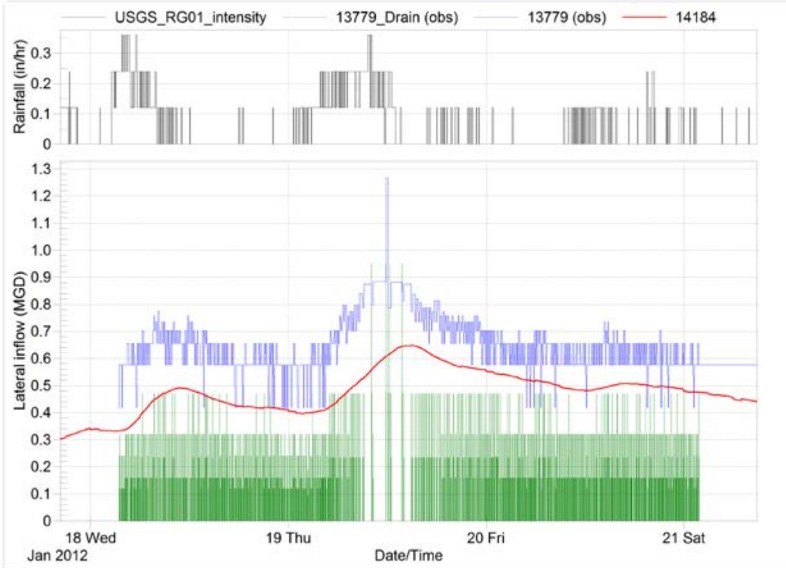



**Figure 21. Cook Street Pumping Station wet well inflow calibration, January 19, 2012 event**

*red = simulated, blue = estimated (pump run), green = estimated (wet well drain)*

| Table 16. Cook Street Observed and Simulated Pump Volume for Calibration Flow Events | | | |
|---|---|---|---|
| Event start date | Event duration,(hours | Simulated pump volume, MG | Observed pump volume, MG |
| 1/18/2012 3:20:00 AM | 70.5 | 1.56 | 1.60 |
| 1/23/2012 11:55:00 PM | 48.42 | 0.69 | 0.71 |
| 2/7/2012 12:00:00 AM | 24 | 0.09 | 0.09 |
| 3/12/2012 6:40:00 PM | 24.58 | 0.40 | 0.33 |
| 3/15/2012 5:55:00 AM | 38.08 | 0.70 | 0.64 |
| 3/21/2012 3:10:00 PM | 21.42 | 0.31 | 0.36 |
| 3/30/2012 2:15:00 AM | 45.08 | 0.63 | 0.74 |

### Amanda Court Pumping Station

The wet well inflow calibration is shown in Figure 22. The simulated inflow value compares well with the observed inflow estimated by both the wet well drain and pump run method. This station was simulated implicitly, so pump flow information is not available.

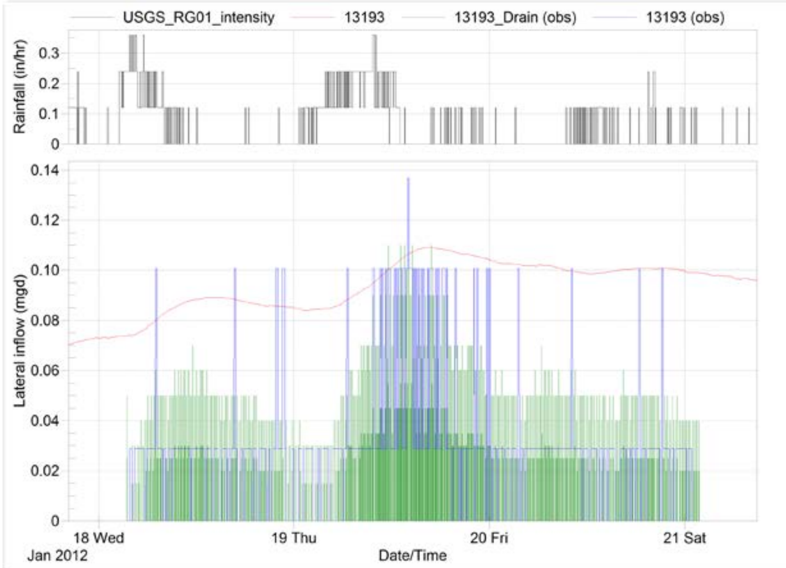



**Figure 22. Amanda Pumping Station wet well inflow calibration, January 19, 2012 event**

*red = simulated, blue = estimated (pump run), green = estimated (wet well drain)*

### 4.2.3.2 Meter 10

The initial calibration of Meter 10 to the January 19th event resulted in flooding at a flow of approximately 1.5 mgd, which was not corroborated by City staff. Therefore, this meter was excluded from calibration. The observed flow data were reported to have a velocity greater than 8 feet per second (fps) and up to 10 fps. These velocities are difficult to measure accurately with the velocity technology used at this site.

### 4.2.3.3 Meter 8

The Meter 8 calibration is shown in Figure 23. There are no observed data for the large January event, but comparison of the observed and simulated flows for the remaining events is suitable.

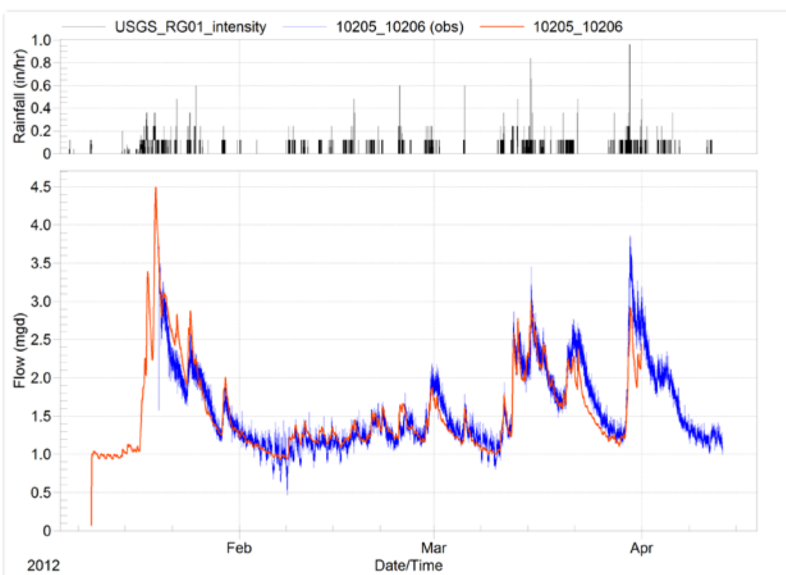



**Figure 23. Calibration of model to Meter 8**

*red = simulated; blue = observed*

#### 4.2.3.4 Meter 5

The Meter 5 calibration is shown in Figure 24. Meter 5 is the most downstream meter in the South Model Zone. The Canemah, Barclay Hills, Newell Crest, and Hilltop Pumping Stations are located upstream of the meter in the basin. The calibration to the meter is suitable based on the comparison of observed and simulated flow data.

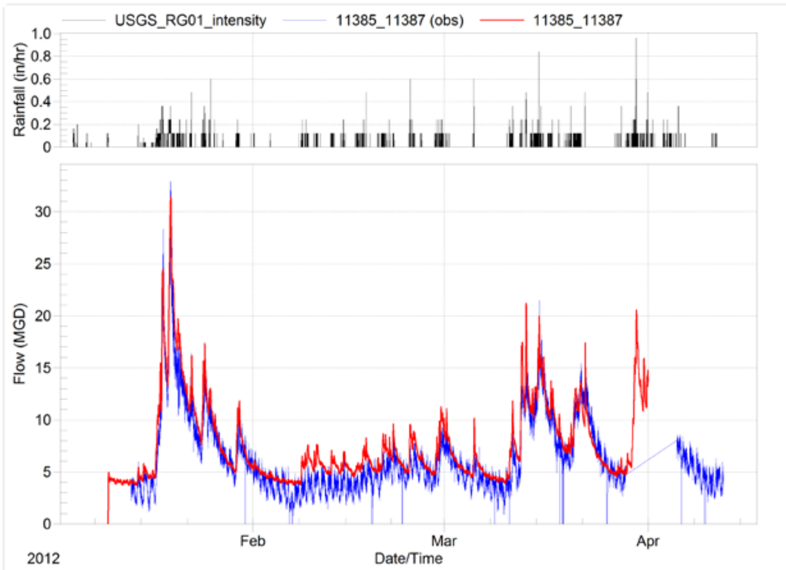



**Figure 24. Calibration of model to Meter 5**

*red = simulated; blue = observed*

This calibration includes about 14 mgd from the TCSD sewer line flowing into the Meter 5 basin. There were no available flow monitoring data to estimate the TCSD contribution to the City's system, so the following was employed based on engineering judgment. The flow from the local Meter 5 sewershed (removing flows from Meters 12 and 8) was estimated as 10 mgd by simulating the Meter 5 model using Meter 8 RTK parameters. The sum of the local Meter 5 flow (10 mgd), Meter 12 flow (4.5 mgd), and Meter 8 flow (4.5 mgd) was subtracted from the peak flow observed at Meter 5 (33 mgd). This resulted in a difference of 14 mgd, which was assumed to be contributed from the TCSD pipe.

**Canemah Pumping Station**

The wet well inflow calibration is shown in Figure 25. The simulated inflow value compares well with the observed inflow estimated by the wet well drain method. The estimate using the pump run method is not used because this station has variable-speed pumps. Therefore, estimating pump flow based on the published pump discharge rate is not possible because the rate varies during operation.

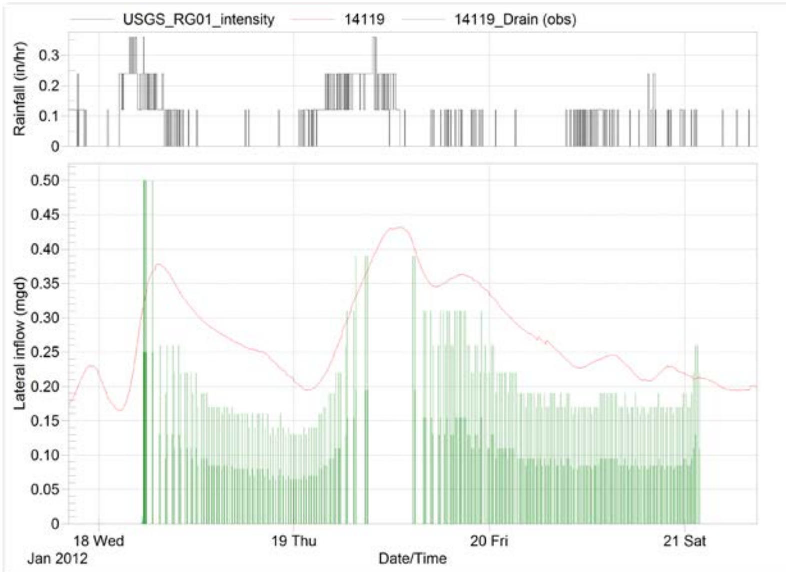



**Figure 25. Canemah Pumping Station wet well inflow calibration, January 19, 2012 event**

*red = simulated, green = estimated (wet well drain)*

### Barclay Hills Pumping Station

The wet well inflow calibration is shown in Figure 26. The simulated inflow value compares well with the observed inflow estimated by both the wet well drain and pump run method. This station was simulated implicitly, so pump flow information is not available.

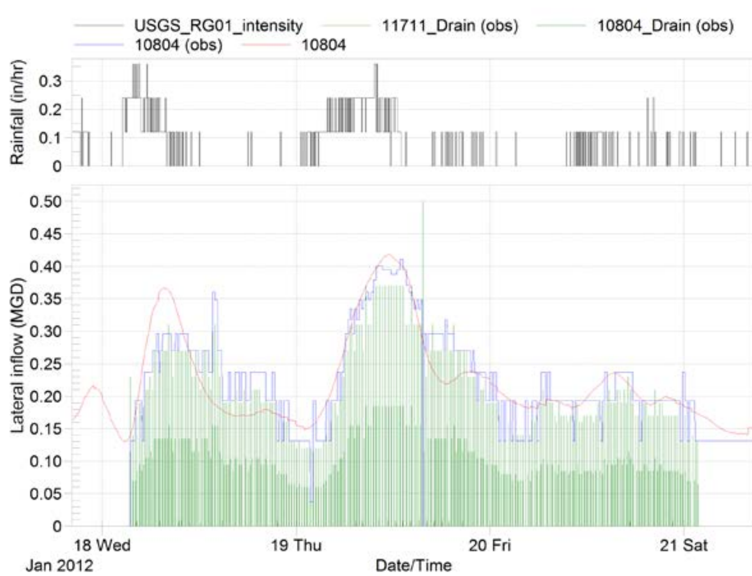



**Figure 26. Barclay Hills Pumping Station wet well inflow calibration, January 19, 2012 event**

*red = simulated, blue = estimated (pump run), green = estimated (wet well drain)*

### Newell Crest Pumping Station

The wet well inflow calibration is shown in Figure 27. The simulated inflow value compares well with the observed inflow estimated by pump run method. The estimate by the wet well drain method appears to underestimate the inflow. This station was simulated implicitly, so pump flow information is not available to verify use of the pump run method for estimating inflow.

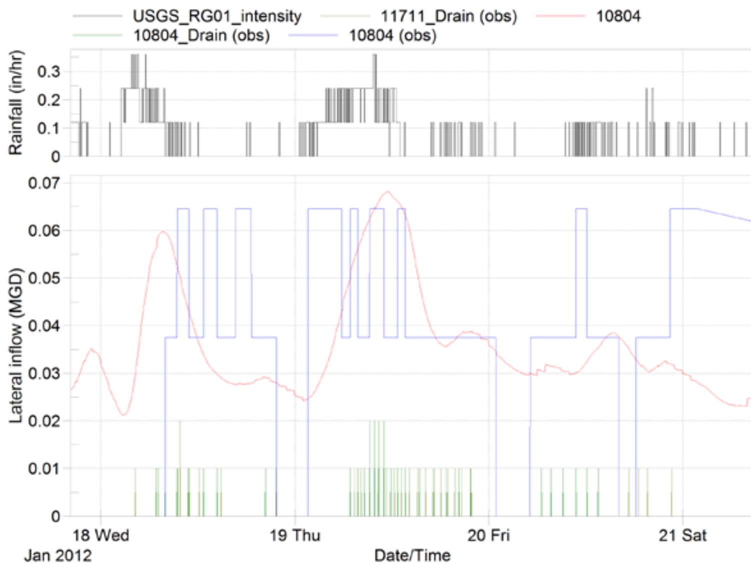



**Figure 27. Newell Crest Pumping Station wet well inflow calibration, January 19, 2012 event**

*red = simulated, blue = estimated (pump run), green = estimated (wet well drain)*

### Hilltop Pumping Station

The simulated inflow for the Hilltop Pumping Station compares well with the observed inflow estimated by the pump run method. The observed SCADA pump volume, in addition to the simulated and observed inflow, is considerably less than the published capacity of the station. This simulated and observed capacity, in addition to no known reported capacity issues, indicates the Hilltop Pumping Station has no problems.

# Section 5 System Evaluation

The calibrated model was used to estimate peak flows in the City's conveyance system for existing and future conditions during the 5- and 10-year rainfall events. After initial review of the 5-year results, the City decided to adopt the 10-year storm event for sizing of replacement and future capital projects. Therefore, the 10-year results are presented in this document.

## 5.1 Existing Conditions

Model evaluation simulation results for existing conditions are presented in this section.

### North Model Zone

The model simulation of existing conditions for the 10-year rainfall event with a 24-hour duration was completed to assess capacity in the North Model Zone conveyance system. The simulation results indicated no flooding or surcharge in the North Model Zone.

### Central Model Zone

The model simulation of existing conditions for the 10-year rainfall event with a 24-hour duration was completed to assess capacity in the Central Model Zone conveyance system. The results indicated no simulated flooding.

The model simulation results were also summarized to identify locations where surcharging (i.e., maximum simulated water surface in manholes above the pipe crown of connected pipes) occurred. These results are shown in Figure 28.

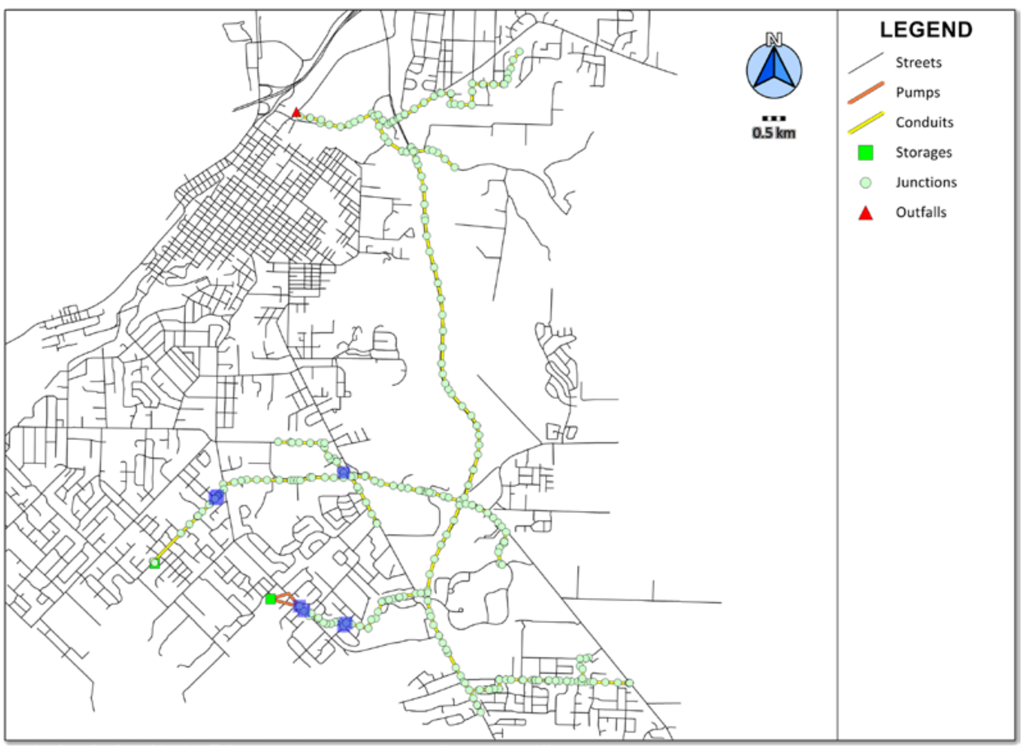



**Figure 28. Simulated surcharge in the Central Model Zone for the existing condition, 10-year, 24-hour event**

*Surcharging indicated by blue highlighted manhole.*

### South Model Zone

The model simulation of existing conditions for the 10-year rainfall event with a 24-hour duration was completed to assess capacity in the South Model Zone conveyance system. The simulated flooding for this simulation is shown in Figure 29.

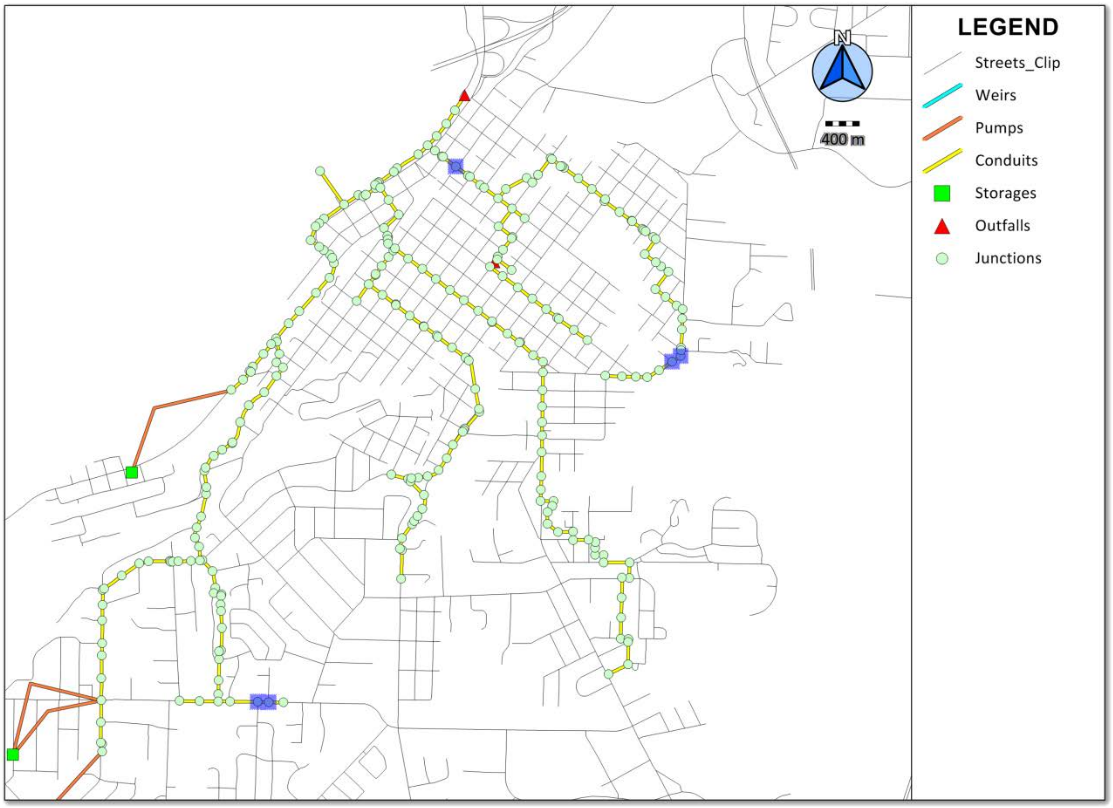



**Figure 29. Simulated flooding in the South Model Zone for the existing condition, 10-year, 24-hour event**

*Flooding indicated by blue highlighted manhole.*

The model simulation results were also summarized to identify locations where surcharging  occurred. These results are shown in Figure 30.

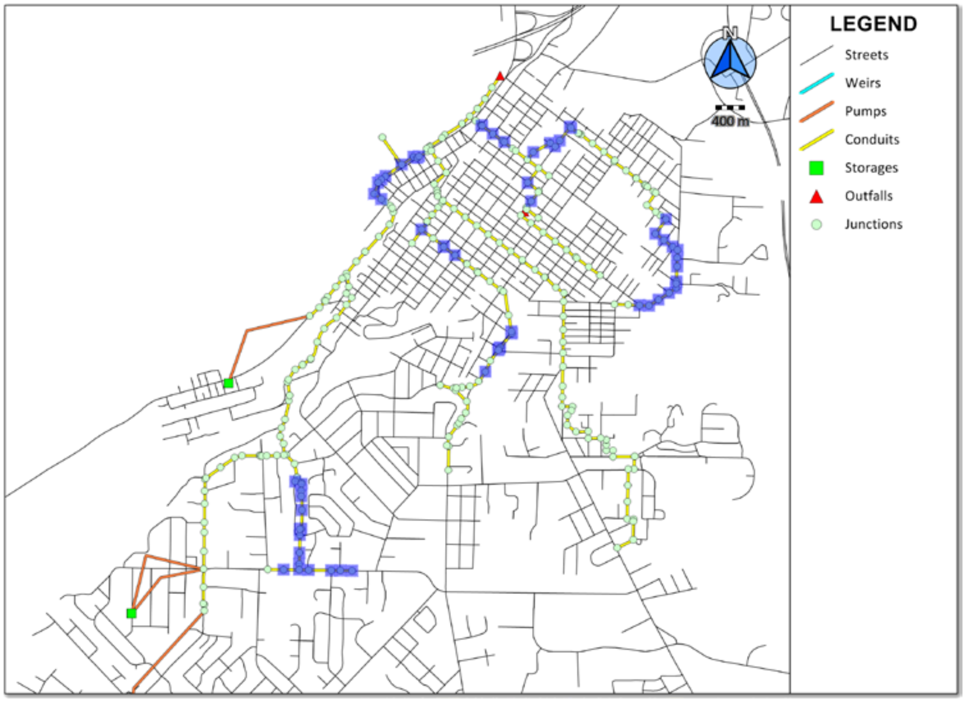



**Figure 30. Simulated surcharge in the South Model Zone for the existing condition, 10-year, 24-hour event**

*Surcharging indicated by blue highlighted manhole.*

### Model Summary Results

A summary of model results for existing conditions is provided in Table 17.

**Table 17. Summary of Model Results for Existing Conditions**

| Meter no. | Estimated sewershed[a], acres | Meter basin pipe length, inch-miles | Average dry weather flow, mgd[b] | Peak 10-year flow, mgd | Peak I/I flow, mgd | Peak I/I low, gpad[c] | Peak I/I flow, gallons per inch-mile per day) | Ratio of peak wet weather flow to average dry weather flow |
|---|---|---|---|---|---|---|---|---|
| 1 | 143 | 56 | 0.07 | 0.6 | 0.5 | 3,467 | 8,907 | 8 |
| 2 | 145 | 48 | 0.08 | 1.0 | 0.9 | 6,158 | 18,598 | 13 |
| 3 | 107 | 33 | 0.09 | 0.5 | 0.5 | 4,236 | 13,533 | 6 |
| 4 | 377 | 197 | 0.51 | 1.9 | 1.4 | 3,591 | 6,883 | 4 |
| 5[d] | 717 | 272 | 1.00 | 7.8 | 6.8 | 9,417 | 24,848 | 8 |
| 8[e] | 244 | 84 | 0.96 | 5.0 | 4.0 | 16,371 | 47,635 | 5 |
| 12 | 513 | 182 | 1.00 | 4.9 | 3.9 | 7,570 | 21,373 | 5 |
| 13 | 415 | 145 | 0.71 | 3.2 | 2.5 | 6,091 | 17,440 | 5 |
| 14 | 100 | 34 | 0.20 | 0.6 | 0.4 | 4,336 | 12,935 | 3 |
| 15 | 209 | 70 | 0.12 | 0.7 | 0.6 | 2,719 | 8,144 | 6 |
| 16 | 304 | 103 | 0.25 | 1.8 | 1.6 | 5,255 | 15,505 | 7 |

*[a]The sewershed is estimated as the area within a 200-foot buffer of all sewer mains in the meter basin.*

*[b]Dry weather flow estimated based on observed flow data for the period of February 1 to 8, 2012, which was the longest dry period during monitoring.*

*[c]The peak I/I flow per acre is based on the sewershed as the contributing area.*

*dThe peak simulated flow shown for Meter 5 excludes approximately 16 mgd, which is the estimated contribution from the TCSD conveyance system.*

[e]The values for Meter Basin 8 include Meter Basin 10, which was not used for calibration.*

## 5.2 Future Conditions

Model evaluation simulation results for future conditions are presented in this section.

### North Model Zone

The model simulation of future conditions for the 10-year rainfall event with a 24-hour duration was completed to assess capacity in the North Model Zone conveyance system. The simulation results indicated no flooding.

The model simulation results were summarized to identify locations where surcharging occurred. These results are shown in Figure 31.

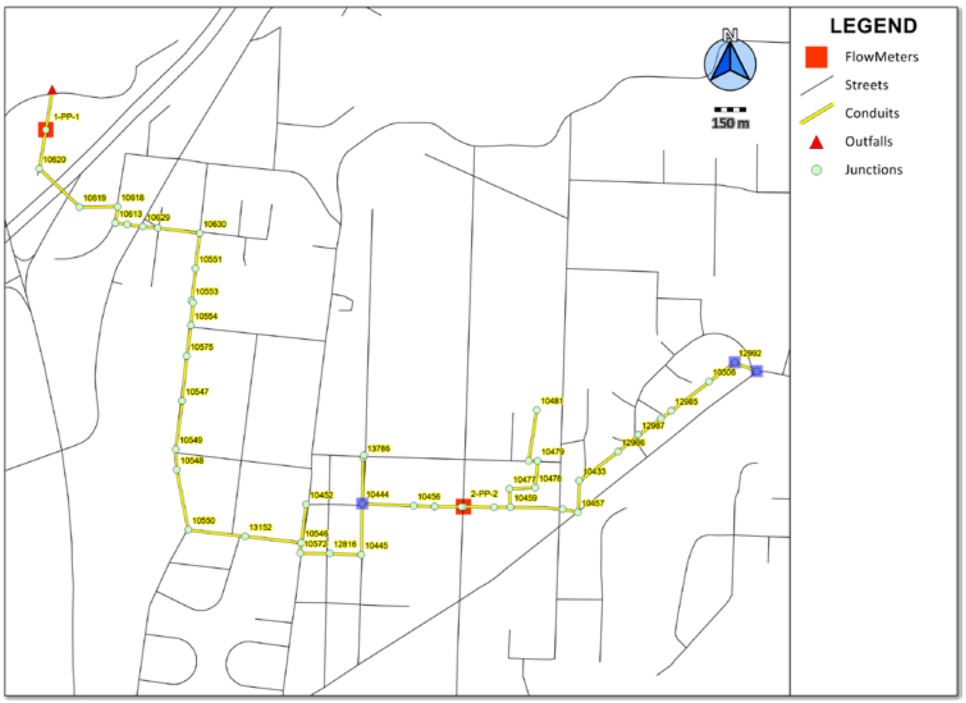



**Figure 31. Simulated surcharge in the North Model Zone for the future condition, 10-year, 24-hour event**

*Surcharging indicated by blue highlighted manhole.*

### Central Model Zone

The model simulation of future conditions for the 10-year rainfall event with a 24-hour duration was completed to assess capacity in the Central Model Zone conveyance system. The simulated flooding for this simulation is shown in Figure 32.

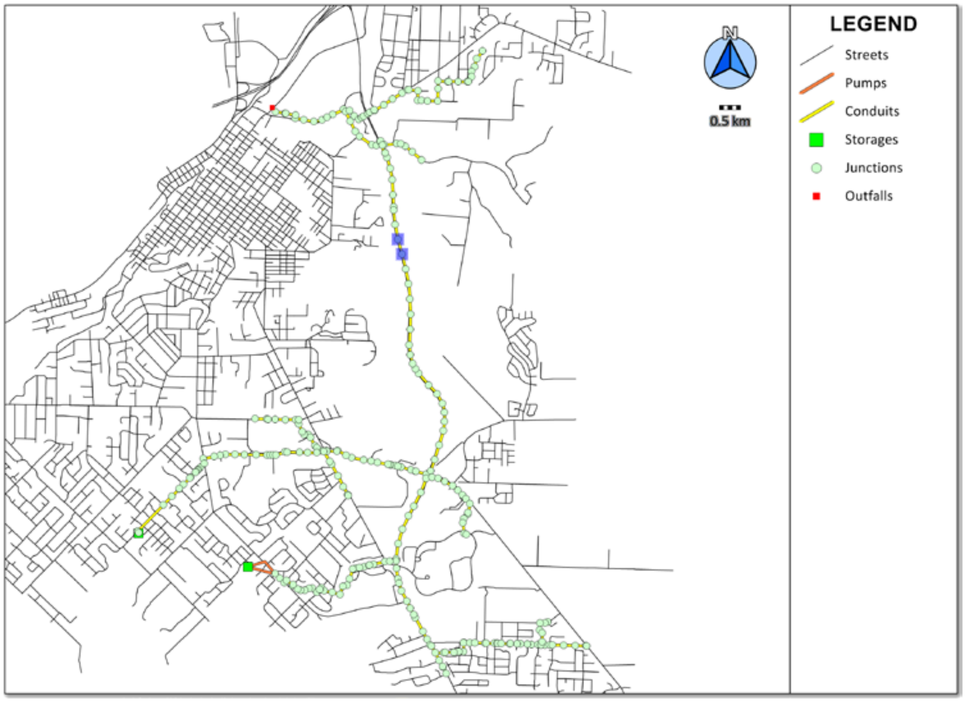



**Figure 32. Simulated flooding in the Central Model Zone for the future condition, 10-year, 24-hour event**

*Flooding indicated by blue highlighted manhole.*

The model simulation results were also summarized to identify locations where surcharging occurred. These results are shown in Figure 33.

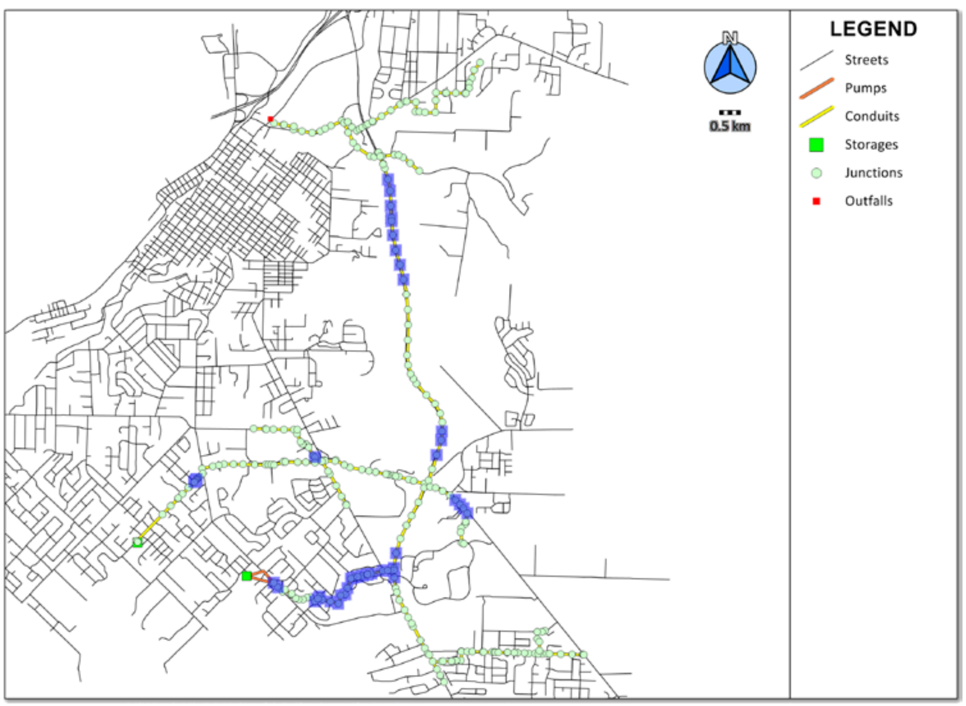



**Figure 33. Simulated surcharge in the Central Model Zone for the future condition, 10-year, 24-hour event**

*Surcharging indicated by blue highlighted manhole.*

### South Model Zone

The model simulation of future conditions for the 10-year rainfall event with a 24-hour duration was completed to assess capacity in the South Model Zone conveyance system. The simulated flooding for this simulation is shown in Figure 34.

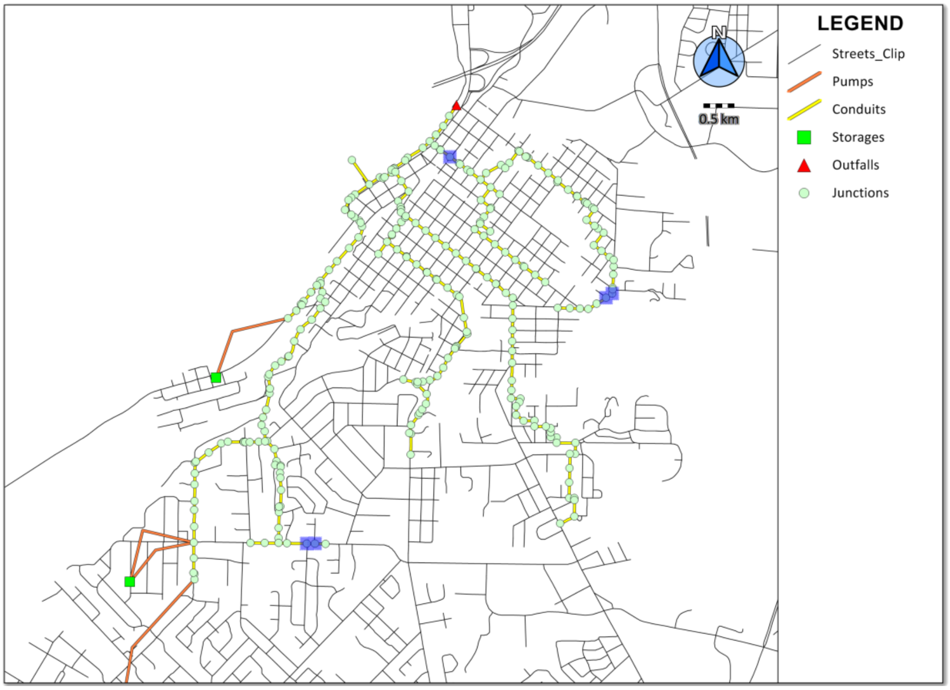



**Figure 34. Simulated flooding in the South Model Zone for the future condition, 10-year, 24-hour event**

*Flooding indicated by blue highlighted manhole.*

The model simulation results were also summarized to identify locations where surcharging occurred. These results are shown in Figure 35.

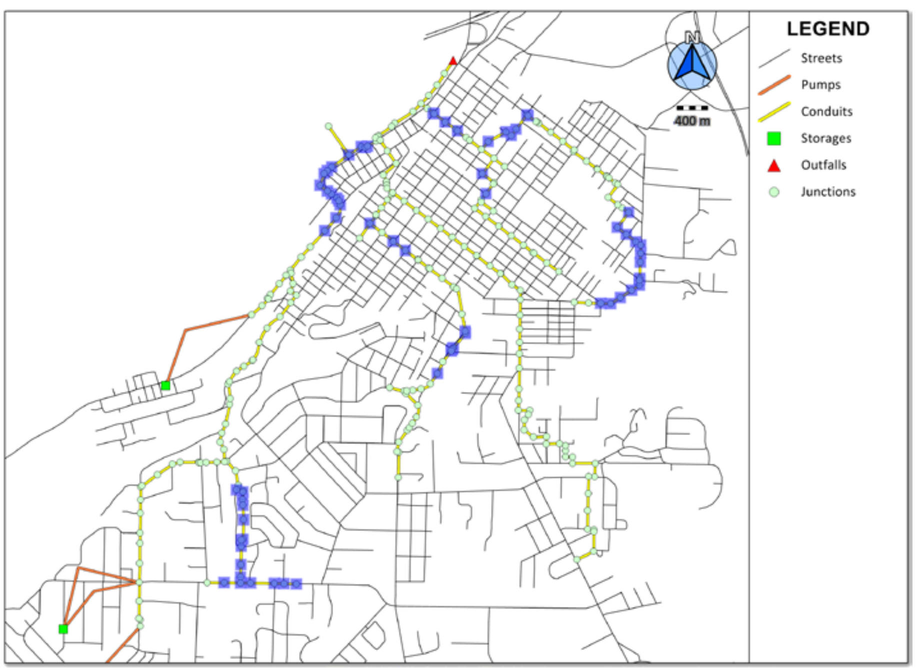



**Figure 35. Simulated surcharge in the South Model Zone for the future condition, 10-year, 24-hour event**

## 5.3 Pumping Stations

A summary of model results for existing and future conditions at the City's pumping stations are summarized in Table 18.

**Table 18. Summary of Model Results for Pumping Stations**

| Pumping station name | Firm capacity, mgd | Simulation Method[a,b] | Simulated capacity, mgd | Simulated 10-year peak inflow, existing, mgd | Simulated average dry weather inflow, existing mgd | Simulated 10-year peak inflow, buildout mgd | Simulated average dry weather inflow, buildout mgd |
|---|---|---|---|---|---|---|---|
| Pease | 1.50 | Explicit | 1.50 | 0.50 | 0.16 | 0.62 | 0.27 |
| Settler's Point | 1.20 | Explicit | 1.20 | 1.34 | 0.17 | 1.57 | 0.36 |
| Hidden Creek | 0.58 | Ideal | NA | 0.33 | 0.07 | 0.39 | 0.15 |
| Nobel Ridge | 0.20 | Ideal | NA | 0.08 | 0.01 | 0.08 | 0.01 |
| Canemah | 1.73 | Explicit | 1.73 | 0.52 | 0.06 | 0.55 | 0.08 |
| Parrish | 1.09 | Explicit | 1.09 | 0.70 | 0.20 | 0.77 | 0.27 |
| Cook | 0.89 | Explicit | 0.89 | 0.93 | 0.09 | 0.93 | 0.10 |
| Barclay Hills | 0.50 | Ideal | NA | 0.45 | 0.08 | 0.45 | 0.09 |
| Amanda | 0.24 | Ideal | NA | 0.12 | 0.06 | 0.12 | 0.06 |
| Newell Crest | 0.17 | Ideal | NA | 0.07 | 0.01 | 0.07 | 0.01 |
| Hilltop | 0.14 | Ideal | NA | 0.10 | 0.01 | 0.10 | 0.01 |

[a] *The explicit simulation method represented the pumping station in the model as an object with defined attributes (e.g., wet well geometry, pump curve, etc.) detailing the pump operation.*

[b] *The ideal simulation method represented the pumping station implicitly, assuming all inflow to the station was conveyed to the downstream model node (i.e., no capacity limitations at the station).*

# Section 6 Summary

The City's model was developed to assess the performance of the existing and future system. The model was suitably calibrated to flow monitoring data and recorded pumping station observations. The H/H model was calibrated using a diverse range of storm characteristics during the calibration period.

# References

MGS Engineering Consultants, Inc. Development of Design Storms for the Portland Oregon Area. July 9, 2001.

NOAA Atlas 2. Precipitation-Frequency Atlas of the Western United States. Volume X Oregon. J.F. Miller, R.H. Frederick, and R.J. Tracey. U.S. Department of Commerce. National Oceanic and Atmospheric Administration. National Weather Service. 1973.

NOAA. Vertcon. http://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html

SFE Global Inc. 2012. Sanitary Sewer Flow Monitoring, 12 Flow Sites – 1 Rain Gauge. Final Report for Oregon City, Oregon, USA.

# Attachment A – Future Development Flow Method

# Attachment A
# Future Development Flows – Analysis Steps

1. Define domain of analysis
    a. Select by location – "OC_taxlot_Clip" intersecting "BASE_UGB_Fill"
    b. Export selected features. Feature class of analysis domain is named "taxlot_model"
2. Determine vacant vs. partially vacant lands
    a. Union "taxlot_model" and selection of "Vacant_Lands" that intersects "BASE_UGB_Fill"
        i. Resulting fc is named "taxlot_vacant_union2"
    b. Calculate vacant area slices
        i. Select features in "taxlot_vacant_union2" where "VAC" = 1. This is all the vacant features.
        ii. Calculate geometry of "AREA" attribute, which represents "Vacant_Lands" area
    c. Dissolve "taxlot_vacant_union2" based on "RNO" and "TLID" attribute
        i. During dissolve, calculate sum of "AREA" attribute, which is area of "Vacant_Lands" slices
        ii. Resulting fc is named "taxlot_vacant_union2_Dissolv3"
    d. Add field named "PRCNT_VACANT" to "taxlot_vacant_union2_Dissolv3" – type Double.
        i. Calculate field as "AREA" divided by shape_area. This is the summed vacant area divided by the parcel area.
    e. Transfer vacant parcel information to the "taxlot_model" fc
        i. Add field to "taxlot_model" fc named "PRCNT_VACANT" – type Double.
        ii. Join "taxlot_vacant_union2_Dissolv3" fc to "taxlot_model" fc based on "TLID" attribute
        iii. Calculate "PRCNT_VACANT" field = "PRCNT_VACANT" field from "taxlot_vacant_union2_Dissolv3"
        iv. Add field to "taxlot_model" fc named "VACANT_ID" – type Double.
        v. Calculate "VACANT_ID" as follows:
            1. "PRCNT_VACANT" = 0, then "VACANT_ID" = "NOT_VACANT"
            2. "PRCNT_VACANT" = 100, then "VACANT_ID" = "VACANT"
            3. "PRCNT_VACANT" > 0 and <1, then "VACANT_ID" = "PARTIAL_VACANT"
                a. Note: this calculation does not account for those parcels where there is a small amount of non-vacant land, which could result from data overlap issues.
3. <u>ASSUME</u> parcels with "vacant" LANDUSE attribute in "taxlot_model," and identified as "NOT_VACANT," are NOT developed in the future. In other words, there is no additional sanitary flow from these parcels in the future.
4. ID "Landuse Category" to each parcel
    a. Add field to "taxlot_model" fc named "LANDUSE_CAT" – type text

b. Create lookup table of landuse to category relationship. Table is shown below.

| LANDUSE | COUNT | CATEGORY |
|---|---|---|
| | 40 | Residential |
| AGR | 94 | Residential |
| COM | 526 | Non-Residential |
| FOR | 100 | Residential |
| IND | 133 | Non-Residential |
| MFR | 149 | Residential |
| RUR | 160 | Residential |
| SFR | 10287 | Residential |
| VAC | 1284 | Residential |

c. Join the lookup table to "taxlot_model" fc based on the "LANDUSE" attribute.

d. Calculate "LANDUSE_CAT" field = "CATEGORY" field from the lookup table

5. Estimate density for existing, single family residential parcels.
   a. Add field to "taxlot_model" fc named "EX_DENSITY" – type text
   b. Use definition query to isolate single family residential parcels. Query applied to "taxlot_model" is "LANDUSE" = "SFR"
   c. Use following City information to identify existing density:

| CITY LAND USE CLASSIFICATIONS | |
|---|---|
| **Residential Plan Classification** | **City Zone** |
| Low-Density Residential | R-10, R-8, R-6 |
| Medium-Density Residential | R-3.5, R-5 |
| High-Density Residential | R-2 |
| **Commercial Plan Classification** | **City Zone** |
| General Commercial | C |
| Mixed-Use Downtown | MUD |
| Mixed-Use Corridor | MUC I, MUC 2, NC, HC |
| Mixed-Use Employment | MUE |
| **Industrial Plan Classification** | **City Zone** |
| Industrial | CI, GI |

| Standard | R-10 | R-8 | R-6 | R-5 | R-3.5 | R-2 |
|---|---|---|---|---|---|---|
| Minimum lot size | 10,000 sq. ft.* | 8,000 sq. ft.* | 6,000 sq. ft.* | 5,000 sq. ft.* | 3,500 sq. ft.* | 2,000 sq. ft.* |

   d. Calculate "EX_DENSITY" as follows:
      i. "Shape_Area" >= 6,000 = "LOW"
      ii. "Shape_Area" <= 2,000 = "HIGH"
      iii. "Shape_Area" > 2,000 and < 6,000 = "MEDIUM"

6. Overlay "taxlots" with "Comprehensive_Plan" to associate future zoning with tax parcels.
   a. Use Features to Points to convert "taxlot_model" fc from polygon to point geometry.
      i. New fc is named "taxlot_model_pt"
   b. Spatial join "taxlot_model_pt" and "Comprehensive_Plan" fc.
      i. Resulting fc is named "taxlot_model_pt_CompPlan_join".
   c. Add field to "taxlot_model" fc named "PLANCIT" – type text
   d. Join "taxlot_model_pt_CompPlan_join" to "taxlot_model" fc based on the "TLID" attribute.
   e. Calculate "PLANCIT" field = "PLANCIT" field from "taxlot_model_pt_CompPlan_join" fc.

7. Estimate future dwelling units for residential zoning
    a. Add field to “taxlot_model” fc named “ZONE_MINLOTSF” – type double
    b. Add field to “taxlot_model” fc named “ZONE_DWELLINGUNIT” – type double
    c. Create lookup table identifying minimum lot size for residential zoning classifications. The lookup table is provided below:

| PLANCIT | Cnt_PLANCIT | First_DESCRIBE | MinLotSF |
|---|---|---|---|
| HR | 21 | Residential - High Density | 2000 |
| LR | 17 | Residential - Low Density | 6000 |
| MR | 28 | Residential - Medium Density | 3500 |

    d. Join the lookup table to “taxlot_model” fc based on the “PLANCIT” attribute.
    e. Calculate “ZONE_MINLOTSF” field = “MinLOTSF” field from the lookup table
    f. Calculate “ZONE_DWELLINGUNIT” field = “Shape_Area” / “ZONE_MINLOTSF”
8. ID change, if any, between current land use and future zoning
    a. Add field to “taxlot_model” fc named “LANDUSE_COMPILE” – type text
    b. Calculate “LANDUSE_COMPILE” according to the following method:
        i. If “VACANT_ID” = “VACANT”, then “LANDUSE_COMPILE” = “VACANT”
        ii. Definition query “VACANT_ID” <> “VACANT”
        iii. If “LANDUSE” = “SFR”, then “LANDUSE_COMPILE” = “EX_DENSITY”
        iv. Select by attribute – “LANDUSE”=”VAC”, then field calculate “LANDUSE_COMPILE” = “LU_VAC”. This identifies the vacant parcels, as defined in the taxlot attributes, which were not included in the City’s vacant lands analysis. The City confirmed, during 9/24/13 phone conference, the assumption these parcels would have NO additional sewer flow.
        v. Select all features – remove “LANDUSE” = “SFR” and “LANDUSE”=”VAC”, then field calculate “LANDUSE_COMPILE” = “LANDUSE”.
    c. Add field to “taxlot_model” fc named “LandUse_Zone” – type text
    d. Calculate “LandUse_Zone” field = “LANDUSE_COMPILE” &”_”& “PLANCIT”
    e. Create lookup table identifying landuse to zoning conversions resulting in future development. The lookup table is provided on the following page.
    f. Join the lookup table to “taxlot_model” fc based on the “LandUse_Zone” attribute.
    g. Add field to “taxlot_model” fc named “DVLPMNT” – type text
    h. Calculate “DVLPMNT” field = “ADD_DEV” field from the lookup table

| Landuse_Zone | Cnt_Landuse_Zone | ADD_DEV | Landuse_Zone | Cnt_Landuse_Zone | ADD_DEV | Landuse_Zone | Cnt_Landuse_Zone | ADD_DEV |
|---|---|---|---|---|---|---|---|---|
| _ | 2 | NO | HIGH_HR | 91 | NO | LU_VAC_MUE | 5 | NO |
| _FUT URBAN | 1 | NO | HIGH_LR | 17 | NO | LU_VAC_P | 46 | NO |
| _HR | 1 | NO | HIGH_MR | 6 | NO | LU_VAC_QP | 45 | NO |
| _I | 9 | NO | HIGH_MUC | 9 | NO | MEDIUM_ | 1 | NO |
| _LR | 7 | NO | HIGH_MUD | 1 | NO | MEDIUM_HR | 142 | YES |
| _MR | 5 | NO | IND_ | 2 | NO | MEDIUM_LR | 1124 | NO |
| _MUC | 3 | NO | IND_C | 4 | NO | MEDIUM_MR | 465 | NO |
| _MUD | 3 | NO | IND_I | 32 | NO | MEDIUM_MUC | 65 | NO |
| _MUE | 2 | NO | IND_LR | 2 | NO | MEDIUM_MUD | 12 | NO |
| _P | 1 | NO | IND_MUC | 4 | NO | MEDIUM_MUE | 20 | NO |
| AGR_ | 27 | NO | IND_MUD | 23 | NO | MEDIUM_QP | 7 | NO |
| AGR_FUT URBAN | 16 | YES | IND_MUE | 59 | NO | MFR_C | 1 | YES |
| AGR_I | 1 | YES | IND_P | 1 | NO | MFR_HR | 51 | NO |
| AGR_LR | 22 | YES | IND_QP | 3 | NO | MFR_LR | 9 | NO |
| AGR_MR | 3 | YES | LOW_ | 101 | NO | MFR_MR | 51 | NO |
| COM_ | 1 | NO | LOW_C | 3 | NO | MFR_MUC | 34 | YES |
| COM_C | 59 | NO | LOW_FUT URBAN | 37 | YES | MFR_MUE | 3 | YES |
| COM_FUT URBAN | 2 | YES | LOW_HR | 88 | YES | RUR_ | 38 | NO |
| COM_HR | 3 | YES | LOW_I | 6 | YES | RUR_C | 2 | YES |
| COM_I | 5 | YES | LOW_LR | 7390 | NO | RUR_FUT URBAN | 23 | YES |
| COM_LR | 7 | NO | LOW_MR | 517 | YES | RUR_HR | 2 | YES |
| COM_MR | 5 | NO | LOW_MUC | 54 | NO | RUR_I | 6 | YES |
| COM_MUC | 246 | NO | LOW_MUD | 18 | NO | RUR_LR | 43 | YES |
| COM_MUD | 158 | NO | LOW_MUE | 22 | NO | RUR_MR | 12 | YES |
| COM_MUE | 18 | NO | LOW_P | 13 | NO | RUR_MUC | 1 | YES |
| COM_P | 6 | NO | LOW_QP | 9 | NO | RUR_P | 8 | NO |
| COM_QP | 8 | NO | LU_VAC_ | 28 | NO | RUR_QP | 18 | YES |
| FOR_ | 43 | NO | LU_VAC_C | 1 | NO | VACANT_ | 53 | NO |
| FOR_FUT URBAN | 5 | YES | LU_VAC_FUT URBAN | 3 | NO | VACANT_C | 1 | YES |
| FOR_HR | 1 | YES | LU_VAC_HR | 118 | NO | VACANT_FUT URBAN | 14 | YES |
| FOR_I | 2 | YES | LU_VAC_I | 9 | NO | VACANT_HR | 118 | YES |
| FOR_LR | 8 | YES | LU_VAC_LR | 341 | NO | VACANT_I | 9 | YES |
| FOR_MR | 8 | YES | LU_VAC_MR | 48 | NO | VACANT_LR | 368 | YES |
| FOR_MUC | 5 | YES | LU_VAC_MUC | 31 | NO | VACANT_MR | 103 | YES |
| | | | LU_VAC_MUD | 13 | NO | VACANT_MUC | 35 | YES |
| | | | | | | VACANT_MUD | 33 | YES |
| | | | | | | VACANT_MUE | 6 | YES |
| | | | | | | VACANT_QP | 2 | YES |

Xxx These are addressed by Step 12 below, which describes the process to incorporate land use, as provided by the City for parcels with missing land use information.

Xxx Parcels with no zoning. Assume these parcels are located outside the UGB, and are not part of the analysis.

Xxx These parcels are addressed by Step 9.j, which examines whether current residential parcels are large enough to increase sanitary flow after conversion to mixed use.

9. Employ logic outlined by the City.
    a. Logic:
        i. If 100% vacant, then develop to future comp code density – COVERED BY ABOVE
        ii. If NOT 100% vacant, and residential, and current land use code = future comp code, then no action – COVERED BY ABOVE
        iii. If NOT 100% vacant, and residential, and current land use code <> future comp code, then redevelop to future comp code density – COVERED BY ABOVE
        iv. If partially vacant, non-residential, current land use code = future comp code ☐ Develop the vacant parts to future comp code density
        v. If partially vacant, non-residential, current land use code <> future comp code ☐ Develop the vacant parts to future comp code density
        vi. If 0% vacant, non-residential, current land use code = future comp code ☐ No action COVERED BY ABOVE
        vii. If 0% vacant, non-residential, current land use code <> future comp code ☐ Examine on by-case basis
    b. Definition query on “taxlot_model” - "VACANT_ID" = 'PARTIAL_VACANT' AND "LANDUSE_CAT" = 'Non-Residential'. Note: in some cases, this assumes some portions of a high density land use parcel (e.g. industrial) is developed to a lower density (e.g. commercial).
    c. Field calculate on remaining features, “DVLPMNT”=”YES_PARTIAL”
    d. Definition query on “taxlot_model” - "VACANT_ID" = 'NOT_VACANT' AND "LANDUSE_CAT" = 'Non-Residential' AND "DVLPMNT" = 'YES'
    e. Field calculate on remaining features, “DVLPMNT”=”CASE_BY_CASE”
    f. Try to identify those large parcels where redevelopment (by increasing density) may occur. These would not have been identified from the logic above b/c, for example, the landuse and zoning may be the same. Definition query on “taxlot_model” - "LANDUSE" = 'SFR' AND "DVLPMNT" = 'NO' AND "ZONE_DWELLINGUNIT">1 AND "GIS_ACRES">1
    g. Field calculate on remaining features, “DVLPMNT”=”YES_LargeLotRedev”
    h. Remove residential to residential conversions with limited or no increase in dwelling units, based on zoning. Assume capacity of less than 3 units (in the future) will NOT be developed. Definition query on “taxlot_model” - "DVLPMNT" = 'YES' AND "LANDUSE" = 'SFR' AND "LANDUSE_COMPILE" <> 'VACANT' AND "PLANCIT" <> 'FUT URBAN' AND "ZONE_DWELLINGUNIT"<3
    i. Field calculate on remaining features, “DVLPMNT”=”NO_LESSthan3”
    j. Add current residential parcels zoned mixed use, and having areas large enough to constitute an increase in flow for future conditions. In other words, if the parcel is greater than 0.2 acres, then the mixed use estimate flow (0.2 ac x 1,000 gal/ac/day = 200 gal/day) will be greater than the residential flow (1 unit x 2.5 people/unit x 80 gal/person/day = 200 gal/day). Use 0.25 acres to include margin of safety. Definition query on “taxlot_model” - "LANDUSE_COMPILE" <> 'VACANT' AND "LANDUSE" = 'SFR' AND ("PLANCIT" = 'MUC' OR "PLANCIT" = 'MUD' OR "PLANCIT" = 'MUE') AND "GIS_ACRES" >0.25
    k. Field calculate on remaining features, “DVLPMNT”=”YES_RES_MU”
    l. Add current residential parcels zoned quasi-public, and having areas large enough to constitute an increase in flow for future conditions. In other words, if the parcel is greater than 0.2 acres, then the mixed use estimate flow (0.2 ac x 1,000 gal/ac/day = 200 gal/day) will be greater than the residential flow (1 unit x 2.5 people/unit x 80 gal/person/day = 200 gal/day). Use 0.25 acres to include margin of safety. Assume quasi-public flow is equivalent to commercial (1,000 gal/acre/day). Definition query on

"taxlot_model" - "LANDUSE_COMPILE" <> 'VACANT' AND "LANDUSE" = 'SFR' AND "PLANCIT" = 'QP' AND "GIS_ACRES" >0.25

m. Field calculate on remaining features, "DVLPMNT"="YES_QP"

10. Add in overlays of specific conditions identified by the City
    a. City provided polygons of "Anticipated Future Development" and "Septic" areas
    b. Spatial Join polygon data to "taxlot_model_pt"
    c. Add fields to "taxlot_model" – type text
        i. ANTICIPATE_FUT_DEV
        ii. SEPTIC
    d. Join fc resulting from spatial join above to "taxlot_model." Isolate those features with septic and anticipated future development, respectively.
        i. Calculate field – if anticipated future development, then "Anticipated Future Development" = "ANTICIPATED_FUTURE"; if septic, then "Septic" = "SEPTIC"
    e. Note: City provided a hard copy markup of parcels known to be septic. These were generally located in the southeast part of the City along Molalla (near Brandon Estates PS).
11. Identify specific parcels the City requested be manually set to NOT develop in the future. Some of these parcels were misrepresented in the land use data – for example, schools were shown to have a land use of rural, so the City wanted to change this so the schools were assumed to not develop in the future.
    a. City provided data for Cemeteries (polygon fc), Home Depot (polygon fc), Schools (points and polygons, which were public schools only), Churches (polygon fc), and Tri Cities WWTP (polygon).
    b. Add field named "MANUAL_RESTRICTION" to "taxlot_model" – type text.
    c. Select by location – "taxlot_model" features with their centroid in "cemetries".
        i. Field calculate selected features, "MANUAL_RESTRICTION" = "NO_CEMETARY"
    d. Select by location – "taxlot_model" features with their centroid in "Home_Depot"
        i. Field calculate selected features, "MANUAL_RESTRICTION" = "NO_HOME_DEPOT"
    e. Select by location – "taxlot_model" features intersecting "School_points"
        i. Field calculate selected features, "MANUAL_RESTRICTION" = "NO_SCHOOL"
    f. Select by location – "taxlot_model" features with their centroid in "School_taxlots"
        i. Field calculate selected features, "MANUAL_RESTRICTION" = "NO_SCHOOL"
    g. Select by location – "taxlot_model" features intersecting "Churches"
        i. Field calculate selected features, "MANUAL_RESTRICTION" = "NO_CHURCH"
    h. Select by location – "taxlot_model" features with their centroid in "TriCities_Sewer_Plant"
        i. Field calculate selected features, "MANUAL_RESTRICTION" = "NO_WWTP"
12. Update land use for 33 parcels with no "LANDUSE" attribute in the taxlot data.
    a. City provided a land use for each of the 33 parcels in a version of "taxlot_model" provided to them. A summary of the information provided by the City is below. Note: the City provided land use is in "LANDUSE_FRM_CITY" and the interpretation by BC is "LANDUSE_TAXLOT."

| TLID | LANDUSE_FRM_CITY | Cnt_LANDUSE | LANDUSE_TAXLOT |
|---|---|---|---|
| 22E29CB01500 | COM | 6 | COM |
| 22E31CC02790 | COM (PGE - No Sanitary) | 1 | COM |
| 22E20DA03300 | IND | 9 | IND |
| 22E31BD00300 | IND - (Not in Business) | 1 | VAC |
| 32E05A 01290 | MFR | 1 | MFR |
| 22E31CA00690 | ODOT ROW | 1 | ROW |
| 22E29 00200 | ODOT ROW & Roundabout | 1 | ROW |
| 21E36DD07400 | Railroad ROW | 4 | ROW |
| 22E31 00600 | RIVER | 1 | RIV |
| 32E09AA00100 | RUR | 2 | RUR |
| 22E28CBNONTL | SFR | 6 | SFR |

i. TLID 22E31BD00300 will be assumed vacant – so “LANDUSE_COMPILE” will be set to “VACANT.” TLID 22E31CC02790 is assumed commercial, recognizing the City identified this as not having any sanitary flow – the zoning for this parcel is LDR, so the analysis will result in NO additional sanitary flow from this parcel.

b. Definition query “LANDUSE_COMPILE”=”” on “taxlot_model” fc. This limits the features to those without a land use.
c. Join the City provided fc to “taxlot_model” based on “TLID” attribute
d. Field calculate “LANDUSE” = “LANDUSE” (as defined by the City)
   i. Correct the calculations to match the “LANDUSE_TAXLOT” values in the table above.
e. Follow Steps 4, 5, 7, 8, 9 above.
   i. Note: Step 4 – “RIV” and “ROW” were assigned “Non-Residential” category
   ii. Field calculate “LANDUSE_COMPILE” = “VACANT” and Field calculate “PLANCIT” = “MUC” for “TLID” = “22E31BD00300.”This approach was discussed and approved during a meeting with the City on Sep 24, 2013.
   iii. Step 8 – ROW and RIV (river) are assumed to NOT develop (i.e. “DVLPMNT” = “NO”). One parcel is MDR and zoned parks – this is assumed to NOT develop.

13. Manually adjust parcels identified by the City as developing in the future. After review of initial future development estimates, the City identified parcels with “LANDUSE_COMPILE” = “LU_VAC” which were known to be developed in the future. In addition, there were five parcels identified as being commercial or industrial, but they were known to be vacant. A list of these parcels (IDs) is provided below, for reference.

| TLID | TLID | TLID | TLID |
|---|---|---|---|
| 22E29CC01400 | 22E30 00601 | 22E29 03200 | 32E09D 00200 |
| 22E29CC01500 | 22E29 01200 | 22E29 03300 | 32E09D 00202 |
| 22E29CC01600 | 22E29 02800 | 22E29 03400 | 32E05D 00401 |
| 22E29CC01700 | 22E29 03000 | 22E29 03700 | 32E05D 00500 |
| 22E29CD00100 | 22E29 03100 | 32E09C 00200 | 32E05D 00501 |

a. Field calculate “LANDUSE_COMPILE” = “VACANT”
b. Assume all the parcels will be developed to commercial landuse. Field calculate “Landuse_Zone” = “VACANT_C”
c. Field calculate “DVLPMNT”=”YES”
d. Field calculate “DVLPMNT_MOD”=”YES”

14. Manually adjust those parcels assigned “CASE_BY_CASE” in Step 9.e above. This is a result from discussions with the City on 9/24/13.

- a. Blue Heron site
  - i. Change "PLANCIT" for TLIDs = 22E31BD00500 and 22E31BD00600 from "I" to "MUC"
- b. Molalla and Gleason
  - i. 3 parcels – TLIDs = 32E05BA03400, 32E05BA03401, and 32E05BA03500
  - ii. Use future zoning
- c. Beavercreek and Hwy 213
  - i. TLID = 32E09B 00400
  - ii. Use future zoning
- d. Molalla and Fir
  - i. TLID = 32E09B 01500
  - ii. Assume commercial in future; Change "PLANCIT" from "I" to "COM"
- e. Glen Oak
  - i. TLID = 32E09C 00400
  - ii. Use future zoning

15. Compile modifications to development/increase in sanitary flow
   - a. Add field to "taxlot_model" attribute table named "DVLPMNT_MOD" – type text
   - b. Case by case parcels
     - i. Use definition query - "DVLPMNT" = 'CASE_BY_CASE' – to isolate only case by case parcels.
     - ii. Join the land use and zoning lookup table to "taxlot_model" fc based on the "LandUse_Zone" attribute.
     - iii. Calculate "DVLPMNT_MOD" field = "ADD_DEV" field from the lookup table
     - iv. Note: 1 parcel had a "COM_COM" value which was not previously encountered. No development was assumed for this parcel.
   - c. Septic parcels
     - i. Select features "SEPTIC" = "SEPTIC"
     - ii. "DVLPMENT_MOD"=YES_Septic"
     - iii. Note: two features are also identified as church/school exclusion. So, ww flow from these features will need to be accounted for based on their land use (v. zoning).
   - d. Exclusions
     - i. Select features "MANUAL_RESTRICTION" <> ''
     - ii. "DVLPMNT_MOD"="MANUAL_RESTRICTION"
     - iii. Note: qualify the 2 parcels with septic
       1. Select features "MANUAL_RESTRICTION" <> ''
       2. Select from the selected features, "DVLPMNT_MOD" = 'YES_Septic'
       3. "DVLPMNT_MOD"="Yes_Septic_LANDUSE"
   - e. Remaining parcels = previous determination
     - i. Select features, "DVLPMNT_MOD"<>''
     - ii. Switch selection
     - iii. "DVLPMNT_MOD"="DVLPMNT"
   - f. Identify those parcels with taxlot landuse attribute = vacant
     - i. During the 9/24/13 phone conference, the City directed BC to assume these parcels would not change in the future. BC will symbolize these explicitly so the City can be aware of this.
     - ii. Select features "LANDUSE_COMPILE" = "LU_VAC"
     - iii. Remove from selection, "DVLPMNT_MOD"="NO_SCHOOL" OR "DVLPMNT_MOD"="NO_CEMETARY" OR "DVLPMNT_MOD"="YES_Septic"

16. ID those parcels located in concept plan areas
    a. Add field, type string, named “CONCEPT”
    b. Select by location parcels in “taxlot_model” with their centroid within any of the 3 concept plan polygons provided by the City.
    c. Field calculate “CONCEPT”=”YES”
17. Determine area of constrained land on each parcel
    a. Union “taxlot_model” and selection of “All_Constraints” that intersects “BASE_UGB_Fill”
        i. Resulting fc is named “taxlot_constrained_union”
        ii. Note: Set definition query on “All_Constraints” of "Building" = 'N'. This omits buildings from the constrained layer.
    b. Union “taxlot_constrained_union” and selection of “Vacant_Lands” that intersects “BASE_UGB_Fill”
        i. Resulting fc is named “taxlot_cnstrnd_vacant_union”
    c. Calculate vacant area slices
        i. Add field, type double, named “AREA_CONSTR”
        ii. Select features in “FID_All_Constraints” <> -1. This is all the constrained features.
        iii. Calculate geometry of “AREA_CONSTR” attribute, which represents “constrained land” area
        iv. Add field, type double, named “AREA_CONSTR_PRTL”
        v. Select features in “FID_All_Constraints” = -1 AND “FID_Vacant_Lands”<> ”-1”. This is vacant land that is also constrained (i.e. vacant and constrained land overlap).
        vi. Calculate geometry of “AREA_CONSTR_PRTL” attribute, which represents “constrained vacant land” area
    d. Dissolve “taxlot_cnstrnd_vacant_union” based on “TLID” attribute
        i. During dissolve, calculate sum of “AREA_CONSTR” and “AREA_CONSTR_PRTL” attributes.
        ii. Resulting fc is named “taxlot_cnstrnd_vcnt_union_dissolv”
    e. Transfer constrained land information to the “taxlot_model” fc
        i. Add field to “taxlot_model” fc named “CONSTR_AREA” – type Double.
        ii. Add field to “taxlot_model” fc named “CONSTR_VAC_AREA” – type Double.
        iii. Join “taxlot_constrained_union_Dissolv” fc to “taxlot_model” fc based on “TLID” attribute
        iv. Calculate “CONSTR_AREA” = “AREA_CONSTR”
            1. Select null values and set to 0
        v. Calculate “CONSTR_VAC_AREA” = “AREA_CONSTR_PRTL”
            1. Select null values and set to 0
18. Estimate net developable acres
    a. Add field to “taxlot_model”, type double, named “NET_DEV_ACRES”
    b. Select those parcels where only the vacant portion will be developed. Select features from “taxlot_model” where “DEV_MOD” = “YES_PARTIAL”
    c. Field calculate “NET_DEV_ACRES” = (“AREA”* “PRCNT_VACANT”- “CONSTR_VAC_AREA”) /43560
    d. Switch the selection
    e. Field calculate “NET_DEV_ACRES” = ([AREA]- [“CONSTR_AREA”])/43560
19. Identify Model Junction where development drains
    a. Add field to “taxlot_model”, type long, named “MANHOLE”
    b. Use “Tax_parcel_redevelopment_5” as a start – join this fc based on Tlid
20. Flow assumptions
    a. MFR is 5 units
21. Estimate ex and future flow

   a. Add fields to "taxlot model"
      i. LU_UNIT_Q, type long
      ii. LU_UNIT_Q_TYPE, type text
      iii. EX_Q, type double
      iv. ZONE_UNIT_Q, type long
      v. ZONE_UNIT_Q_TYPE, type text
      vi. FUT_Q, type double
      vii. "AREA_RED", type double
   b. Create lookup tables
   c. Join tables
   d. Estimate flow by following logic
      i. Existing
         1. If gpd, then same
         2. if gpad, then unit q by area
      ii. Future
         1. Select features with "NET_DEV_ACRES" > 1
         2. Field calc "AREA_RED" = 0.8
         3. Switch selection
         4. Field calc "AREA_RED" = 1.0
         5. if gpd, then unit q x ("NET_DEV_ACRES" x "AREA_RED" x 43560) / "ZONE_MINLOTSF"
         6. if gpad, then unit q x ("NET_DEV_ACRES" x "AREA_RED")
   e. Identify areas where additional I/I could be expected (i.e. currently unsewered areas)
      i. Add field named "II_GPD", type double
      ii. Select "SEPTIC" = "SEPTIC" and "VACANT_ID"="VACANT" and "LANDUSE_COMPILE" = "RUR" and "LANDUSE_COMPILE" = "FOR" and "LANDUSE_COMPILE" = "AGR"
      iii. Field calc "II_GPD" = 1000 x "NET_DEV_ACRES"
         1. Assume 1,000 acre/day I/I
      iv. Switch selection, and calculate "II_GPD"= 0

22. Estimate additional flow
   a. Add field named "ADD_FLOW_GPD", type double
      i. Select "SEPTIC" = "SEPTIC" and "DVLPMNT_MOD" = 'YES_PARTIAL'
      ii. Calc "ADD_FLOW_GPD" = "FUT_Q"
      iii. Select all features with no value for "ADD_FLOW_GPD"
      iv. Calc "ADD_FLOW_GPD" --

```
dim flow
if ([FUT_Q] + [II_GPD])  < [EX_FLOW] then
flow = 0
elseif ([FUT_Q]  - [EX_FLOW]) < 0 then
flow = 0
else
flow = [FUT_Q]  - [EX_FLOW]
end if
```

# Appendix B: Pumping Station Assessment

Brown AND Caldwell

## Appendix B

# Pumping Station Assessment

## Pumping Stations

The topography of Oregon City has required that pumping stations be used to serve a number of areas throughout the city. Currently, there are 12 major pumping stations within the service area owned and operated by the City of Oregon City (City). In addition, the City owns several minor pumping stations (i.e., Jon Storm Park and Elevator) and approximately seven residences with individual septic tank effluent pumping (STEP) systems. The focus of this review is on the 12 major pumping stations owned and operated by the City.

The pumping stations are generally in good condition. The City has a thorough routine maintenance and inspection program. With the exception of the STEP systems, each pumping station is inspected twice a week. Run-time readings are taken once a week.

## Pumping Station Evaluation Approach

Interviews with City staff were conducted in December 2012. The purpose of the interviews was to document operational and maintenance-related deficiencies in each pumping station so that major deficiencies could be identified and included as capital costs in the Sanitary Sewer Master Plan (SSMP). Hands-on inspection and physical testing of the equipment were not performed as part of this analysis.

Firm capacity is defined as the capacity of the pumping station with the highest-capacity pump out of service as per Oregon Department of Environmental Quality guidelines.

## Major Pumping Stations

The City's major pumping stations are described in this section.

#### Amanda Court

In 2007, the original Amanda Pumping Station and smaller station on Riverview Street were both abandoned and replaced by a new station located at the Amanda Pumping Station site. The new station included a new wet well, two submersible pumps, and upgrades to the onsite generator. The wet well capacity was increased to 300 gallons and its two 12-horsepower pumps discharge flows through the existing 4-inch force main. Since it was constructed, operators have noted no capacity issues and have observed only a few malfunctions with the air compressor and check valves. In 2007, a future flow of 167 gpm was projected for the new Amanda Pumping Station. As shown in Section 4, the modeling shows that the pumping station is adequately sized for the existing and future flows. The firm capacity of the station is 170 gpm with the peak buildout flow estimated to be 81 gpm.

No capital improvements are recommended at this time.

#### Barclay Hills

The original Barclay Hills Pumping Station was constructed in 1974 and included two wet wells with a firm pumping capacity of 300 gpm. In 2011, the station had a major control system failure which resulted in basement flooding in a nearby residence.

The City will be refurbishing the station in 2014. The *Preliminary Design Report for the Barclay Hills Pump Station*, prepared by Murray, Smith & Associates, December 2012 calls for replacing the existing pumps with new 350 gpm pumps and providing upgrades to the electrical system, flow meter, dry well, and site piping. The preliminary design report calls for future flows to be 343 gpm which is about 10 percent higher than the model prediction prepared for this SSMP. This difference in modeling results is not unusual and can in part be attributed to the difference is scale from modeling the entire City for the SSMP versus modeling a discrete area. The pumping station was modeled with a firm capacity of 350 gpm for this SSMP.

The existing 6-inch force main is adequately sized to convey the projected future flows. However, due to its age and condition, the City has decided to replace this force main with another pipe of the same diameter.

No major upgrades to this station and force main beyond the planned improvements are recommended at this time.

**Brendon Estates**

This submersible-type pumping station serves only a few homes. Staff report that there have not been any modifications to the Brendon Estates Pumping station since completion of the *2003 SSMP*. There are no air vacuum/release valves and no onsite generator. The station uses float controls and does not have control backup. The steps in the wet well are inaccessible because the cover overhangs the wet well wall. The station's firm pumping capacity is 100 gpm with the peak buildout flow estimated to be 7 gpm.

No major upgrades to this station are recommended at this time.

**Canemah**

Originally constructed in 1940, a significant upgrade was performed in 1993 on the Canemah Pumping Station that included the installation of a new wet well/dry well with flooded suction pumps, soft starts, and pressure transducers. The station has a firm capacity of 1,200 gallons per minute (gpm), far above the estimated peak buildout flow estimation of 379 gpm. Regardless, City staff suspect that this pumping station is heavily influenced by infiltration/inflow (I/I) and is prone to overflows as a result of pump clogs. Operators believe that the wet well floor is poorly shaped which results in the frequent clogging and ragging of Pump # 1. As a result, maintenance staff must clean the wet well quarterly to prevent problems. Staff note that the electrical control systems are outdated and need to be replaced. Other defects noted by operators include a leaky flat roof and penetration seal leakage around suction pipes from the wet well into the dry well. The existing site is small and located in a residential district, making the installation of a permanent generator difficult and requiring the continued use of a portable generator during power failures.

Recommended improvements include wet well refurbishment and upgrade of the pumping controls. Given the limited information available to estimate this work, a cost range between $122,000 and $364,000 is provided. Estimated cost for these improvements summarized in the SSMP document reference the high end of the range, rounded to the ten thousand.

**Cook Street**

The *2003 City of Oregon City Sanitary Sewer Master Plan* (*2003 SSMP*) noted peak flows of almost four times the firm capacity of the pumping station, which was built in 1985. Using the existing wet well, the below-grade station was abandoned in 2008 and replaced with an above-ground facility that includes a duplex submersible pumping system and an onsite generator. The firm capacity of the pumping station is 620 gpm with the peak existing flow estimated to be 647 gpm and the peak buildout flow estimated to be 648 gpm. The operators noted no issues with clogging or capacity since the upgrade.

No major upgrades to this station are recommended at this time, but City staff are advised to monitor flows coming into the station to see if they approach the design flows.

### Hidden Creek

The Hidden Creek Pumping Station was originally built in 1992 and was upgraded in 2005. The 2005 upgrade included the installation of a manhole to provide additional wet well capacity and a new onsite generator. Since completion of the *2003 SSMP*, air vacuum/release valves have been installed. There is ample space for expansion; however current access is through an apartment complex parking area that makes wet well maintenance difficult. Staff state that they must rebuild the Hydromatic pumps every 3 years and that the station currently experiences issues with grease buildup. Additionally, the control panel is currently mounted to the pump motor frame, causing wear on controls due to vibration. As a result of these issues, this station is currently scheduled for a building and pump upgrade this fiscal year. The station's firm pumping capacity is 404 gpm with the peak buildout flow estimated to be 270 gpm.

No major upgrades to this station beyond the planned improvements are recommended at this time.

### Hilltop

The original Hilltop Pumping Station was constructed in 1972 and was completely rebuilt in 2007. The 2007 rebuild included new cans set over the existing wet well with suction lift pumps. The station is within 40 feet of a house and serves a small area. It is controlled with floats with no backup and it has no onsite generator. The station's firm pumping capacity is 95 gpm with the peak buildout flow estimated to be 73 gpm.

There is an anticipated Walmart development to the south of the Hilltop Pumping Station. One option for conveying future flows could be to de-commission the station and replace it with a gravity sewer, approximately 1,240 linear feet, that would convey the flows to Beavercreek Way. An initial review of the topography and flow condition finds that a new 8-inch sewer would be sufficient for conveying the flows. The estimated cost of constructing a new 8-inch sewer to replace the Hilltop Pumping Station is $440,000. The cost does not include the cost of acquiring an easement for the sewer.

The existing 4-inch force main is adequately sized to convey the projected future flows.

This SSMP recommends that this station be decommissioned and a new gravity sewer installed to convey the flows.

### Newell Crest

The Newell Crest Pumping Station was constructed on a steep slope in 1995. City staff are concerned about the potential instability of the slope. Air injection is used for hydrogen sulfide control. Staff report no surcharging issues, but grease buildup is an issue due to the low flows at this station. It is controlled with floats with no backup, and an onsite generator has been installed since completion of the *2003 SSMP*. The station's firm pumping capacity is 120 gpm with the peak buildout flow estimated to be 51 gpm.

No major upgrades to this station are recommended at this time.

### Nobel Ridge

This suction lift pumping station has had and continues to have issues with hydrogen sulfide corrosion due to the pinch valve system not functioning properly. Additionally, the overall station does not work well because the force main volume is almost equal to the wet well volume. Staff state that the hydromatic pumps are outdated. Additionally, pump parts associated with routine maintenance are difficult to find. The Nobel Ridge Pumping Station experiences low flows with little I/I issues. Since completion of the *2003 SSMP*, air vacuum/release valves have been installed at this site. The station's firm pumping capacity is 140 gpm with the peak buildout flow estimated to be 55 gpm.

Recommended improvements include upgrade of the pumping and control systems. Given the limited information available to estimate this work, a cost range between $85,000 and $255,000 is provided. Estimated cost for these improvements summarized in the SSMP document reference the high end of the range, rounded to the ten thousand digit.

### Parrish Road

Operators noted no capacity issues with the Parrish Road Pumping Station since the installation of an additional manhole, variable-frequency drives, and new controls in 2001. The wet well/dry well station has a firm pumping capacity of 760 gpm with the peak buildout flow estimated at 535 gpm. The air compressor no longer runs constantly to control hydrogen sulfide. In addition to the pumping station, there is also an onsite natural gas generator and room at the site for future expansion, if required. Operators have noted possible settlement issues near the dry well and paint chipping on the side of the dry well. Staff are advised to monitor the wet well's coating and to replace the coating if concrete becomes exposed.

Major upgrades to this station are required if it is to serve flows from portions of the South End Road Concept Area.

### Pease Road

Due to the constrained site and capacity issues, the 1992 Pease Road Pumping Station was abandoned in 2009 and a new triple-submersible station and generator were built across the street. Operators note that the station has no issues with clogging or surcharging. As one of the larger stations in the system, firm capacity for this station is 1,040 gpm with buildout peak flow expected to be 430 gpm.

No major upgrades to this station are recommended at this time.

### Settlers Point

This suction lift pumping station was originally constructed in 1999. In 2000, the pump pulleys were increased in size to increase discharge capacity. There is no room inside the fenced area for expansion; however there is room inside the building for larger pumps. The Settlers Point Pumping Station currently experiences long run times from suspected I/I issues and staff stated that the Hydromatic pumps are outdated, noisy, and often lose their prime. Additionally, pump parts required for routine maintenance are difficult to find.

Settlers Point has a current pumping capacity of 831 gpm. Modeled existing flows are predicted to be 931 gpm and projected future flows are approximately 1,092 gpm. To convey these higher flows the pumping station will require upgrades in its pumping capacity.

At a minimum, the pumps should be upgraded at this station to address the frequent maintenance problems and the projected capacity issue. Fortunately, City staff report that there is room in the wet well for larger pumps. A predesign effort will be required to determine if larger pumps will trigger the need for an upgrade to the electrical system, auxillary generator system and the structures that house these units. City estimate to upgrade the pump station is $300,000.

The existing 8-inch diameter, 1,210 feet long force main is slightly undersized to convey the projected future flows. The predicted velocity of 7.4 feet per second (fps) for future conditions is above the maximum recommended velocity of 7 fps. A 10-inch diameter force main would convey the future flows at 4.7 fps. Operation at the higher velocity would require larger motors and less efficient energy usage. A predesign effort should be performed to determine if a second force main should be constructed or whether the existing force main should be replaced.

## Minor Pumping Stations

The City's minor pumping stations are described in this section.

### Jon Storm Park Restroom

A new pumping station was built in 2005 for the bathroom located at the Jon Storm Park and Dock Ramp. This station includes two submersible pumps and no onsite generator.

### Elevator

This station's wet well is located at the top of an elevator off of High Street. It serves one office building. A special Allen wrench is required to open the access lid. The flow from this station could be conveyed by gravity to the sewer line in High Street, but frequent past blockages resulted in the construction of this station. The discharge gate valve is located in the wet well, making access difficult.

### 18th Street STEP Systems

There are three STEP systems in this area, each serving one home. The homeowners are responsible for maintenance of these stations.

### South End Road STEP Systems 1 through 4

These four STEP systems each serve a single home. The homeowners are responsible for maintenance of these stations. The nearest sewer is 700 feet to the northeast in South End Road.

## Recommended Pumping Station Upgrades

Recommended upgrades to the City's major pumping stations are summarized in Table B-1.

**Table B-1. Recommended Existing Pumping Station and Force Main Improvements**

| Pumping station | Description of improvement | Estimated cost of improvements, dollars[a] |
|---|---|---|
| Canemah | Wet well refurbishment and update of control system | 360,000 |
| Settler's Point | Upgrade pumping station | 300,000 |
| Nobel Ridge | Upgrade pumps and control systems | 260,000 |
| Hidden Creek | Building and pump upgrade | 60,000 |
| Hilltop | Decommission existing pumping station and replace with 8-inch, 1,300–foot-long gravity sewer | 440,000[b] |
| Parrish Road | Upgrade pumping station | 750,000 |
| Total all pump station and force main improvements | | 2,170,000 |

[a]*Estimated costs include a 50 percent allowance for construction contingencies, engineering, and overhead. Costs are rounded to the nearest $10,000. Costs for gravity sewer extensions assume an average depth of 10 feet using cost condition 2. See Appendix C for unit cost tables.*

[b]*This gravity line is planned to serve future development and a portion for the installation costs will be system development charge-reimbursable to the developer for this new gravity sewer line.*

# Appendix C: Basis of Sewer Replacement and Rehabilitation Costs

## Appendix C

# Basis of Sewer Replacement and Rehabilitation Costs

This appendix describes how the costs were estimated for developing the budgets of capital improvements. The total capital investment necessary to perform a project (i.e., engineering through construction) consists of expenditures for engineering services, construction, contingencies, and overhead items such as legal, contract administration, and financing. The various components of the capital costs are described below.

## Cost Index

A good indicator of changes over time in construction costs is the *Engineering News Record (ENR)* 20-city Construction Cost Index (CCI), which is computed from prices of construction materials and labor, and is based on a value of 100 in 1913. Cost data in this report are based on an *ENR* CCI of 9418, representing costs in January 2013. The costs provided in this Sanitary Sewer Master Plan (SSMP) should be adjusted based on the *ENR* CCI at the time that a project is being planned.

## Construction Costs

Construction costs were prepared for improvements identified by the hydraulic modeling and the limited sewer condition assessment information. Construction costs presented below represent preliminary estimates of the materials, labor, and services necessary to construct the proposed projects. The cost estimates were prepared to be indicative of the cost of construction in the study area. It is important to recognize that changes during design and future changes in the cost of materials, labor, and equipment, will cause comparable changes in the estimated costs. Unit costs used in this SSMP were obtained from a review of pertinent sources of reliable construction cost information. Construction cost data given in this report are not intended to represent the lowest prices that can be achieved, but rather are intended to represent planning level estimates for budgeting purposes.

## Engineering, Overhead, and Contingencies

Engineering and overhead are assumed to be 21 percent of the construction cost. Engineering services associated with typical projects include preliminary investigations and reports, site and route surveys, geotechnical explorations, preparation of drawings and specifications, construction services, surveying and staking, and sampling and testing of materials. These costs can vary considerably depending on the nature and complexity of the project. Additional engineering costs could be realized if additional geotechnical investigations are required and if environmental permitting and public involvement and notification activities are required. Also, these activities could impact the engineering and construction schedule.

Overhead charges cover items such as legal fees, financing expenses, administrative costs, and interest during construction.

The construction contingency used in this SSMP is 30 percent. The contingency is added after inclusion of the engineering and overhead costs. It is appropriate to allow for this degree of uncertainty due to the limited information available during the master planning level development of projects. Factors such as unknown geotechnical and groundwater conditions, utility relocation, and alignment changes are a few of the items that can increase project cost, for which it is wise to make allowance in preliminary estimates.

This SSMP used three pricing schedules for sewer construction. Each schedule is described as follows:

- *Price Condition No. 1: Off-street construction.* This condition includes pipe, pipe installation, excavation, import of all fill, hauling of all excavated material, manholes, trench safety, sump dewatering, and traffic control. In general, this condition is for the construction of sewers in future streets with no street restoration.
- *Price Condition No. 2: In-street construction, street restoration required*. This condition includes pipe, pipe installation, excavation, import of all fill, hauling of all excavated material, manholes, existing utilities, trench safety, sump dewatering, street restoration, and traffic control.
- *Price Condition No. 3: In-street construction, with significant dewatering required.* This condition is the same as Condition No. 2 with the inclusion of well point dewatering required to keep the trench dry for construction of the sewer. Actual dewatering costs can vary significantly with site conditions.

Tables C-1 through C-3 present unit costs for a range of pipe sizes and depths for the three construction condition schedules. Specialized construction techniques, such as pipe jacking or pipe boring work, are not included in any of the estimates. Most of the SSMP recommended improvements will be to replace sewers in existing streets; therefore, the Condition No. 2 pricing schedule is used accordingly unless other information is available for selecting one of the other pricing schedules.

**Table C-1. Cost Per Foot of Installed Pipe**

| Price Condition No. 1 | | | | |
|---|---|---|---|---|
| Size, inches | Depth of cover, feet | | | |
| | 6 | 10 | 14 | 18 |
| 8 | $171 | $274 | $398 | $544 |
| 10 | $186 | $293 | $420 | $568 |
| 12 | $205 | $314 | $445 | $596 |
| 15 | $237 | $353 | $490 | $648 |
| 18 | $277 | $398 | $540 | $703 |
| 21 | $305 | $442 | $599 | $766 |
| 24 | $353 | $504 | $675 | $851 |
| 27 | $391 | $536 | $700 | $882 |
| 30 | $420 | $570 | $738 | $925 |
| 36 | $485 | $648 | $830 | $1,030 |
| 42 | $564 | $744 | $936 | $1,147 |
| 48 | $655 | $844 | $1,045 | $1,266 |

| Table C-2. Cost Per Foot of Installed Pipe | | | | |
|---|---|---|---|---|
| Price Condition No. 2 | | | | |
| Size, inches | Depth of cover, feet | | | |
| | 6 | 10 | 14 | 18 |
| 8 | $234 | $352 | $491 | $650 |
| 10 | $251 | $372 | $514 | $677 |
| 12 | $272 | $396 | $541 | $706 |
| 15 | $309 | $443 | $596 | $771 |
| 18 | $353 | $491 | $649 | $829 |
| 21 | $383 | $537 | $711 | $895 |
| 24 | $437 | $607 | $797 | $993 |
| 27 | $478 | $642 | $824 | $1,026 |
| 30 | $510 | $678 | $865 | $1,071 |
| 36 | $587 | $773 | $978 | $1,202 |
| 42 | $671 | $874 | $1,090 | $1,325 |
| 48 | $771 | $985 | $1,212 | $1,459 |

| Table C-3. Cost Per Foot of Installed Pipe | | | | |
|---|---|---|---|---|
| Price Condition No. 3 | | | | |
| Size, inches | Depth of cover, feet | | | |
| | 6 | 10 | 14 | 18 |
| 8 | $330 | $446 | $582 | $740 |
| 10 | $348 | $466 | $606 | $766 |
| 12 | $368 | $490 | $632 | $796 |
| 15 | $402 | $531 | $680 | $851 |
| 18 | $446 | $579 | $733 | $908 |
| 21 | $476 | $625 | $795 | $974 |
| 24 | $544 | $704 | $885 | $1,072 |
| 27 | $584 | $739 | $913 | $1,105 |
| 30 | $616 | $776 | $954 | $1,151 |
| 36 | $686 | $859 | $1,051 | $1,262 |
| 42 | $810 | $1,000 | $1,202 | $1,424 |
| 48 | $910 | $1,111 | $1,325 | $1,559 |

As the collection system ages, upgrades to existing lift stations may be required to improve reliability and expand hydraulic capacity. Costs to rehabilitate or replace an existing lift station vary considerably depending on the specific needs of each station. These needs were not established as part of SSMP development other than identifying if hydraulic improvements are required. Costs included in the capital improvement program are based on a hydraulic upgrade only unless otherwise noted.

## Bypass Pumping Cost Tables

The replacement of an existing sewer will require bypass pumping in most cases. Bypass pumping costs are not included in the per foot construction costs listed above. These costs must be calculated separately and are based on the flow rates in the sewer and the amount of time that pumping is required. Guidelines for these costs are listed in Table C-4. Several vendors are located within the study area that can provide current quotes if requested.

**Table C-4. Bypass Pumping Costs**

| Diameter, inches | Size of pump(s), inches[a] | Assumed flow rate, gallons per minute[b] | Approximate pumping capacity, gallons per minute | Monthly rate[c] |
|---|---|---|---|---|
| 8 – 12 | 4 | 200 – 600 | 600 | $7,000 |
| 15 – 18 | 6 | 1000 – 1,600 | 1,600 | $10,500 |
| 18 – 24 | 12 | 1,600 – 3,600 | 3,800 | $19,000 |
| >24 | Consider combinations of above sized pumps based on known flow rates in project pipes. | | | |

*[a]A variety of pump sizes most likely will be used for projects to accommodate actual flows. Pump sizes shown are based on 1/2 pipe full conditions. Full pipe and/or work during wet weather periods could require much larger pumps.*

*[b]Flow rates shown are based on ½ pipe full conditions and average pipe slope. Assumed pipe flow in 18-inch pipe is slightly less than 1/2 pipe full conditions.*

*[c]Costs were provided by Rain for Rent (Portland) and based on a 28-day (monthly cycle). Actual costs will vary depending on site conditions.*

# Appendix D: Infiltration and Inflow Abatement Program

Appendix D

# Infiltration and Inflow Abatement Program

## Background

The U.S. Environmental Protection Agency's (USEPA) interest in reducing infiltration/inflow (I/I) started in the early 1970s with the Water Pollution Control Act Amendments of 1972. The USEPA recognized that many treatment plant bypasses and failures and collection system sanitary sewer overflows were the result of high flows associated with wet weather events. Consequently, language was added to National Pollution Discharge Elimination System permits requiring the permittee to take actions to reduce I/I within the sanitary collection system.

Tri-City Service District (TCSD) holds the permit for treated wastewater discharges from the Tri-City Water Pollution Control Plant. The current permit expires April 15, 2016. The permit does not have specific requirements or targets for I/I removal. Instead, the permit states that the permittee shall have in place a program for identifying and reducing I/I into the sewage collection system. Annual reports are to be submitted to Oregon Department of Environmental Quality detailing the results of those efforts.Most early I/I reduction programs focused on three phases: analysis, survey, and rehabilitation. The analysis phase identified the priority areas of the collection system that leaked. Survey activities included additional field work to isolate and identify the specific sources of leakage. Also, the survey phase included a cost-effectiveness analysis to ensure that proposed rehabilitation costs were less expensive than the transport and treat approach to the I/I problem. The last phase implemented the recommended rehabilitation and/or replacement projects.

While the process was straightforward, field experience demonstrated many weaknesses to this approach. The primary weaknesses are described as follows:

- *Incomplete financial analysis*—The costs of ongoing and increased maintenance due to sewer defects not eliminated are seldom included in the analysis. For example, costs of cleaning pipe that experience sediment deposition from external sources often are not analyzed. Likewise, the loss of hydraulic capacity associated with sediment deposition usually is not evaluated. Perhaps more importantly, deferring upgrades allows continuing and accelerating deterioration, which in turn leads to more costly replacement, sometimes on an emergency basis. This lack of accounting of true costs resulted in greater use of the transport and treat approach.
- *Moving problem*—Elimination of I/I sources in the main line often results in increased I/I contributions in service laterals (if they are not part of the rehabilitation) or in upstream locations in the sewer. The granular pipe bedding and trench backfill used for sewers tends to act as a basin-wide French drain, allowing groundwater to move freely through this pervious material until entry points are found at sewer defects. Because infiltration is closely related to groundwater levels, fixing problems in one part of a basin only moves the problem elsewhere. In many cases, it is not until the defects in an entire basin are addressed that the expected drop in infiltration is achieved.
- *Limited flow monitoring data*—Short monitoring periods and large sanitary drainage basins do not allow for meaningful characterization of the I/I problem. Long-term flow monitoring at a number of key locations is required for accurate definition of I/I sources and quantity. Capturing flow data from

only a few wet-weather events does not necessarily quantify the true extent of the system's response to the peak wet-weather events.

- *Inaccurate flow monitoring data*—The accuracy of flow monitoring equipment is variable even in ideal conditions. Inaccurate flow monitoring information impacts the hydraulic calculations and the cost-effective analysis. Type and age of equipment, monitoring location, installation, and equipment maintenance can all affect the accuracy and completeness of flow monitoring data.
- *Surcharged pipes mask true I/I potential*—Surcharged sewers during the wet season limit the amount of groundwater that can enter the collection system physically. Once this surcharged situation is alleviated by upsizing capacity bottlenecks or rehabilitating downstream defects, more flow is allowed to enter the system. Without a modeling methodology that can take this into account, capacity upgrades may be insufficient to eliminate overflows. Likewise, predictions of rehabilitation required to eliminate overflows may be underestimated.

In summary, many municipalities and sewer utilities throughout the country will attest that reducing I/I is not an easy or inexpensive endeavor. Due to the factors noted above, it is difficult to locate and quantify I/I sources accurately and to measure the effect of I/I reduction projects. Consequently, many I/I reduction programs require large-scale and costly sewer rehabilitation projects to attain the desired level of I/I reduction. Short-term goals may be difficult to achieve, but a long-term, sustainable program ultimately will achieve I/I reductions at the bottom of a basin and at the treatment plant.

# Development of an I/I Reduction Program

The following steps are suggested for developing and implementing an I/I reduction program:

Step 1. Collect flow monitoring data for the major basins in the collection system.

Step 2. Construct and calibrate hydrologic and hydraulic models of the collection system.

Step 3. Predict current and future peak wet weather flows for each of the basins.

Step 4. Rank basins according to normalized peak I/I rates.

Step 5. Perform further investigations to focus the I/I reduction program.

Step 6. Develop I/I reduction projects that are manageable and measurable.

Step 7. Perform post-rehabilitation monitoring/modeling to determine impact of projects so that any needed adjustments can be made to scope, budget, and schedule for future projects.

Steps 1 through 4 were developed for this Sanitary Sewer Master Plan (SSMP) and are documented herein. The City of Oregon City's (City) long-term I/I program will be further developed by implementing Steps 5 through 7, which are discussed in greater detail below.

## Step 5. Perform Further Investigations

Additional field work is required to help focus the I/I reduction program on basins with the highest I/I contributions as well as to identify the highest sources of I/I within a basin. Figure D-1 shows the meter basins and locations of major pump stations.

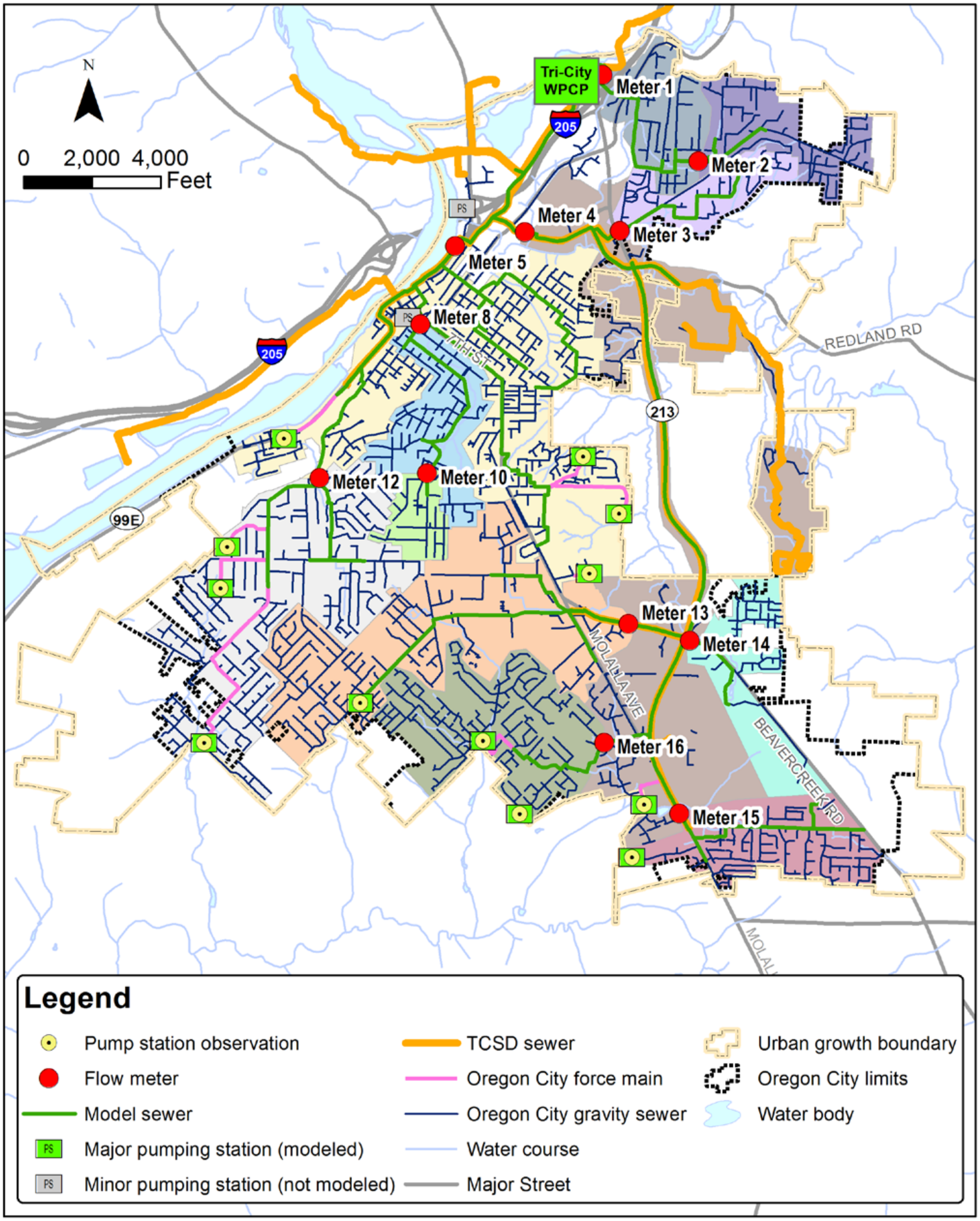



Figure D-1. Meter basins and major pump stations

## Selection of Basins

Table D-1 lists the I/I contributions in the 10-year recurrence event for each of the major sanitary drainage basins within the City and also shows I/I normalized by sewershed area and by pipe length as well as peaking factors for each basin. Many of the drainage basins have relatively high I/I contributions.

Table D-2 lists similar information, but the meter basins are in descending priority order using pipe length to normalize results. The basins could also be ranked using sewershed area but the relative ranking of the top 6 leakiest basins would not change.

**Table D-1. I/I Contributions by Flow Meter Location**

| Meter no. | Model zone | Upstream meters | Estimated sewershed[a], acres | Meter basin pipe length, inch-miles | Average dry weather flow (ADWF), million gallons per day (mgd)[b] | Peak 10-year flow, mgd | Simulated wet weather flow existing conditions, 10-year storm | | | Ratio of peak flow to average dry weather flow |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Peak I/I, mgd | Peak I/I, gallons per acre per day[c] | Peak I/I, gallons per inch-mile per day | |
| 1 | North | 2 | 143 | 56 | 0.07 | 0.6 | 0.5 | 3,464 | 8,899 | 8 |
| 2 | North | None | 145 | 48 | 0.08 | 1.0 | 0.9 | 6,160 | 18,606 | 13 |
| 3 | Central | None | 107 | 33 | 0.09 | 0.5 | 0.5 | 4,236 | 13,533 | 6 |
| 4 | Central | 3,13,14, 15,16 | 377 | 197 | 0.51 | 1.9 | 1.4 | 3,647 | 6,990 | 4 |
| 5[d] | South | 8,10,12 | 717 | 272 | 1.0 | 8.4 | 7.4 | 10,376 | 27,378 | 8 |
| 8[e] | South | 10 | 244 | 84 | 0.96 | 5.0 | 4.0 | 16,371 | 47,635 | 5 |
| 12 | South | None | 513 | 182 | 1.0 | 4.7 | 3.7 | 7,178 | 20,267 | 5 |
| 13 | Central | None | 415 | 145 | 0.71 | 3.2 | 2.5 | 6,091 | 17,440 | 5 |
| 14 | Central | None | 100 | 34 | 0.20 | 0.6 | 0.4 | 4,336 | 12,935 | 3 |
| 15 | Central | None | 209 | 70 | 0.12 | 0.7 | 0.6 | 2,719 | 8,144 | 6 |
| 16 | Central | None | 304 | 103 | 0.25 | 1.8 | 1.6 | 5,255 | 15,505 | 7 |
| **Total** | | | **3,276** | **1,223** | **5.0** | **0.6** | **23.5** | | | |

[a]*The sewershed is estimated as the area within a 200-foot buffer of all sewer mains in the meter basin.*

[b]*DWF is estimated based on observed flow data for the period of February 1 to 8, 2012, which was the longest dry period during monitoring.*

[c]*The peak I/I flow per acre is based on the sewershed as the contributing area.*

[d]*The peak simulated flow shown for Meter 5 excludes approximately 16 mgd, which is the estimated contribution from the Water Environment Services' conveyance system.*

[e]*The values for Meter Basin 8 include Meter Basin 10, which was not used for calibration.*

| Table D-2. I/I Contributions Ranked by Highest I/I per Pipe Length | | | | | | | |
|---|---|---|---|---|---|---|---|
| Meter no. | Model zone | Ranking, I/I flow by pipe length | Peak I/I flow, mgd | Cumulative I/I flow, mgd | Cumulative total I/I, percent | Cumulative pipe length, inch-miles | Cumulative total pipe length, percent |
| 8 | South | 1 | 4.0 | 4.0 | 17 | 84 | 7 |
| 5 | South | 2 | 7.4 | 11.4 | 49 | 356 | 29 |
| 12 | South | 3 | 3.7 | 15.1 | 64 | 538 | 44 |
| 2 | North | 4 | 0.9 | 16.0 | 68 | 586 | 48 |
| 13 | Central | 5 | 2.5 | 18.5 | 79 | 731 | 60 |
| 16 | Central | 6 | 1.6 | 20.1 | 86 | 834 | 68 |
| 3 | Central | 7 | 0.5 | 20.6 | 88 | 867 | 71 |
| 14 | Central | 8 | 0.4 | 21.0 | 90 | 901 | 74 |
| 1 | North | 9 | 0.5 | 21.5 | 92 | 956 | 78 |
| 15 | Central | 10 | 0.6 | 22.1 | 94 | 1,026 | 84 |
| 4 | Central | 11 | 1.4 | 23.5 | 100 | 1,223 | 100 |

As listed in Table D-2, the South Zone meter basins are the highest contributors to I/I flows in the city. Meter basins 5 and 8 contribute almost 50 percent of the peak I/I flows, but comprise only 29 percent of the sewershed area and 29 percent of the pipe within the city.

As discussed in Appendix A, pumping station data were analyzed and peak inflow was estimated. Based on these modeling results, peaking factors were calculated as listed in Table D-3. While there are ratios that are within the expected range (e.g., Pease and Parrish Pump Stations), there are other pump station basins that have high peaking factors (i.e., Settler's Point, Canemah, and Cook) that may warrant further field investigation.

| Table D-3. Pump Station Peaking Factors | | | | | | |
|---|---|---|---|---|---|---|
| Pump station name | Meter basin no. | ADWF, existing simulation | | Peak inflow, existing simulation | | Ratio of peak flow to ADWF |
| | | mgd | gallons per minute (gpm) | mgd | gpm | |
| **Central Zone** | | | | | | |
| Pease | 13 | 0.16 | 110 | 0.50 | 347 | 3 |
| Settler's Point | 16 | 0.17 | 119 | 1.34 | 931 | 8 |
| **South Zone** | | | | | | |
| Canemah | 5 | 0.06 | 38 | 0.52 | 360 | 9 |
| Parrish | 12 | 0.20 | 139 | 0.70 | 485 | 3 |
| Cook | 12 | 0.09 | 66 | 0.93 | 647 | 10 |
| Barclay Hills | 5 | 0.08 | 59 | 0.45 | 309 | 6 |

## Identifying I/I Sources

The crux of developing an effective I/I reduction program is to identify the sources of I/I within a basin, the most common of which are shown in Figure D-2. This section identifies some of the more successful techniques available to identify I/I sources.

Inflow sources include the following:

- Manhole covers and frames
- Basement sump pumps
- Foundation and area drains
- Pipe cleanouts
- Roof drain connections
- Cross-connections to stormwater system

Techniques available to identify inflow include the following:

- *Smoke testing*–A nontoxic, odorless, non-staining smoke is injected into the collection system via a blower. The smoke will travel throughout the system and detect specific inflow points such as storm sewer cross-connections, roof connections, yard and area drains, foundation drains, and faulty service connections. In some cases, smoke testing will reveal locations of defective pipes and joints.
- *Dye testing*–Dyed water is injected into catch basins or storm drains to check for public storm drain cross-connections. Dyed water can be injected into downspouts, area drains, and floor drains to check for private sector connections to the sanitary sewer.
- *Visual inspections*–Visual inspections include the internal pipe closed-circuit television (CCTV) inspections performed by City staff and can include external inspections conducted at the ground level.

Infiltration sources include:

- Defective areas of pipes and manholes
- Defective pipe joints and manhole connections
- Defective service laterals and lateral connections to mainline

As shown in Figure D-2, infiltration is the result of groundwater entering into the collection system at pipe and manhole defects.

Techniques available to identify infiltration include:

- *CCTV pipe inspections*—CCTV inspections are an excellent tool for identifying structural and operational defects in the collection system, but they are not always good at identifying specific locations of I/I due to the temporal nature of I/I. In general, the identification of separated and broken joints, holes in pipes, and many other forms of structural decay indicate potential sources of I/I. It is difficult to quantify the amount of I/I from the inspections.
- *Exfiltration testing*—Exfiltration testing primarily identifies mainline defects, as service laterals cannot be isolated easily and tested with this method. This method is sensitive to the groundwater elevation at the time of the test and is most reliable in periods of dry weather or, at a minimum, after several days without significant rainfall. Exfiltration testing should be performed in similar groundwater conditions in both the pre- and post-rehabilitation stages.
- *Flow monitoring*—Flow monitoring is the primary tool available for quantifying the amount of I/I coming into the collection system. Flow monitoring is required throughout dry and wet periods to establish both the base flow and wet weather contributions. Judicious use of flow monitors within a basin will help identify the I/I contributions for smaller, more localized areas. Flow monitoring also can be used to quantify inflow contributions into the collection system.

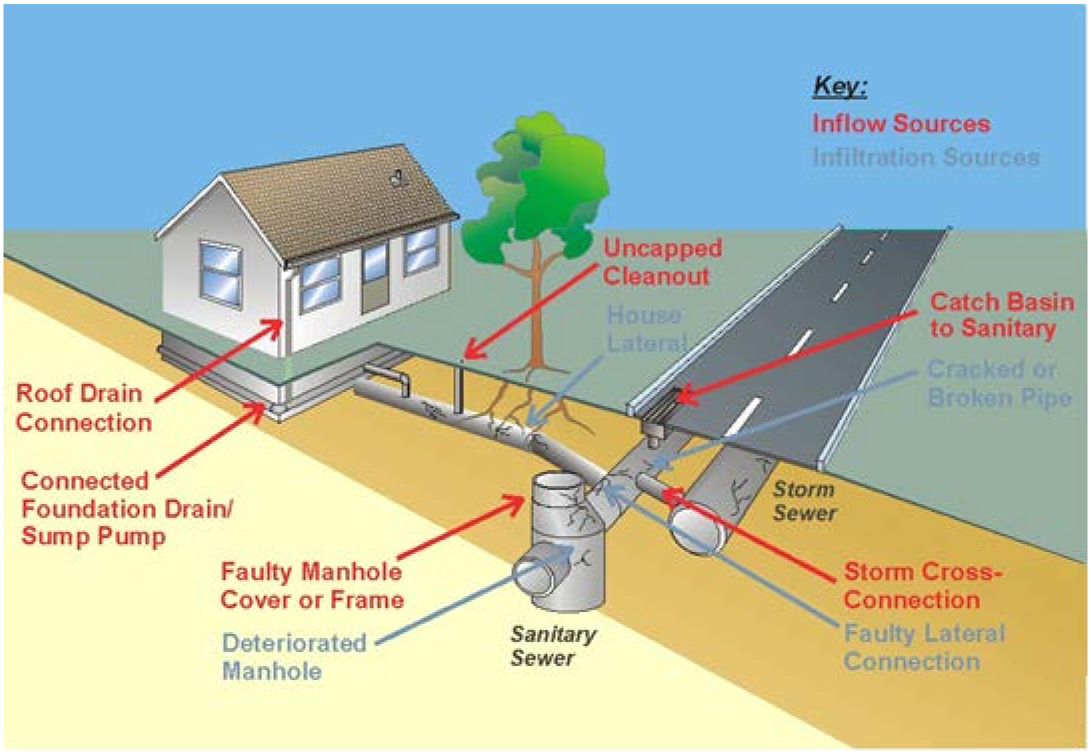



**Figure D-2. The variety of I/I sources requires a combination of field investigation and pilot rehabilitation projects to help focus resources**

All existing smoke, dye, CCTV, maintenance records, etc., should be collected and reviewed for the South Zone meter basins. If there are gaps in any of the records, then further testing should be conducted. City Engineering and Operations staff should jointly develop a field investigation strategy to identify the most appropriate methods to be used in collecting the additional information. This approach, along with City staff's existing knowledge of the collection system, should yield an effective program for identifying and quantifying I/I contributions. The resulting information should be used to identify appropriate I/I reduction projects.

## Step 6. Develop I/I Reduction Projects

Sewer and manhole rehabilitation to reduce I/I can be on a block-by-block or basin-wide basis. The approach will depend on many factors, but in general, the condition of the sewers, the surface and sub-surface conditions (under road or gravel, in bedrock or soil), and available funding for the project will dictate if it is feasible to rehabilitate the entire basin or simply focus on the worst defects. In addition, if storm cross-connections, broken pipes near streams, roof drain connections, etc., were identified in Step 5, then these isolated sources should be corrected.

In several locations where long-term rehabilitation projects have been initiated, pilot projects have been conducted prior to commencing any large-scale rehabilitation program. The purpose of pilot projects is to perform a single type of rehabilitation on an entire sub-basin that can be monitored before and after system rehabilitation to determine the impact of the approach. This allows rehabilitation methods to be directly compared to each other and the most cost-effective method applied on a more system-wide basis. Rehabilitation techniques that have been used in other pilot projects include main line and lateral connections only; main line and the laterals to the property lines (lower laterals) only; laterals from the property line to the building (upper laterals) and lower laterals only; and upper laterals only.

Understanding the lateral contributions to the I/I problem would provide important information to assist policy makers in adopting this or alternate approaches. Ultimately, the City may elect to follow practices employed by numerous other agencies and adopt a lateral replacement policy.

To plan for I/I abatement, the City needs to estimate the I/I removal that can be expected when rehabilitating the system. Figure D-3 shows the anticipated removal percentages of rainfall-derived I/I (RDII) depending on the extent of rehabilitation. The removal percentages are based on several pilot studies and projects in Sweet Home, Oregon. The work consisted of rehabilitation of sewer mains and lateral connections only, laterals only (both lower and upper), and full rehabilitation of the mains and entire laterals to the building. It can be seen that full rehabilitation was much more cost-effective than partial rehabilitation. These types of reductions have been validated by I/I work performed throughout the country.

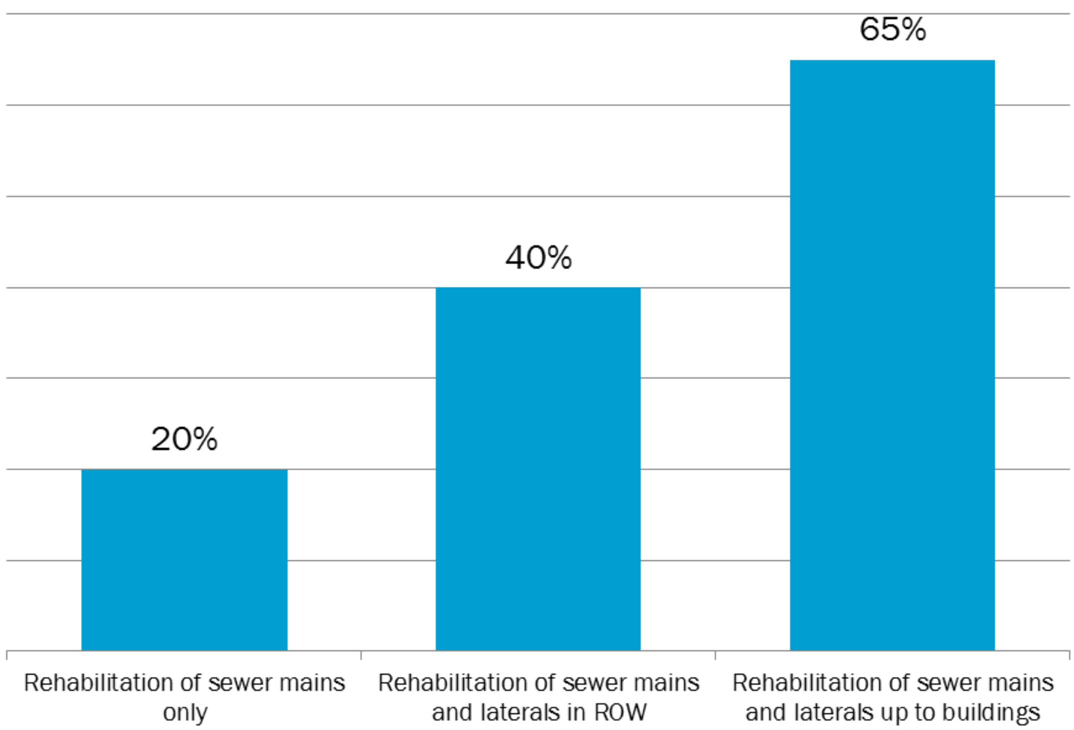



**Figure D-3. Percent of RDII removal possible**

Additional investigations can and should be conducted to focus I/I reduction efforts to achieve the highest benefit for the investment. However, for comparison purposes, construction costs were calculated to holistically replace and rehabilitate, respectively, the pipe in each basin using open-cut and trenchless methods on the three different scenarios (mains only, mains and lower laterals, and mains and lower/upper laterals). Table D-4 lists the key statistics of the meter basins, including the assumed number of laterals and pipe length by pipe diameter in each basin. Tables D-5 and D-6 list the approximate construction costs by basin. The basins are ranked by cost-effectiveness of the work ($ per gallon of I/I removed). Costs are for replacement/rehabilitation of small diameter (15 inches and smaller) sewer mains only and assume one lateral per parcel in each meter basin. Costs do not account for any additional needed stormwater conveyance or for administrative, design, construction management, or other ancillary project costs such as traffic control and bypass pumping.

| Table D-4. Basin Characteristics | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Meter basin no. | Zone | Number of assumed laterals | Length of pipe by pipe diameter (linear feet) | | | | | |
| | | | 6" | 8" | 10" | 12" | 15" | 18" to 54" |
| South Zone | | | | | | | | |
| 8 | South | 1,051 | 5,954 | 38,108 | 2,393 | 5,064 | 402 | 598 |
| 5 | South | 2,589 | 19,068 | 102,438 | 5,191 | 9,137 | 4,349 | 12401 |
| 12 | South | 2,231 | 3,074 | 97,273 | 7,132 | 6,415 | 0 | 4286 |
| North and Central Zones | | | | | | | | |
| 2 | North | 421 | 351 | 29,833 | 331 | 783 | 0 | 0 |
| 13 | Central | 1,603 | 2,711 | 71,171 | 4,051 | 3,434 | 3,956 | 2,050 |
| 16 | Central | 1,504 | 2,770 | 58,446 | 1,970 | 2,413 | 1,370 | 0 |
| 3 | Central | 327 | 3,256 | 17,331 | 1,642 | 203 | 0 | 0 |
| 14 | Central | 358 | 422 | 17,020 | 1,115 | 2,040 | 196 | 41 |
| 1 | North | 368 | 0 | 24,614 | 0 | 1,484 | 2,978 | 1529 |
| 15 | Central | 1,079 | 2,899 | 37,789 | 1,643 | 2,911 | 0 | 20 |
| 4 | Central | 717 | 4,991 | 47,515 | 888 | 3,144 | 1,336 | 22635 |
| **City total** | | **12,248** | **45,496** | **541,538** | **26,356** | **37,028** | **14,587** | **43,560** |

| Table D-5. Comparative Construction Costs for I/I Removal Using Open-Cut Replacement | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Meter basin no. | Zone | Peak I/I, mgd | Replace mains only (20 percent of peak I/I removal) | | | Replace mains and laterals in ROW (40 percent of peak I/I removal) | | | Replace mains and laterals to private building (65 percent of peak I/I removal) | | |
| | | | I/I removed, mgd | Open-cut cost, $million | $ per gallon removed | I/I removed, mgd | Open-cut Cost, $million | $ per gallon removed | I/I removed, mgd | Open-cut cost, $million | $ per gallon removed |
| South Zone | | | | | | | | | | | |
| 8 | South | 4.00 | 0.80 | 12.8 | 16 | 1.60 | 16.0 | 10 | 2.60 | 18.1 | 7 |
| 5 | South | 7.44 | 1.49 | 36.4 | 25 | 2.98 | 44.2 | 15 | 4.84 | 49.4 | 10 |
| 12 | South | 3.68 | 0.74 | 28.4 | 39 | 1.47 | 35.1 | 24 | 2.39 | 39.6 | 17 |
| South Zone subtotal | | | 3.03 | 77.6 | 26 | 6.05 | 95.2 | 16 | 9.83 | 107 | 11 |
| North and Central Zones | | | | | | | | | | | |
| 2 | North | 0.89 | 0.18 | 7.7 | 43 | 0.36 | 9.0 | 25 | 0.58 | 9.8 | 17 |
| 13 | Central | 2.53 | 0.51 | 22.1 | 44 | 1.01 | 26.9 | 27 | 1.64 | 30.1 | 18 |
| 16 | Central | 1.60 | 0.32 | 16.6 | 52 | 0.64 | 21.1 | 33 | 1.04 | 24.1 | 23 |
| 3 | Central | 0.45 | 0.09 | 5.7 | 63 | 0.18 | 6.7 | 37 | 0.29 | 7.3 | 25 |
| 14 | Central | 0.43 | 0.09 | 5.4 | 62 | 0.17 | 6.5 | 37 | 0.28 | 7.2 | 26 |
| 1 | North | 0.50 | 0.10 | 7.3 | 74 | 0.20 | 8.4 | 43 | 0.32 | 9.2 | 29 |
| 15 | Central | 0.57 | 0.11 | 11.2 | 98 | 0.23 | 14.4 | 63 | 0.37 | 16.6 | 45 |
| 4[a] | Central | 1.38 | 0.28 | 14.5 | 53 | 0.55 | 16.6 | 30 | 0.89 | 18.1 | 20 |
| North and Central subtotal | | | 1.67 | 90.5 | 54 | 3.34 | 110 | 33 | 5.43 | 122 | 23 |
| **City total** | | | **4.7** | **168** | | **9.4** | **205** | | **15.3** | **229** | |

*[a]The cost-effectiveness realized in Meter Basin 4 is because a high amount of pipe in this basin is larger diameter (greater than 15 inches) and I/I removal rates did not change even though rehabilitation costs assume that only 15-inch and smaller pipe is rehabilitated.*

| Table D-6. Comparative Construction Costs for I/I Removal Using Trenchless Rehabilitation | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Meter basin no. | Zone | Peak I/I, mgd | Rehab mains only (20 percent of peak I/I removal) | | | Rehab mains and laterals in ROW (40 percent of peak I/I removal) | | | Rehab mains and laterals to private building (65 percent of peak I/I removal) | | |
| | | | I/I removed, mgd | Trenchless rehab cost, $million | $ per gallon removed | I/I removed, mgd | Trenchless rehab cost, $million | $ per gallon removed | I/I removed, mgd | Trenchless rehab cost, $million | $ per gallon removed |
| South Zone | | | | | | | | | | | |
| 8 | South | 4.00 | 0.80 | 3.4 | 4 | 1.60 | 6.5 | 4 | 2.60 | 8.6 | 3 |
| 5 | South | 7.44 | 1.49 | 10.3 | 7 | 2.98 | 18.1 | 6 | 4.84 | 23.3 | 5 |
| 12 | South | 3.68 | 0.74 | 7.3 | 10 | 1.47 | 13.9 | 9 | 2.39 | 18.4 | 8 |
| South Zone subtotal | | | 3.03 | 20.9 | 7 | 6.05 | 38.6 | 6 | 9.83 | 50.3 | 5 |
| North and Central Zones | | | | | | | | | | | |
| 2 | North | 0.89 | 0.18 | 1.8 | 10 | 0.36 | 3.0 | 8 | 0.58 | 3.9 | 7 |
| 13 | Central | 2.53 | 0.51 | 5.1 | 10 | 1.01 | 9.9 | 10 | 1.64 | 13.1 | 8 |
| 16 | Central | 1.60 | 0.32 | 3.8 | 12 | 0.64 | 8.3 | 13 | 1.04 | 11.3 | 11 |
| 3 | Central | 0.45 | 0.09 | 1.3 | 15 | 0.18 | 2.3 | 13 | 0.29 | 3.0 | 10 |
| 14 | Central | 0.43 | 0.09 | 1.3 | 15 | 0.17 | 2.4 | 14 | 0.28 | 3.1 | 11 |
| 1 | North | 0.50 | 0.10 | 2.3 | 23 | 0.20 | 3.4 | 17 | 0.32 | 4.1 | 13 |
| 15 | Central | 0.57 | 0.11 | 2.5 | 22 | 0.23 | 5.8 | 25 | 0.37 | 7.9 | 21 |
| 4[a] | Central | 1.38 | 0.28 | 3.7 | 14 | 0.55 | 5.9 | 11 | 0.89 | 7.3 | 8 |
| North and Central subtotal | | | 1.67 | 21.8 | 13 | 3.34 | 40.9 | 12 | 5.43 | 53.7 | 10 |
| **City total** | | | **4.69** | **42.7** | | **9.39** | **79.5** | | **15.3** | **104** | |

*[a]The cost-effectiveness realized in Meter Basin 4 is because a high amount of pipe in this basin is larger diameter (greater than 15 inches) and I/I removal rates did not change even though rehabilitation costs assume only 15-inch and smaller pipe is rehabilitated.*

Three important conclusions can be drawn from these tables:

- Trenchless rehabilitation is far more affordable than open-cut replacement.
- Addressing mains as well as upper and lower laterals provides the best value.
- The value of rehabilitation/replacement work beyond the South Zone meter basins quickly decreases.

To reduce costs and gain the greatest I/I reduction for the City's investment, it will be important to narrow the focus within the South Zone basins further by conducting investigations as defined above in Step 5. Since the South Zone meter basins are fairly large, projects can be delineated further by field investigation, collection system operator knowledge, and examination of maintenance records.

As described in Section 4 of the SSMP, a majority of the sewers that are predicted to surcharge under existing flows are located in the South Zone meter basins. As I/I projects are defined, further analysis should be completed to determine if I/I abatement work could defer or even eliminate the need for future upsizing.

Lastly, defining cost-effective I/I projects requires consideration of the costs of conveying and treating the flows. In spring of 2014, TCSD initiated a district wide I/I investigation that will look into the sources of I/I throughout the service district and identify where cost-effective I/I removal may be realiazed. Since Oregon City is part of TCSD, discussions should be initiated and mutual decisions made to determine the appropriate scope and funding for future I/I reduction projects.

### Step 7. Perform Post-Rehabilitation Monitoring and Modeling

Post-rehabilitation monitoring and modeling should be used to determine the impact of I/I reduction activities and specifically, the impact of rehabilitation projects. Also, this information should be used to further refine the focus of the I/I projects.

Although there are many different ways to approach I/I reduction projects, the common denominator is that there needs to be a way to quantify I/I reduction achieved from the various efforts so that mid-stream refinements to the program can be made and future investments can be better focused. For the City, this would be done most efficiently by conducting pre- and post-rehabilitation flow monitoring and recalibration of the hydrologic model and/or pre- and post-rehabilitation exfiltration testing. The key ingredient in determining the impact of rehabilitation is having sufficient and accurate flow and rainfall data that is collected at similar locations so that a direct comparison can be made between pre- and post-rehabilitation results.

By implementing Steps 5 through 7, the City can expect to further quantify I/I problems, focus the I/I reduction program, and quantify the impact of specific projects. This will allow the City to continue working toward the goal of reducing peak wet weather flows in a cost-effective and flexible manner. By addressing I/I with a methodical and long-term approach, the City can expect to minimize the financial burden of the projects, while implementing a program for improving system performance.

# Appendix E: Existing and Future Conditions Modeling Results

**Appendix E-1. Existing and Future Modeling Results**

| Existing Pipe and Manhole Characteristics | | | | | | | | Existing Sewers - Existing Flows | | | | Existing Sewers - Buildout Peak Flows | | | | Upsized Sewer - Buildout Peak Flows | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pipe ID | Owner | Length (ft) | U/S MH Depth (ft) | Avg Pipe Depth (ft) | Average Rounded Depth (ft) | Existing Pipe Diameter (in) | Existing Capacity (gpm) | Peak Flow (gpm) | Current % Capacity Used[1] | U/S MH Current d/D [2] | Current U/S MH Freeboard (ft) [3] | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D [2] | Future U/S MH Freeboard (ft) [3] | Upsize Diameter (in) | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D [2] | Future U/S MH Freeboard (ft) [3] | Unit Cost ($/ft) | Current Total Cost ($) | Project Name |
| North Model | | | | | | | | | | | | | | | | | | | | | | | |
| 10433_10457 | OC | 212 | 8.4 | 8.3 | 10 | 8 | 1,573 | 424 | 27% | 0.4 | 8.1 | 612 | 39% | 0.4 | 8.1 | | 612 | 39% | 0.4 | 8.1 | | | |
| 10444_10445 | OC | 343 | 9.7 | 10.5 | 14 | 12 | 899 | 770 | 86% | 0.8 | 9.0 | 1,017 | 113% | 1.4 | 8.3 | | 1,017 | 113% | 1.4 | 8.3 | | | |
| 10445_12816 | OC | 211 | 11.3 | 11.4 | 14 | 12 | 2,985 | 773 | 26% | 0.4 | 10.9 | 1,019 | 34% | 0.4 | 10.9 | | 1,019 | 34% | 0.4 | 10.9 | | | |
| 10452_10546 | OC | 259 | 10.1 | 11.2 | 14 | 8 | 464 | 42 | 9% | 0.2 | 9.9 | 45 | 10% | 0.2 | 9.9 | | 45 | 10% | 0.2 | 9.9 | | | |
| 10455_18032 | OC | 14 | 13.4 | 13.6 | 14 | 12 | 2,472 | 676 | 27% | 0.4 | 13.0 | 898 | 36% | 0.4 | 13.0 | | 898 | 36% | 0.4 | 13.0 | | | |
| 10456_10444 | OC | 346 | 10.6 | 10.1 | 14 | 12 | 4,359 | 685 | 16% | 0.3 | 10.3 | 913 | 21% | 0.3 | 10.3 | | 913 | 21% | 0.3 | 10.3 | | | |
| 10457_10458 | OC | 104 | 8.2 | 8.5 | 10 | 12 | 3,186 | 477 | 15% | 0.3 | 7.9 | 673 | 21% | 0.3 | 7.8 | | 673 | 21% | 0.3 | 7.8 | | | |
| 10458_10459 | OC | 349 | 8.8 | 10.0 | 14 | 12 | 3,850 | 485 | 13% | 0.3 | 8.6 | 681 | 18% | 0.3 | 8.5 | | 681 | 18% | 0.3 | 8.5 | | | |
| 10459_12818 | OC | 108 | 11.2 | 11.6 | 14 | 12 | 3,646 | 671 | 18% | 0.3 | 10.9 | 891 | 24% | 0.4 | 10.9 | | 891 | 24% | 0.4 | 10.9 | | | |
| 10470_13786 | OC | 18 | 10.0 | 10.0 | 14 | 8 | 479 | 77 | 16% | 0.3 | 9.8 | 94 | 20% | 0.3 | 9.8 | | 94 | 20% | 0.3 | 9.8 | | | |
| 10477_10459 | OC | 124 | 7.2 | 9.2 | 10 | 8 | 508 | 183 | 36% | 0.4 | 6.9 | 206 | 40% | 0.5 | 6.9 | | 206 | 40% | 0.5 | 6.9 | | | |
| 10478_10477 | OC | 174 | 12.7 | 10.0 | 10 | 8 | 1,411 | 181 | 13% | 0.3 | 12.5 | 203 | 14% | 0.3 | 12.5 | | 203 | 14% | 0.3 | 12.5 | | | |
| 10479_10478 | OC | 178 | 13.0 | 12.9 | 14 | 8 | 416 | 177 | 43% | 0.5 | 12.7 | 199 | 48% | 0.5 | 12.7 | | 199 | 48% | 0.5 | 12.7 | | | |
| 10480_10479 | OC | 60 | 9.4 | 11.2 | 14 | 8 | 497 | 174 | 35% | 0.4 | 9.1 | 195 | 39% | 0.4 | 9.1 | | 195 | 39% | 0.4 | 9.1 | | | |
| 10481_10480 | OC | 345 | 12.5 | 11.0 | 14 | 8 | 957 | 167 | 17% | 0.3 | 12.3 | 189 | 20% | 0.3 | 12.3 | | 189 | 20% | 0.3 | 12.3 | | | |
| 10494_12987 | OC | 187 | 13.7 | 10.8 | 14 | 8 | 2,009 | 369 | 18% | 0.3 | 13.5 | 557 | 28% | 0.4 | 13.4 | | 557 | 28% | 0.4 | 13.4 | | | |
| 10505_12992 | OC | 161 | 5.8 | 7.4 | 10 | 8 | 540 | 328 | 61% | 0.6 | 5.4 | 459 | 85% | 2.0 | 4.5 | 10 | 458 | 47% | 0.5 | 5.4 | 372 | 60,107 | Holcomb |
| 10506_12985 | OC | 320 | 10.0 | 8.6 | 10 | 8 | 805 | 363 | 45% | 0.5 | 9.6 | 551 | 68% | 0.7 | 9.5 | | 551 | 68% | 0.7 | 9.5 | | | |
| 10546_13152 | OC | 377 | 12.4 | 11.3 | 14 | 15 | 4,395 | 863 | 20% | 0.3 | 12.0 | 1,114 | 25% | 0.4 | 12.0 | | 1,114 | 25% | 0.4 | 12.0 | | | |
| 10547_10575 | OC | 302 | 12.0 | 11.1 | 14 | 15 | 4,283 | 882 | 21% | 0.3 | 11.5 | 1,131 | 26% | 0.4 | 11.5 | | 1,131 | 26% | 0.4 | 11.5 | | | |
| 10548_10549 | OC | 137 | 12.1 | 12.1 | 14 | 15 | 1,427 | 874 | 61% | 0.5 | 11.4 | 1,123 | 79% | 0.6 | 11.3 | | 1,123 | 79% | 0.6 | 11.3 | | | |
| 10549_10547 | OC | 327 | 12.1 | 12.0 | 14 | 15 | 4,919 | 878 | 18% | 0.3 | 11.7 | 1,127 | 23% | 0.3 | 11.6 | | 1,127 | 23% | 0.3 | 11.6 | | | |
| 10550_10548 | OC | 409 | 15.0 | 13.5 | 14 | 15 | 1,117 | 872 | 78% | 0.7 | 14.1 | 1,122 | 100% | 0.9 | 13.9 | | 1,122 | 100% | 0.9 | 13.9 | | | |
| 10551_10630 | OC | 239 | 10.8 | 12.2 | 14 | 15 | 1,780 | 933 | 52% | 0.5 | 10.1 | 1,182 | 66% | 0.6 | 10.0 | | 1,182 | 66% | 0.6 | 10.0 | | | |
| 10552_10553 | OC | 16 | 10.4 | 11.1 | 14 | 16 | 13,211 | 928 | 7% | 0.2 | 10.1 | 1,176 | 9% | 0.2 | 10.1 | | 1,176 | 9% | 0.2 | 10.1 | | | |
| 10553_10551 | OC | 216 | 11.7 | 11.3 | 14 | 15 | 4,264 | 931 | 22% | 0.3 | 11.3 | 1,178 | 28% | 0.4 | 11.3 | | 1,178 | 28% | 0.4 | 11.3 | | | |
| 10554_10552 | OC | 151 | 10.4 | 10.4 | 14 | 16 | 10,997 | 927 | 8% | 0.2 | 10.1 | 1,176 | 11% | 0.2 | 10.1 | | 1,176 | 11% | 0.2 | 10.1 | | | |
| 10572_10546 | OC | 70 | 11.9 | 12.1 | 14 | 12 | 1,887 | 816 | 43% | 0.5 | 11.4 | 1,065 | 56% | 0.6 | 11.3 | | 1,065 | 56% | 0.6 | 11.3 | | | |
| 10575_10554 | OC | 208 | 10.2 | 10.3 | 14 | 15 | 9,823 | 885 | 9% | 0.2 | 9.9 | 1,134 | 12% | 0.2 | 9.9 | | 1,134 | 12% | 0.2 | 9.9 | | | |
| 10613_10618 | OC | 109 | 7.0 | 6.8 | 10 | 18 | 2,309 | 1,047 | 45% | 0.5 | 6.3 | 1,323 | 57% | 0.6 | 6.1 | | 1,323 | 57% | 0.6 | 6.1 | | | |
| 10618_10619 | OC | 255 | 6.6 | 6.7 | 10 | 18 | 1,865 | 1,061 | 57% | 0.6 | 5.7 | 1,337 | 72% | 0.7 | 5.6 | | 1,337 | 72% | 0.7 | 5.6 | | | |
| 10619_10620 | OC | 372 | 6.9 | 9.3 | 10 | 18 | 1,844 | 1,066 | 58% | 0.6 | 6.0 | 1,344 | 73% | 0.7 | 5.9 | | 1,344 | 73% | 0.7 | 5.9 | | | |
| 10620_12815 | OC | 264 | 11.7 | 13.4 | 14 | 18 | 2,484 | 1,069 | 43% | 0.5 | 11.0 | 1,347 | 54% | 0.5 | 10.9 | | 1,347 | 54% | 0.5 | 10.9 | | | |
| 10629_10652 | OC | 106 | 12.0 | 11.1 | 14 | 18 | 2,084 | 1,042 | 50% | 0.5 | 11.2 | 1,315 | 63% | 0.6 | 11.1 | | 1,315 | 63% | 0.6 | 11.1 | | | |
| 10630_10648 | OC | 282 | 13.7 | 12.1 | 14 | 15 | 5,762 | 957 | 17% | 0.3 | 13.3 | 1,212 | 21% | 0.3 | 13.3 | | 1,211 | 21% | 0.3 | 13.3 | | | |
| 10648_10629 | OC | 100 | 10.4 | 11.2 | 14 | 15 | 7,151 | 965 | 13% | 0.3 | 10.1 | 1,219 | 17% | 0.3 | 10.1 | | 1,219 | 17% | 0.3 | 10.1 | | | |
| 10652_10613 | OC | 79 | 10.1 | 8.6 | 10 | 18 | 2,473 | 1,043 | 42% | 0.5 | 9.4 | 1,319 | 53% | 0.6 | 9.3 | | 1,319 | 53% | 0.6 | 9.3 | | | |
| 12815_10622 | OC | 271 | 15.2 | 12.6 | 14 | 18 | 2,484 | 1,069 | 43% | 0.5 | 14.4 | 1,347 | 54% | 0.6 | 14.3 | | 1,347 | 54% | 0.6 | 14.3 | | | |
| 12816_10572 | OC | 198 | 11.6 | 11.7 | 14 | 12 | 2,985 | 776 | 26% | 0.4 | 11.2 | 1,022 | 34% | 0.4 | 11.2 | | 1,022 | 34% | 0.4 | 11.2 | | | |
| 12817_10456 | OC | 138 | 11.9 | 11.3 | 14 | 12 | 5,252 | 680 | 13% | 0.3 | 11.7 | 906 | 17% | 0.3 | 11.6 | | 906 | 17% | 0.3 | 11.6 | | | |
| 12818_10455 | OC | 205 | 12.0 | 12.7 | 14 | 12 | 3,648 | 675 | 19% | 0.3 | 11.7 | 895 | 25% | 0.4 | 11.6 | | 895 | 25% | 0.4 | 11.6 | | | |
| 12985_10494 | OC | 86 | 7.2 | 10.4 | 14 | 8 | 2,329 | 365 | 16% | 0.3 | 7.0 | 553 | 24% | 0.3 | 7.0 | | 553 | 24% | 0.3 | 7.0 | | | |
| 12986_10433 | OC | 324 | 8.9 | 8.6 | 10 | 8 | 1,576 | 379 | 24% | 0.3 | 8.7 | 567 | 36% | 0.4 | 8.6 | | 567 | 36% | 0.4 | 8.6 | | | |
| 12987_12986 | OC | 175 | 7.9 | 8.4 | 10 | 8 | 1,634 | 372 | 23% | 0.3 | 7.6 | 560 | 34% | 0.4 | 7.6 | | 560 | 34% | 0.4 | 7.6 | | | |
| 12992_10506 | OC | 214 | 8.9 | 9.5 | 10 | 8 | 489 | 353 | 72% | 0.7 | 8.5 | 542 | 111% | 2.2 | 7.5 | | 541 | 111% | 2.8 | 7.1 | | | |
| 13152_10550 | OC | 382 | 10.1 | 12.5 | 14 | 15 | 1,259 | 867 | 69% | 0.6 | 9.3 | 1,117 | 89% | 0.8 | 9.1 | | 1,117 | 89% | 0.8 | 9.1 | | | |
| 13786_10444 | OC | 306 | 10.0 | 9.9 | 10 | 8 | 481 | 83 | 17% | 0.3 | 9.8 | 100 | 21% | 0.3 | 9.8 | | 100 | 21% | 0.3 | 9.8 | | | |
| 18032_12817 | OC | 180 | 13.7 | 12.8 | 14 | 12 | 5,250 | 678 | 13% | 0.3 | 13.5 | 904 | 17% | 0.3 | 13.4 | | 904 | 17% | 0.3 | 13.4 | | | |

**Appendix E-1. Existing and Future Modeling Results**

| Existing Pipe and Manhole Characteristics | | | | | | | | Existing Sewers - Existing Flows | | | | Existing Sewers - Buildout Peak Flows | | | | Upsized Sewer - Buildout Peak Flows | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pipe ID | Owner | Length (ft) | U/S MH Depth (ft) | Avg Pipe Depth (ft) | Average Rounded Depth (ft) | Existing Pipe Diameter (in) | Existing Capacity (gpm) | Peak Flow (gpm) | Current % Capacity Used[1] | U/S MH Current d/D [2] | Current U/S MH Freeboard (ft) [3] | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D [2] | Future U/S MH Freeboard (ft) [3] | Upsize Diameter (in) | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D [2] | Future U/S MH Freeboard (ft) [3] | Unit Cost ($/ft) | Current Total Cost ($) | Project Name |
| **Central Model** | | | | | | | | | | | | | | | | | | | | | | | |
| 10039_10053 | TCSD | 394 | 10.3 | 9.2 | 10 | 18 | 5,720 | 5,222 | 91% | 0.8 | 9.1 | 6,128 | 107% | 4.5 | 3.5 | 21 | 7,547 | 87% | 0.8 | 8.9 | 537 | - | No projects |
| 10050_10051 | TCSD | 502 | 6.3 | 6.5 | 10 | 18 | 6,548 | 5,098 | 78% | 0.7 | 5.2 | 6,051 | 92% | 4.2 | 0.0 | 21 | 7,413 | 75% | 0.7 | 5.1 | 537 | - | |
| 10051_10052 | TCSD | 472 | 6.8 | 6.8 | 10 | 18 | 6,383 | 5,106 | 80% | 0.7 | 5.7 | 6,056 | 95% | 4.5 | 0.0 | 21 | 7,422 | 77% | 0.7 | 5.6 | 537 | - | |
| 10052_10039 | TCSD | 106 | 6.9 | 8.6 | 10 | 18 | 6,421 | 5,108 | 80% | 0.7 | 5.8 | 6,056 | 94% | 4.5 | 0.1 | 21 | 7,423 | 77% | 0.7 | 5.6 | 537 | - | |
| 10053_10054 | TCSD | 499 | 8.2 | 7.7 | 10 | 18 | 5,968 | 5,231 | 88% | 0.8 | 7.0 | 6,138 | 103% | 3.4 | 3.0 | 21 | 7,556 | 84% | 0.7 | 6.9 | 537 | - | |
| 10054_10055 | TCSD | 377 | 7.2 | 7.2 | 10 | 18 | 6,195 | 5,238 | 85% | 0.7 | 6.0 | 6,145 | 99% | 2.5 | 3.5 | 21 | 7,563 | 81% | 0.7 | 5.9 | 537 | - | |
| 10055_10763 | TCSD | 375 | 7.3 | 6.8 | 10 | 18 | 5,780 | 5,244 | 91% | 0.8 | 6.2 | 6,153 | 106% | 2.0 | 4.3 | 21 | 7,569 | 87% | 0.8 | 6.0 | 537 | - | |
| 10288_10491 | OC | 28 | 9.4 | 9.5 | 10 | 8 | 1,314 | 148 | 11% | 0.2 | 9.2 | 174 | 13% | 0.3 | 9.2 | | 174 | 13% | 0.3 | 9.2 | | | |
| 10330_12656 | OC | 330 | 6.3 | 7.1 | 10 | 12 | 1,805 | 308 | 17% | 0.3 | 6.0 | 392 | 22% | 0.3 | 6.0 | | 392 | 22% | 0.3 | 6.0 | | | |
| 10358_11785 | OC | 200 | 7.9 | 5.8 | 6 | 12 | 1,895 | 320 | 17% | 0.3 | 7.6 | 406 | 21% | 0.3 | 7.6 | | 406 | 21% | 0.3 | 7.6 | | | |
| 10382_11798 | OC | 155 | 5.7 | 4.7 | 6 | 15 | 1,722 | 1,282 | 74% | 0.7 | 4.8 | 1,551 | 90% | 1.8 | 3.4 | | 1,497 | 87% | 0.8 | 4.7 | | | |
| 10383_11799 | OC | 125 | 6.7 | 7.2 | 10 | 15 | 1,592 | 1,279 | 80% | 0.8 | 5.7 | 1,549 | 97% | 2.1 | 4.1 | | 1,493 | 94% | 1.0 | 5.4 | | | |
| 10422_10490 | OC | 301 | 9.9 | 8.5 | 10 | 8 | 394 | 128 | 33% | 0.5 | 9.6 | 152 | 39% | 0.5 | 9.5 | | 152 | 39% | 0.5 | 9.5 | | | |
| 10429_10430 | OC | 322 | 10.2 | 12.6 | 14 | 8 | 371 | 92 | 25% | 0.4 | 9.9 | 105 | 28% | 0.4 | 9.9 | | 105 | 28% | 0.4 | 9.9 | | | |
| 10430_10431 | OC | 275 | 15.0 | 12.0 | 14 | 8 | 855 | 97 | 11% | 0.2 | 14.8 | 114 | 13% | 0.3 | 14.8 | | 114 | 13% | 0.3 | 14.8 | | | |
| 10431_10432 | OC | 179 | 9.1 | 10.4 | 14 | 8 | 928 | 99 | 11% | 0.2 | 8.9 | 117 | 13% | 0.2 | 8.9 | | 117 | 13% | 0.2 | 8.9 | | | |
| 10432_10487 | OC | 165 | 11.7 | 8.3 | 10 | 8 | 883 | 102 | 12% | 0.2 | 11.5 | 119 | 14% | 0.3 | 11.5 | | 119 | 14% | 0.3 | 11.5 | | | |
| 10487_10488 | OC | 201 | 5.0 | 5.6 | 6 | 8 | 407 | 105 | 26% | 0.4 | 4.8 | 122 | 30% | 0.4 | 4.7 | | 122 | 30% | 0.4 | 4.7 | | | |
| 10488_10422 | OC | 33 | 6.2 | 8.0 | 10 | 8 | 389 | 106 | 27% | 0.4 | 6.0 | 130 | 33% | 0.4 | 5.9 | | 130 | 33% | 0.4 | 5.9 | | | |
| 10489_10288 | OC | 315 | 11.2 | 10.3 | 14 | 8 | 1,415 | 144 | 10% | 0.2 | 11.1 | 168 | 12% | 0.2 | 11.1 | | 168 | 12% | 0.2 | 11.1 | | | |
| 10490_10489 | OC | 12 | 7.2 | 9.2 | 10 | 8 | 3,666 | 128 | 4% | 0.1 | 7.1 | 153 | 4% | 0.1 | 7.1 | | 153 | 4% | 0.1 | 7.1 | | | |
| 10491_10492 | OC | 309 | 9.6 | 9.9 | 10 | 8 | 1,157 | 153 | 13% | 0.3 | 9.5 | 180 | 16% | 0.3 | 9.5 | | 180 | 16% | 0.3 | 9.5 | | | |
| 10492_10742 | OC | 255 | 10.2 | 10.8 | 14 | 8 | 741 | 160 | 22% | 0.3 | 10.0 | 186 | 25% | 0.4 | 10.0 | | 186 | 25% | 0.4 | 10.0 | | | |
| 10740_10747 | OC | 10 | 10.1 | 10.2 | 14 | 8 | 322 | 208 | 64% | 0.6 | 9.8 | 243 | 75% | 0.6 | 9.7 | | 243 | 75% | 0.6 | 9.7 | | | |
| 10742_10743 | OC | 402 | 11.5 | 11.1 | 14 | 8 | 388 | 166 | 43% | 0.5 | 11.1 | 194 | 50% | 0.6 | 11.1 | | 194 | 50% | 0.6 | 11.1 | | | |
| 10743_10744 | OC | 335 | 10.8 | 9.9 | 10 | 8 | 936 | 190 | 20% | 0.3 | 10.6 | 222 | 24% | 0.4 | 10.6 | | 222 | 24% | 0.4 | 10.6 | | | |
| 10744_10745 | OC | 196 | 9.0 | 9.2 | 10 | 8 | 1,436 | 193 | 13% | 0.3 | 8.9 | 227 | 16% | 0.3 | 8.8 | | 227 | 16% | 0.3 | 8.8 | | | |
| 10745_10746 | OC | 127 | 9.3 | 8.1 | 10 | 8 | 595 | 195 | 33% | 0.4 | 9.0 | 230 | 39% | 0.4 | 9.0 | | 230 | 39% | 0.4 | 9.0 | | | |
| 10746_10740 | OC | 316 | 6.8 | 8.5 | 10 | 8 | 309 | 201 | 65% | 0.6 | 6.4 | 236 | 76% | 0.7 | 6.4 | | 236 | 76% | 0.7 | 6.4 | | | |
| 10747_10750 | OC | 301 | 10.2 | 9.5 | 10 | 10 | 603 | 213 | 35% | 0.4 | 9.8 | 248 | 41% | 0.5 | 9.8 | | 248 | 41% | 0.5 | 9.8 | | | |
| 10748_10770 | OC | 191 | 9.5 | 9.2 | 10 | 10 | 627 | 252 | 40% | 0.5 | 9.1 | 288 | 46% | 0.5 | 9.1 | | 288 | 46% | 0.5 | 9.1 | | | |
| 10750_10748 | OC | 50 | 8.9 | 9.2 | 10 | 10 | 883 | 213 | 24% | 0.3 | 8.6 | 249 | 28% | 0.4 | 8.6 | | 249 | 28% | 0.4 | 8.6 | | | |
| 10759_12944 | TCSD | 374 | 10.6 | 10.5 | 14 | 48 | 19,488 | 5,674 | 29% | 0.4 | 9.0 | 7,805 | 40% | 0.5 | 8.8 | | 9,226 | 47% | 0.5 | 8.6 | | | |
| 10760_10759 | TCSD | 212 | 12.0 | 11.3 | 14 | 48 | 19,488 | 5,667 | 29% | 0.4 | 10.5 | 7,799 | 40% | 0.5 | 10.2 | | 9,221 | 47% | 0.5 | 10.0 | | | |
| 10761_10760 | TCSD | 500 | 11.0 | 11.5 | 14 | 48 | 19,488 | 5,658 | 29% | 0.4 | 9.5 | 7,770 | 40% | 0.5 | 9.2 | | 9,193 | 47% | 0.5 | 9.0 | | | |
| 10762_10761 | TCSD | 147 | 8.4 | 9.7 | 10 | 48 | 21,236 | 5,650 | 27% | 0.4 | 6.9 | 7,760 | 37% | 0.5 | 6.6 | | 9,183 | 43% | 0.5 | 6.4 | | | |
| 10763_12950 | TCSD | 160 | 6.3 | 8.6 | 10 | 24 | 6,923 | 5,247 | 76% | 0.7 | 4.9 | 6,155 | 89% | 0.8 | 4.8 | | 7,572 | 109% | 0.9 | 4.4 | | | |
| 10764_10765 | TCSD | 420 | 5.9 | 5.8 | 6 | 24 | 8,654 | 5,254 | 61% | 0.6 | 4.7 | 6,163 | 71% | 0.7 | 4.6 | | 7,578 | 88% | 0.8 | 4.3 | | | |
| 10765_10778 | TCSD | 19 | 5.6 | 7.5 | 10 | 24 | 39,773 | 5,255 | 13% | 0.3 | 5.1 | 6,164 | 15% | 0.3 | 5.1 | | 7,579 | 19% | 0.3 | 5.0 | | | |
| 10769_10787 | OC | 178 | 13.9 | 12.6 | 14 | 12 | 2,396 | 376 | 16% | 0.3 | 13.6 | 464 | 19% | 0.3 | 13.6 | | 464 | 19% | 0.3 | 13.6 | | | |
| 10770_10771 | OC | 372 | 8.9 | 9.2 | 10 | 10 | 602 | 264 | 44% | 0.5 | 8.5 | 300 | 50% | 0.5 | 8.5 | | 300 | 50% | 0.5 | 8.5 | | | |
| 10771_10772 | OC | 358 | 9.6 | 10.4 | 14 | 10 | 604 | 269 | 45% | 0.5 | 9.2 | 307 | 51% | 0.5 | 9.1 | | 307 | 51% | 0.5 | 9.1 | | | |
| 10772_10773 | OC | 346 | 11.3 | 8.1 | 10 | 10 | 685 | 275 | 40% | 0.5 | 10.8 | 315 | 46% | 0.6 | 10.8 | | 315 | 46% | 0.6 | 10.8 | | | |
| 10773_10769 | OC | 25 | 5.0 | 9.4 | 10 | 10 | 6,526 | 276 | 4% | 0.1 | 4.9 | 315 | 5% | 0.2 | 4.9 | | 315 | 5% | 0.2 | 4.9 | | | |
| 10778_12698 | TCSD | 150 | 9.4 | 9.9 | 10 | 24 | 51,848 | 5,272 | 10% | 0.2 | 9.0 | 6,188 | 12% | 0.2 | 8.9 | | 7,603 | 15% | 0.3 | 8.9 | | | |
| 10787_10788 | OC | 69 | 11.4 | 11.1 | 14 | 12 | 2,399 | 376 | 16% | 0.3 | 11.1 | 466 | 19% | 0.3 | 11.1 | | 466 | 19% | 0.3 | 11.1 | | | |
| 10788_10789 | OC | 160 | 10.8 | 10.1 | 14 | 12 | 2,396 | 379 | 16% | 0.3 | 10.5 | 469 | 20% | 0.3 | 10.5 | | 469 | 20% | 0.3 | 10.5 | | | |
| 10789_10793 | OC | 90 | 9.4 | 8.8 | 10 | 12 | 4,397 | 381 | 9% | 0.2 | 9.2 | 470 | 11% | 0.2 | 9.1 | | 470 | 11% | 0.2 | 9.1 | | | |
| 10790_10791 | TCSD | 197 | 6.0 | 4.8 | 6 | 12 | 5,541 | 388 | 7% | 0.2 | 5.8 | 483 | 9% | 0.2 | 5.8 | | 483 | 9% | 0.2 | 5.8 | | | |
| 10791_10792 | TCSD | 230 | 3.6 | 7.7 | 10 | 12 | 5,929 | 391 | 7% | 0.2 | 3.4 | 487 | 8% | 0.2 | 3.4 | | 487 | 8% | 0.2 | 3.4 | | | |
| 10792_12943 | TCSD | 138 | 11.8 | 12.9 | 14 | 12 | 5,762 | 394 | 7% | 0.2 | 11.6 | 489 | 8% | 0.2 | 11.6 | | 489 | 8% | 0.2 | 11.6 | | | |
| 10793_10790 | TCSD | 106 | 8.2 | 7.1 | 10 | 12 | 3,959 | 385 | 10% | 0.2 | 8.0 | 476 | 12% | 0.3 | 8.0 | | 476 | 12% | 0.3 | 8.0 | | | |
| 10938_14968 | OC | 47 | 7.3 | 7.7 | 10 | 12 | 1,951 | 406 | 21% | 0.3 | 7.0 | 424 | 22% | 0.3 | 7.0 | | 424 | 22% | 0.3 | 7.0 | | | |
| 10950_11325 | OC | 312 | 14.9 | 18.6 | 18 | 15 | 1,913 | 1,110 | 58% | 0.6 | 14.2 | 1,292 | 68% | 0.6 | 14.1 | | 1,265 | 66% | 0.6 | 14.1 | | | |

**Appendix E-1. Existing and Future Modeling Results**

| Existing Pipe and Manhole Characteristics | | | | | | | | Existing Sewers - Existing Flows | | | | Existing Sewers - Buildout Peak Flows | | | | Upsized Sewer - Buildout Peak Flows | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pipe ID | Owner | Length (ft) | U/S MH Depth (ft) | Avg Pipe Depth (ft) | Average Rounded Depth (ft) | Existing Pipe Diameter (in) | Existing Capacity (gpm) | Peak Flow (gpm) | Current % Capacity Used[1] | U/S MH Current d/D [2] | Current U/S MH Freeboard (ft) [3] | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D [2] | Future U/S MH Freeboard (ft) [3] | Upsize Diameter (in) | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D [2] | Future U/S MH Freeboard (ft) [3] | Unit Cost ($/ft) | Current Total Cost ($) | Project Name |
| 10951_10950 | OC | 315 | 17.3 | 16.1 | 18 | 15 | 1,745 | 1,102 | 63% | 0.6 | 16.5 | 1,291 | 74% | 0.7 | 16.4 | | 1,262 | 72% | 0.7 | 16.5 | | | |
| 10952_10951 | OC | 175 | 13.0 | 15.1 | 18 | 15 | 4,818 | 1,024 | 21% | 0.3 | 12.5 | 1,213 | 25% | 0.4 | 12.5 | | 1,183 | 25% | 0.4 | 12.5 | | | |
| 10953_10952 | OC | 205 | 12.1 | 12.5 | 14 | 15 | 2,018 | 1,010 | 50% | 0.5 | 11.4 | 1,190 | 59% | 0.6 | 11.4 | | 1,160 | 58% | 0.6 | 11.4 | | | |
| 10960_10953 | OC | 360 | 12.2 | 12.1 | 14 | 15 | 1,913 | 1,008 | 53% | 0.5 | 11.5 | 1,192 | 62% | 0.6 | 11.5 | | 1,161 | 61% | 0.6 | 11.5 | | | |
| 10961_10960 | OC | 165 | 9.2 | 10.7 | 14 | 12 | 2,089 | 756 | 36% | 0.4 | 8.8 | 908 | 43% | 0.5 | 8.7 | | 877 | 42% | 0.5 | 8.7 | | | |
| 11130_11138 | TCSD | 177 | 20.6 | 17.6 | 18 | 24 | 8,849 | 4,934 | 56% | 0.6 | 19.5 | 7,159 | 81% | 0.7 | 19.1 | | 7,226 | 82% | 0.7 | 19.1 | | | |
| 11131_11132 | TCSD | 499 | 6.2 | 31.2 | 18 | 22 | 16,345 | 4,963 | 30% | 0.4 | 5.5 | 7,215 | 44% | 0.5 | 5.3 | | 7,281 | 45% | 0.5 | 5.3 | | | |
| 11132_11136 | TCSD | 501 | 56.2 | 31.3 | 18 | 18 | 7,551 | 4,972 | 66% | 0.6 | 55.3 | 7,224 | 96% | 3.8 | 50.5 | | 7,288 | 97% | 0.9 | 54.9 | | | |
| 11133_11135 | TCSD | 300 | 6.5 | 7.0 | 10 | 18 | 8,281 | 4,988 | 60% | 0.6 | 5.6 | 7,240 | 87% | 0.8 | 5.3 | | 7,303 | 88% | 0.8 | 5.3 | | - | |
| 11134_11133 | TCSD | 300 | 8.5 | 7.5 | 10 | 18 | 7,125 | 4,982 | 70% | 0.7 | 7.5 | 7,235 | 102% | 2.1 | 5.4 | 21 | 7,299 | 68% | 0.6 | 7.4 | 537 | - | |
| 11135_11692 | TCSD | 356 | 7.6 | 7.4 | 10 | 18 | 8,281 | 4,994 | 60% | 0.6 | 6.7 | 7,245 | 87% | 0.8 | 6.4 | | 7,310 | 88% | 0.8 | 6.4 | | - | |
| 11136_11134 | TCSD | 300 | 6.5 | 7.5 | 10 | 18 | 7,125 | 4,977 | 70% | 0.6 | 5.5 | 7,230 | 101% | 2.9 | 2.1 | 21 | 7,293 | 68% | 0.6 | 5.4 | 537 | - | |
| 11137_11130 | TCSD | 140 | 12.0 | 16.3 | 18 | 18 | 16,416 | 2,204 | 13% | 0.3 | 11.7 | 2,804 | 17% | 0.3 | 11.6 | | 2,866 | 17% | 0.3 | 11.6 | | | |
| 11138_11131 | TCSD | 390 | 14.7 | 10.5 | 14 | 24 | 14,759 | 4,954 | 34% | 0.4 | 13.9 | 7,206 | 49% | 0.5 | 13.7 | | 7,273 | 49% | 0.5 | 13.6 | | | |
| 11139_11140 | OC | 196 | 8.5 | 6.5 | 10 | 15 | 4,637 | 442 | 10% | 0.2 | 8.2 | 1,790 | 39% | 0.4 | 8.0 | | 1,790 | 39% | 0.4 | 8.0 | | | |
| 11140_11130 | OC | 214 | 4.5 | 12.5 | 14 | 16 | 4,225 | 445 | 11% | 0.2 | 4.2 | 1,792 | 42% | 0.5 | 3.9 | | 1,792 | 42% | 0.5 | 3.9 | | | |
| 11141_12930 | TCSD | 342 | 9.4 | 9.4 | 10 | 24 | 27,862 | 2,276 | 8% | 0.2 | 9.0 | 2,588 | 9% | 0.2 | 9.0 | | 2,574 | 9% | 0.2 | 9.0 | | | |
| 11142_14304 | TCSD | 17 | 7.4 | 7.8 | 10 | 24 | 24,081 | 2,294 | 10% | 0.2 | 7.0 | 2,613 | 11% | 0.2 | 7.0 | | 2,599 | 11% | 0.2 | 7.0 | | | |
| 11143_11166 | OC | 168 | 13.3 | 14.3 | 18 | 12 | 1,202 | 193 | 16% | 0.3 | 13.0 | 1,415 | 118% | 2.5 | 10.8 | | 1,415 | 118% | 2.5 | 10.8 | | | |
| 11144_11143 | OC | 209 | 12.6 | 13.0 | 14 | 12 | 2,303 | 190 | 8% | 0.2 | 12.4 | 1,407 | 61% | 0.6 | 12.0 | | 1,407 | 61% | 0.6 | 12.0 | | | |
| 11145_14289 | OC | 54 | 7.8 | 8.3 | 10 | 10 | 1,101 | 94 | 9% | 0.2 | 7.6 | 94 | 9% | 0.2 | 7.6 | | 94 | 9% | 0.2 | 7.6 | | | |
| 11147_11145 | OC | 189 | 9.8 | 8.8 | 10 | 10 | 1,352 | 93 | 7% | 0.2 | 9.6 | 93 | 7% | 0.2 | 9.6 | | 93 | 7% | 0.2 | 9.6 | | | |
| 11148_11147 | OC | 140 | 9.6 | 9.7 | 10 | 10 | 794 | 90 | 11% | 0.2 | 9.4 | 90 | 11% | 0.2 | 9.4 | | 90 | 11% | 0.2 | 9.4 | | | |
| 11149_11148 | OC | 352 | 7.1 | 8.3 | 10 | 10 | 766 | 87 | 11% | 0.2 | 6.9 | 87 | 11% | 0.2 | 6.9 | | 87 | 11% | 0.2 | 6.9 | | | |
| 11150_11149 | OC | 77 | 6.0 | 6.5 | 10 | 10 | 831 | 79 | 10% | 0.2 | 5.8 | 79 | 10% | 0.2 | 5.8 | | 79 | 10% | 0.2 | 5.8 | | | |
| 11152_11167 | OC | 229 | 17.0 | 15.7 | 18 | 12 | 1,298 | 212 | 16% | 0.3 | 16.7 | 1,438 | 111% | 1.3 | 15.7 | | 1,438 | 111% | 1.3 | 15.7 | | | |
| 11153_11155 | TCSD | 499 | 12.0 | 14.5 | 18 | 21 | 2,403 | 2,151 | 89% | 0.8 | 10.7 | 2,760 | 115% | 1.3 | 9.8 | 24 | 2,808 | 82% | 0.7 | 10.6 | 993 | - | |
| 11154_11161 | TCSD | 481 | 21.5 | 24.0 | 18 | 21 | 2,451 | 2,163 | 88% | 0.8 | 20.2 | 2,767 | 113% | 1.0 | 19.8 | 24 | 2,826 | 81% | 0.7 | 20.1 | 993 | - | |
| 11155_11154 | TCSD | 499 | 17.0 | 19.3 | 18 | 21 | 2,403 | 2,157 | 90% | 0.8 | 15.7 | 2,783 | 116% | 1.1 | 15.0 | 24 | 2,815 | 82% | 0.7 | 15.6 | 993 | - | |
| 11160_11162 | TCSD | 499 | 26.4 | 22.8 | 18 | 21 | 2,944 | 2,193 | 75% | 0.7 | 25.2 | 2,794 | 95% | 0.8 | 25.0 | 24 | 2,855 | 68% | 0.6 | 25.1 | 993 | - | |
| 11161_11160 | TCSD | 361 | 26.5 | 26.5 | 18 | 21 | 2,403 | 2,169 | 90% | 0.7 | 25.2 | 2,772 | 115% | 0.9 | 24.9 | 24 | 2,831 | 83% | 0.7 | 25.1 | 993 | - | |
| 11162_11137 | TCSD | 501 | 19.1 | 15.6 | 18 | 18 | 6,901 | 2,201 | 32% | 0.4 | 18.5 | 2,802 | 41% | 0.5 | 18.4 | | 2,863 | 41% | 0.5 | 18.4 | | - | |
| 11166_11152 | OC | 216 | 15.3 | 16.1 | 18 | 12 | 1,150 | 207 | 18% | 0.3 | 15.0 | 1,433 | 125% | 2.1 | 13.3 | | 1,433 | 125% | 2.1 | 13.2 | | | |
| 11167_12713 | OC | 290 | 14.4 | 10.5 | 14 | 12 | 1,983 | 433 | 22% | 0.3 | 14.1 | 1,775 | 89% | 0.8 | 13.6 | | 1,775 | 89% | 0.8 | 13.6 | | | |
| 11174_11184 | OC | 303 | 9.7 | 13.5 | 14 | 10 | 727 | 122 | 17% | 0.3 | 9.5 | 126 | 17% | 0.3 | 9.5 | | 126 | 17% | 0.3 | 9.5 | | | |
| 11184_12070 | OC | 393 | 17.3 | 19.7 | 18 | 10 | 379 | 225 | 59% | 0.6 | 16.8 | 230 | 61% | 0.6 | 16.8 | | 230 | 61% | 0.6 | 16.8 | | | |
| 11191_11174 | OC | 27 | 8.8 | 9.3 | 10 | 10 | 350 | 15 | 4% | 0.3 | 8.6 | 15 | 4% | 0.3 | 8.6 | | 15 | 4% | 0.3 | 8.6 | | | |
| 11271_11272 | OC | 199 | 11.7 | 11.0 | 14 | 15 | 2,025 | 1,269 | 63% | 0.6 | 10.9 | 1,455 | 72% | 0.7 | 10.9 | | 1,438 | 71% | 0.6 | 10.9 | | | |
| 11272_11273 | OC | 130 | 10.4 | 10.6 | 14 | 18 | 2,929 | 1,788 | 61% | 0.6 | 9.5 | 2,017 | 69% | 0.6 | 9.5 | | 2,001 | 68% | 0.6 | 9.5 | | | |
| 11273_11280 | OC | 22 | 10.7 | 11.1 | 14 | 18 | 1,069 | 1,788 | 167% | 0.5 | 9.9 | 2,017 | 189% | 0.6 | 9.9 | | 2,001 | 187% | 0.6 | 9.9 | | | |
| 11276_11288 | TCSD | 319 | 11.2 | 12.3 | 14 | 24 | 6,346 | 2,206 | 35% | 0.4 | 10.3 | 2,511 | 40% | 0.5 | 10.3 | | 2,497 | 39% | 0.5 | 10.3 | | | |
| 11277_11289 | TCSD | 400 | 17.3 | 20.2 | 18 | 24 | 5,501 | 2,231 | 41% | 0.5 | 16.3 | 2,536 | 46% | 0.5 | 16.3 | | 2,522 | 46% | 0.5 | 16.3 | | | |
| 11278_14314 | TCSD | 141 | 12.0 | 11.2 | 14 | 24 | 6,002 | 2,265 | 38% | 0.4 | 11.1 | 2,572 | 43% | 0.5 | 11.0 | | 2,559 | 43% | 0.5 | 11.0 | | | |
| 11279_11280 | OC | 10 | 12.3 | 11.9 | 14 | 24 | 3,431 | 343 | 10% | 0.7 | 10.9 | 394 | 11% | 0.7 | 10.8 | | 394 | 11% | 0.7 | 10.8 | | | |
| 11280_13680 | TCSD | 12 | 11.5 | 11.8 | 14 | 24 | 8,902 | 2,120 | 24% | 0.3 | 10.8 | 2,410 | 27% | 0.4 | 10.7 | | 2,395 | 27% | 0.4 | 10.7 | | | |
| 11281_11297 | OC | 379 | 17.2 | 13.6 | 14 | 10 | 842 | 340 | 40% | 0.5 | 16.8 | 390 | 46% | 0.5 | 16.8 | | 390 | 46% | 0.5 | 16.8 | | | |
| 11287_11276 | TCSD | 37 | 11.0 | 11.1 | 14 | 24 | 10,916 | 2,184 | 20% | 0.3 | 10.3 | 2,474 | 23% | 0.4 | 10.2 | | 2,459 | 23% | 0.4 | 10.2 | | | |
| 11288_11277 | TCSD | 201 | 13.4 | 15.3 | 18 | 24 | 6,636 | 2,216 | 33% | 0.4 | 12.6 | 2,521 | 38% | 0.4 | 12.5 | | 2,506 | 38% | 0.4 | 12.5 | | | |
| 11289_18007 | TCSD | 240 | 23.2 | 20.9 | 18 | 24 | 4,705 | 2,242 | 48% | 0.5 | 22.2 | 2,547 | 54% | 0.5 | 22.1 | | 2,533 | 54% | 0.5 | 22.1 | | | |
| 11290_18033 | TCSD | 348 | 14.1 | 12.2 | 14 | 24 | 8,106 | 2,258 | 28% | 0.4 | 13.4 | 2,566 | 32% | 0.4 | 13.3 | | 2,552 | 31% | 0.4 | 13.3 | | | |
| 11296_11272 | OC | 217 | 12.8 | 11.6 | 14 | 10 | 494 | 540 | 109% | 1.2 | 11.8 | 559 | 113% | 1.4 | 11.6 | | 559 | 113% | 1.4 | 11.6 | | | |
| 11297_11279 | OC | 92 | 10.0 | 11.1 | 14 | 10 | 1,012 | 343 | 34% | 0.8 | 9.4 | 393 | 39% | 0.9 | 9.3 | | 393 | 39% | 0.9 | 9.3 | | | |
| 11309_11313 | OC | 93 | 19.0 | 15.5 | 18 | 15 | 4,140 | 1,192 | 29% | 0.4 | 18.5 | 1,381 | 33% | 0.4 | 18.5 | | 1,360 | 33% | 0.4 | 18.5 | | | |
| 11311_11312 | OC | 358 | 23.2 | 23.5 | 18 | 15 | 1,694 | 1,132 | 67% | 0.6 | 22.4 | 1,315 | 78% | 0.7 | 22.3 | | 1,294 | 76% | 0.7 | 22.3 | | | |
| 11312_14088 | OC | 101 | 23.8 | 23.7 | 18 | 15 | 1,686 | 1,135 | 67% | 0.6 | 23.1 | 1,317 | 78% | 0.7 | 23.0 | | 1,298 | 77% | 0.7 | 23.0 | | | |

**Appendix E-1. Existing and Future Modeling Results**

| Existing Pipe and Manhole Characteristics | | | | | | | | Existing Sewers - Existing Flows | | | | Existing Sewers - Buildout Peak Flows | | | | Upsized Sewer - Buildout Peak Flows | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pipe ID | Owner | Length (ft) | U/S MH Depth (ft) | Avg Pipe Depth (ft) | Average Rounded Depth (ft) | Existing Pipe Diameter (in) | Existing Capacity (gpm) | Peak Flow (gpm) | Current % Capacity Used[1] | U/S MH Current d/D [2] | Current U/S MH Freeboard (ft) [3] | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D [2] | Future U/S MH Freeboard (ft) [3] | Upsize Diameter (in) | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D [2] | Future U/S MH Freeboard (ft) [3] | Unit Cost ($/ft) | Current Total Cost ($) | Project Name |
| 11313_11315 | OC | 318 | 12.0 | 11.7 | 14 | 15 | 2,343 | 1,203 | 51% | 0.6 | 11.3 | 1,392 | 59% | 0.6 | 11.2 | | 1,372 | 59% | 0.6 | 11.2 | | | |
| 11314_11316 | OC | 402 | 12.2 | 12.5 | 14 | 15 | 1,583 | 1,220 | 77% | 0.7 | 11.3 | 1,408 | 89% | 0.8 | 11.2 | | 1,389 | 88% | 0.8 | 11.2 | | | |
| 11315_11314 | OC | 71 | 11.5 | 11.8 | 14 | 15 | 7,414 | 1,206 | 16% | 0.3 | 11.1 | 1,394 | 19% | 0.3 | 11.1 | | 1,375 | 19% | 0.3 | 11.1 | | | |
| 11316_11317 | OC | 271 | 12.9 | 13.0 | 14 | 15 | 1,851 | 1,231 | 67% | 0.6 | 12.1 | 1,417 | 77% | 0.7 | 12.0 | | 1,399 | 76% | 0.7 | 12.1 | | | |
| 11317_11271 | OC | 300 | 13.1 | 12.4 | 14 | 15 | 1,788 | 1,263 | 71% | 0.7 | 12.3 | 1,449 | 81% | 0.7 | 12.2 | | 1,432 | 80% | 0.7 | 12.2 | | | |
| 11325_11311 | OC | 382 | 22.4 | 22.8 | 18 | 15 | 1,875 | 1,121 | 60% | 0.6 | 21.6 | 1,309 | 70% | 0.6 | 21.6 | | 1,283 | 68% | 0.6 | 21.6 | | | |
| 11331_10938 | OC | 381 | 8.0 | 7.6 | 10 | 8 | 360 | 128 | 36% | 0.4 | 7.7 | 140 | 39% | 0.4 | 7.7 | | 140 | 39% | 0.4 | 7.7 | | | |
| 11334_12759 | OC | 284 | 11.3 | 9.2 | 10 | 12 | 977 | 505 | 52% | 0.5 | 10.7 | 524 | 54% | 0.6 | 10.7 | | 524 | 54% | 0.6 | 10.7 | | | |
| 11346_12948 | TCSD | 175 | 11.3 | 10.6 | 14 | 48 | 18,743 | 6,133 | 33% | 0.3 | 9.9 | 8,394 | 45% | 0.4 | 9.7 | | 9,813 | 52% | 0.4 | 9.6 | | | |
| 11347_11346 | TCSD | 319 | 8.5 | 9.9 | 10 | 48 | 21,788 | 6,133 | 28% | 0.4 | 7.0 | 8,393 | 39% | 0.4 | 6.8 | | 9,813 | 45% | 0.5 | 6.6 | | | |
| 11348_11351 | TCSD | 282 | 12.3 | 12.4 | 14 | 48 | 21,679 | 6,123 | 28% | 0.4 | 10.8 | 8,383 | 39% | 0.4 | 10.5 | | 9,802 | 45% | 0.5 | 10.3 | | | |
| 11351_11352 | TCSD | 103 | 12.5 | 12.6 | 14 | 48 | 21,458 | 6,124 | 29% | 0.4 | 11.0 | 8,385 | 39% | 0.4 | 10.8 | | 9,804 | 46% | 0.5 | 10.6 | | | |
| 11352_13823 | TCSD | 334 | 12.6 | 12.0 | 14 | 48 | 21,011 | 6,131 | 29% | 0.4 | 11.1 | 8,390 | 40% | 0.4 | 10.9 | | 9,810 | 47% | 0.5 | 10.7 | | | |
| 11415_11417 | TCSD | 500 | 7.4 | 7.4 | 10 | 18 | 10,329 | 5,054 | 49% | 0.5 | 6.6 | 7,304 | 71% | 0.6 | 6.4 | | 7,369 | 71% | 0.7 | 6.4 | | | |
| 11416_11418 | TCSD | 503 | 6.4 | 7.3 | 10 | 18 | 10,519 | 5,072 | 48% | 0.5 | 5.6 | 7,322 | 70% | 0.6 | 5.4 | | 7,388 | 70% | 0.6 | 5.4 | | | |
| 11417_11416 | TCSD | 499 | 7.4 | 6.9 | 10 | 18 | 10,340 | 5,063 | 49% | 0.5 | 6.6 | 7,313 | 71% | 0.7 | 6.4 | | 7,378 | 71% | 0.7 | 6.4 | | | |
| 11418_11441 | TCSD | 498 | 8.3 | 8.0 | 10 | 18 | 8,890 | 5,081 | 57% | 0.6 | 7.4 | 7,331 | 82% | 5.5 | 0.0 | | 7,396 | 83% | 0.7 | 7.2 | | | |
| 11441_10050 | TCSD | 499 | 7.8 | 7.0 | 10 | 18 | 6,183 | 5,089 | 82% | 0.7 | 6.7 | 6,329 | 102% | 5.2 | 0.0 | 21 | 7,405 | 79% | 0.7 | 6.5 | 537 | - | |
| 11692_11693 | TCSD | 400 | 7.2 | 7.1 | 10 | 18 | 8,281 | 5,001 | 60% | 0.6 | 6.3 | 7,252 | 88% | 0.8 | 6.0 | | 7,317 | 88% | 0.8 | 6.0 | | - | |
| 11693_11694 | TCSD | 501 | 7.0 | 7.6 | 10 | 18 | 8,476 | 5,010 | 59% | 0.6 | 6.1 | 7,261 | 86% | 0.8 | 5.8 | | 7,326 | 86% | 0.8 | 5.8 | | - | |
| 11694_11695 | TCSD | 190 | 8.1 | 6.5 | 10 | 18 | 8,305 | 5,013 | 60% | 0.6 | 7.3 | 7,264 | 87% | 0.8 | 7.0 | | 7,328 | 88% | 0.8 | 7.0 | | - | |
| 11695_11696 | TCSD | 191 | 4.8 | 5.5 | 6 | 18 | 7,701 | 5,016 | 65% | 0.6 | 3.9 | 7,267 | 94% | 0.8 | 3.6 | | 7,332 | 95% | 0.8 | 3.5 | | - | |
| 11696_11697 | TCSD | 299 | 6.3 | 6.2 | 10 | 18 | 8,446 | 5,022 | 59% | 0.6 | 5.4 | 7,272 | 86% | 0.8 | 5.1 | | 7,338 | 87% | 0.8 | 5.1 | | - | |
| 11697_11698 | TCSD | 330 | 6.2 | 7.3 | 10 | 18 | 9,694 | 5,027 | 52% | 0.5 | 5.4 | 7,278 | 75% | 0.7 | 5.1 | | 7,343 | 76% | 0.7 | 5.1 | | | |
| 11698_11699 | TCSD | 503 | 8.4 | 9.7 | 10 | 18 | 10,299 | 5,036 | 49% | 0.5 | 7.6 | 7,287 | 71% | 0.7 | 7.4 | | 7,352 | 71% | 0.7 | 7.4 | | | |
| 11699_11415 | TCSD | 500 | 11.1 | 9.2 | 10 | 18 | 10,329 | 5,045 | 49% | 0.5 | 10.3 | 7,296 | 71% | 0.6 | 10.1 | | 7,361 | 71% | 0.7 | 10.1 | | | |
| 11774_14190 | TCSD | 269 | 6.5 | 7.3 | 10 | 18 | 1,738 | 682 | 39% | 0.5 | 5.8 | 1,090 | 63% | 0.8 | 5.3 | | 1,086 | 62% | 0.6 | 5.6 | | | |
| 11775_11774 | TCSD | 371 | 6.5 | 6.5 | 10 | 18 | 1,738 | 677 | 39% | 0.5 | 5.9 | 1,070 | 62% | 0.6 | 5.6 | | 1,083 | 62% | 0.6 | 5.6 | | | |
| 11776_11784 | TCSD | 239 | 11.7 | 13.3 | 14 | 21 | 1,202 | 720 | 60% | 0.7 | 10.6 | 1,143 | 95% | 1.2 | 9.6 | | 1,118 | 93% | 0.7 | 10.5 | | | |
| 11779_11776 | TCSD | 350 | 9.0 | 10.4 | 14 | 18 | 2,314 | 694 | 30% | 0.4 | 8.4 | 1,120 | 48% | 1.0 | 7.5 | | 1,097 | 47% | 0.5 | 8.2 | | | |
| 11780_14195 | TCSD | 116 | 9.3 | 8.9 | 10 | 18 | 1,810 | 486 | 27% | 0.4 | 8.7 | 806 | 45% | 0.5 | 8.6 | | 806 | 45% | 0.5 | 8.6 | | | |
| 11781_11775 | TCSD | 262 | 6.7 | 6.6 | 10 | 18 | 1,760 | 492 | 28% | 0.4 | 6.2 | 814 | 46% | 0.5 | 5.9 | | 817 | 46% | 0.5 | 5.9 | | | |
| 11782_11780 | TCSD | 514 | 16.7 | 13.0 | 14 | 12 | 959 | 485 | 51% | 0.5 | 16.1 | 781 | 81% | 0.7 | 15.9 | | 781 | 81% | 0.7 | 15.9 | | - | |
| 11783_11782 | TCSD | 298 | 16.6 | 16.6 | 18 | 12 | 755 | 481 | 64% | 0.6 | 16.0 | 772 | 102% | 0.9 | 15.7 | | 772 | 102% | 0.9 | 15.7 | | - | |
| 11784_11153 | TCSD | 73 | 14.8 | 13.4 | 14 | 21 | 4,438 | 2,144 | 48% | 0.7 | 13.6 | 2,757 | 62% | 1.2 | 12.7 | 24 | 2,801 | 44% | 0.6 | 13.5 | 797 | - | |
| 11785_13696 | OC | 20 | 3.8 | 3.5 | 6 | 16 | 2,177 | 320 | 15% | 0.3 | 3.4 | 422 | 19% | 0.3 | 3.3 | | 422 | 19% | 0.3 | 3.3 | | | |
| 11787_14206 | OC | 131 | 8.7 | 10.4 | 14 | 12 | 1,144 | 1,402 | 123% | 3.2 | 5.4 | 1,467 | 128% | 2.7 | 5.9 | | 1,466 | 128% | 3.7 | 5.0 | | | |
| 11788_11809 | OC | 141 | 13.3 | 12.0 | 14 | 12 | 1,322 | 1,400 | 106% | 0.9 | 12.4 | 1,510 | 114% | 2.0 | 11.3 | | 1,510 | 114% | 1.7 | 11.6 | | | |
| 11797_12866 | OC | 382 | 13.7 | 15.9 | 18 | 15 | 1,486 | 1,341 | 90% | 0.8 | 12.6 | 1,643 | 111% | 1.9 | 11.3 | | 1,582 | 106% | 1.0 | 12.5 | | | |
| 11798_11887 | OC | 20 | 3.8 | 4.9 | 6 | 15 | 1,844 | 1,280 | 69% | 0.7 | 3.0 | 1,554 | 84% | 1.8 | 1.5 | | 1,495 | 81% | 0.8 | 2.8 | | | |
| 11799_10382 | OC | 159 | 7.7 | 6.7 | 10 | 15 | 814 | 1,281 | 157% | 0.9 | 6.6 | 1,549 | 190% | 2.1 | 5.1 | | 1,496 | 184% | 1.0 | 6.4 | | | |
| 11800_10383 | OC | 104 | 11.1 | 8.9 | 10 | 15 | 1,393 | 1,283 | 92% | 0.8 | 10.1 | 1,549 | 111% | 2.2 | 8.4 | | 1,491 | 107% | 1.1 | 9.7 | | | |
| 11804_11800 | OC | 341 | 16.5 | 13.8 | 14 | 15 | 1,651 | 1,264 | 77% | 0.7 | 15.6 | 1,488 | 90% | 2.1 | 13.8 | | 1,428 | 86% | 0.9 | 15.4 | | | |
| 11805_11804 | OC | 220 | 7.0 | 11.7 | 14 | 15 | 1,479 | 1,277 | 86% | 0.8 | 6.0 | 1,484 | 100% | 2.2 | 4.2 | | 1,451 | 98% | 0.9 | 5.9 | | | |
| 11806_11805 | OC | 151 | 7.9 | 7.4 | 10 | 15 | 1,470 | 1,284 | 87% | 0.8 | 7.0 | 1,483 | 101% | 2.3 | 5.1 | | 1,458 | 99% | 0.9 | 6.8 | | | |
| 11807_11806 | OC | 277 | 3.8 | 5.8 | 6 | 15 | 1,220 | 1,302 | 107% | 0.9 | 2.7 | 1,481 | 121% | 2.4 | 0.8 | | 1,472 | 121% | 1.0 | 2.5 | | | |
| 11808_11807 | OC | 264 | 4.5 | 4.1 | 6 | 15 | 1,586 | 1,340 | 84% | 0.7 | 3.6 | 1,479 | 93% | 2.5 | 1.5 | | 1,475 | 93% | 0.9 | 3.3 | | | |
| 11809_11808 | OC | 269 | 10.6 | 7.6 | 10 | 12 | 1,960 | 1,386 | 71% | 0.7 | 10.0 | 1,507 | 77% | 1.7 | 8.9 | | 1,510 | 77% | 0.7 | 9.9 | | | |
| 11887_11797 | OC | 136 | 6.0 | 9.8 | 10 | 15 | 1,783 | 1,340 | 75% | 0.7 | 5.1 | 1,635 | 92% | 1.9 | 3.7 | | 1,576 | 88% | 0.9 | 4.9 | | | |
| 11996_12009 | OC | 14 | 10.7 | 12.1 | 14 | 12 | 2,545 | 509 | 20% | 0.4 | 10.4 | 624 | 25% | 0.4 | 10.3 | | 610 | 24% | 0.4 | 10.3 | | | |
| 11997_11998 | OC | 291 | 11.7 | 12.0 | 14 | 12 | 1,226 | 551 | 45% | 0.5 | 11.2 | 669 | 55% | 0.6 | 11.2 | | 652 | 53% | 0.6 | 11.2 | | | |
| 11998_18009 | OC | 31 | 12.3 | 9.3 | 10 | 12 | 1,338 | 544 | 41% | 0.5 | 11.9 | 662 | 49% | 0.5 | 11.8 | | 647 | 48% | 0.5 | 11.8 | | | |
| 11999_14158 | OC | 39 | 16.4 | 16.3 | 18 | 12 | 276 | 603 | 219% | 1.2 | 15.2 | 722 | 262% | 1.5 | 14.9 | | 701 | 255% | 1.4 | 14.9 | | | |
| 12009_11997 | OC | 190 | 13.4 | 12.6 | 14 | 12 | 1,123 | 531 | 47% | 0.5 | 12.9 | 647 | 58% | 0.6 | 12.9 | | 630 | 56% | 0.6 | 12.9 | | | |
| 12070_12072 | OC | 439 | 22.1 | 19.6 | 18 | 10 | 512 | 294 | 58% | 0.6 | 21.6 | 344 | 67% | 0.6 | 21.5 | | 344 | 67% | 0.6 | 21.5 | | | |

**Appendix E-1. Existing and Future Modeling Results**

| Existing Pipe and Manhole Characteristics | | | | | | | | Existing Sewers - Existing Flows | | | | Existing Sewers - Buildout Peak Flows | | | | Upsized Sewer - Buildout Peak Flows | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pipe ID | Owner | Length (ft) | U/S MH Depth (ft) | Avg Pipe Depth (ft) | Average Rounded Depth (ft) | Existing Pipe Diameter (in) | Existing Capacity (gpm) | Peak Flow (gpm) | Current % Capacity Used[1] | U/S MH Current d/D[2] | Current U/S MH Freeboard (ft)[3] | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D[2] | Future U/S MH Freeboard (ft)[3] | Upsize Diameter (in) | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D[2] | Future U/S MH Freeboard (ft)[3] | Unit Cost ($/ft) | Current Total Cost ($) | Project Name |
| 12072_11281 | OC | 108 | 17.1 | 17.1 | 18 | 10 | 286 | 326 | 114% | 0.7 | 16.5 | 376 | 132% | 0.8 | 16.4 | | 376 | 132% | 0.8 | 16.4 | | | |
| 12248_11996 | OC | 346 | 9.1 | 9.9 | 10 | 12 | 1,197 | 525 | 44% | 0.5 | 8.6 | 647 | 54% | 0.6 | 8.5 | | 629 | 53% | 0.6 | 8.6 | | | |
| 12249_12248 | OC | 390 | 5.4 | 7.3 | 10 | 12 | 1,233 | 649 | 53% | 0.6 | 4.9 | 748 | 61% | 0.6 | 4.8 | | 730 | 59% | 0.6 | 4.8 | | | |
| 12366_12367 | OC | 234 | 16.8 | 14.4 | 18 | 12 | 1,017 | 96 | 9% | 0.2 | 16.6 | 177 | 17% | 0.3 | 16.5 | | 177 | 17% | 0.3 | 16.5 | | | |
| 12367_12370 | OC | 280 | 12.0 | 11.3 | 14 | 12 | 743 | 127 | 17% | 0.3 | 11.7 | 217 | 29% | 0.4 | 11.6 | | 217 | 29% | 0.4 | 11.6 | | | |
| 12368_11783 | TCSD | 209 | 14.8 | 15.7 | 18 | 12 | 1,170 | 476 | 41% | 0.5 | 14.3 | 714 | 61% | 0.6 | 14.2 | | 714 | 61% | 0.6 | 14.2 | | | |
| 12369_12368 | OC | 54 | 14.2 | 14.5 | 18 | 12 | 955 | 474 | 50% | 0.5 | 13.6 | 685 | 72% | 0.6 | 13.5 | | 685 | 72% | 0.6 | 13.5 | | | |
| 12370_12369 | OC | 256 | 10.6 | 12.4 | 14 | 12 | 1,180 | 474 | 40% | 0.5 | 10.1 | 683 | 58% | 0.6 | 10.0 | | 683 | 58% | 0.6 | 10.0 | | | |
| 12371_12370 | OC | 279 | 2.6 | 6.6 | 10 | 12 | 1,078 | 344 | 32% | 0.4 | 2.2 | 458 | 43% | 0.5 | 2.1 | | 458 | 43% | 0.5 | 2.1 | | | |
| 12372_12371 | OC | 54 | 3.1 | 2.8 | 6 | 12 | 1,066 | 341 | 32% | 0.4 | 2.7 | 450 | 42% | 0.5 | 2.6 | | 450 | 42% | 0.5 | 2.6 | | | |
| 12375_14617 | OC | 147 | 17.2 | 14.3 | 18 | 12 | 630 | 324 | 51% | 0.5 | 16.7 | 428 | 68% | 0.6 | 16.6 | | 428 | 68% | 0.6 | 16.6 | | | |
| 12581_12582 | OC | 258 | 12.0 | 10.9 | 14 | 12 | 1,612 | 1,338 | 83% | 0.8 | 11.3 | 1,365 | 85% | 0.8 | 11.3 | | 1,365 | 85% | 0.8 | 11.3 | | | |
| 12582_12585 | OC | 34 | 9.7 | 10.0 | 10 | 12 | 2,032 | 1,334 | 66% | 0.6 | 9.1 | 1,367 | 67% | 0.6 | 9.1 | | 1,367 | 67% | 0.6 | 9.1 | | | |
| 12585_12586 | OC | 208 | 10.2 | 9.5 | 10 | 12 | 1,874 | 1,340 | 71% | 0.7 | 9.6 | 1,377 | 74% | 0.7 | 9.6 | | 1,376 | 73% | 0.7 | 9.6 | | | |
| 12586_12587 | OC | 97 | 8.7 | 8.5 | 10 | 12 | 1,343 | 1,318 | 98% | 0.9 | 7.8 | 1,362 | 101% | 1.0 | 7.7 | | 1,362 | 101% | 1.0 | 7.7 | | | |
| 12587_12588 | OC | 141 | 8.2 | 7.9 | 10 | 12 | 1,264 | 1,306 | 103% | 0.9 | 7.3 | 1,360 | 108% | 0.9 | 7.3 | | 1,360 | 108% | 0.9 | 7.3 | | | |
| 12588_12589 | OC | 157 | 7.6 | 7.9 | 10 | 12 | 1,991 | 1,306 | 66% | 0.6 | 7.0 | 1,362 | 68% | 0.6 | 6.9 | | 1,361 | 68% | 0.6 | 6.9 | | | |
| 12589_12590 | OC | 102 | 8.2 | 8.1 | 10 | 12 | 2,076 | 1,306 | 63% | 0.6 | 7.6 | 1,363 | 66% | 0.6 | 7.6 | | 1,363 | 66% | 0.6 | 7.6 | | | |
| 12590_11787 | OC | 203 | 8.1 | 8.4 | 10 | 12 | 2,680 | 1,306 | 49% | 0.5 | 7.6 | 1,365 | 51% | 0.5 | 7.5 | | 1,365 | 51% | 0.5 | 7.5 | | | |
| 12620_12627 | OC | 205 | 14.1 | 11.7 | 14 | 12 | 961 | 1,447 | 151% | 14.1 | PS | 1,440 | 150% | 14.1 | PS | | 1,499 | 156% | 14.1 | PS | | | |
| 12621_12581 | OC | 110 | 9.6 | 10.8 | 14 | 12 | 1,448 | 1,335 | 92% | 0.8 | 8.8 | 1,354 | 94% | 0.8 | 8.8 | | 1,353 | 93% | 0.8 | 8.8 | | | |
| 12627_12621 | OC | 215 | 9.4 | 9.5 | 10 | 12 | 1,256 | 1,365 | 109% | 1.6 | 7.8 | 1,362 | 108% | 1.4 | 7.9 | | 1,363 | 108% | 1.2 | 8.1 | | | |
| 12655_10330 | OC | 40 | 5.1 | 5.7 | 6 | 10 | 927 | 284 | 31% | 0.4 | 4.8 | 369 | 40% | 0.5 | 4.8 | | 369 | 40% | 0.5 | 4.8 | | | |
| 12656_10358 | OC | 167 | 7.8 | 7.9 | 10 | 12 | 1,919 | 310 | 16% | 0.3 | 7.5 | 394 | 21% | 0.3 | 7.5 | | 394 | 21% | 0.3 | 7.5 | | | |
| 12684_12699 | TCSD | 298 | 7.3 | 7.5 | 10 | 12 | 823 | 413 | 50% | 0.5 | 6.7 | 615 | 75% | 0.7 | 6.6 | | 615 | 75% | 0.7 | 6.6 | | | |
| 12685_12684 | TCSD | 399 | 7.4 | 7.4 | 10 | 12 | 821 | 408 | 50% | 0.5 | 6.9 | 613 | 75% | 0.7 | 6.8 | | 613 | 75% | 0.7 | 6.8 | | | |
| 12696_12697 | TCSD | 414 | 8.1 | 9.2 | 10 | 12 | 998 | 428 | 43% | 0.5 | 7.6 | 626 | 63% | 0.6 | 7.5 | | 625 | 63% | 0.7 | 7.4 | | | |
| 12697_12698 | TCSD | 57 | 10.3 | 10.4 | 14 | 24 | 5,742 | 428 | 7% | 0.5 | 9.2 | 627 | 11% | 0.7 | 8.9 | | 626 | 11% | 0.8 | 8.7 | | | |
| 12698_10762 | TCSD | 198 | 10.5 | 9.4 | 10 | 48 | 31,723 | 5,647 | 18% | 0.3 | 9.2 | 7,758 | 24% | 0.4 | 9.0 | | 9,181 | 29% | 0.4 | 8.8 | | | |
| 12699_12700 | TCSD | 167 | 7.7 | 8.0 | 10 | 12 | 816 | 417 | 51% | 0.5 | 7.1 | 617 | 76% | 0.7 | 7.0 | | 617 | 76% | 0.7 | 7.0 | | | |
| 12700_12696 | TCSD | 142 | 8.3 | 8.2 | 10 | 12 | 823 | 419 | 51% | 0.5 | 7.8 | 619 | 75% | 0.7 | 7.7 | | 619 | 75% | 0.7 | 7.7 | | | |
| 12713_11139 | OC | 247 | 6.6 | 7.6 | 10 | 12 | 2,459 | 439 | 18% | 0.3 | 6.3 | 1,785 | 73% | 0.7 | 5.9 | | 1,785 | 73% | 0.7 | 5.9 | | | |
| 12744_13701 | OC | 228 | 14.6 | 15.6 | 18 | 10 | 1,675 | 93 | 6% | 0.2 | 14.4 | 175 | 10% | 0.2 | 14.4 | | 175 | 10% | 0.2 | 14.4 | | | |
| 12759_18034 | OC | 113 | 7.2 | 7.3 | 10 | 12 | 2,298 | 509 | 22% | 0.3 | 6.9 | 529 | 23% | 0.3 | 6.9 | | 529 | 23% | 0.3 | 6.9 | | | |
| 12866_14214 | OC | 165 | 18.1 | 17.3 | 18 | 15 | 1,945 | 1,428 | 73% | 0.7 | 17.2 | 1,742 | 90% | 1.7 | 16.0 | | 1,678 | 86% | 0.8 | 17.1 | | | |
| 12903_12655 | OC | 279 | 7.0 | 6.0 | 10 | 10 | 935 | 283 | 30% | 0.4 | 6.6 | 369 | 39% | 0.5 | 6.6 | | 369 | 39% | 0.5 | 6.6 | | | |
| 12930_11142 | TCSD | 157 | 9.5 | 8.5 | 10 | 24 | 25,554 | 2,293 | 9% | 0.2 | 9.1 | 2,612 | 10% | 0.2 | 9.1 | | 2,599 | 10% | 0.2 | 9.1 | | | |
| 12937_11348 | TCSD | 344 | 12.4 | 12.3 | 14 | 48 | 22,643 | 6,108 | 27% | 0.4 | 10.9 | 8,362 | 37% | 0.4 | 10.6 | | 9,781 | 43% | 0.5 | 10.5 | | | |
| 12938_12937 | TCSD | 279 | 12.1 | 12.3 | 14 | 48 | 21,788 | 6,103 | 28% | 0.4 | 10.6 | 8,356 | 38% | 0.4 | 10.3 | | 9,776 | 45% | 0.5 | 10.2 | | | |
| 12939_13810 | TCSD | 204 | 11.7 | 12.5 | 14 | 48 | 21,569 | 6,081 | 28% | 0.4 | 10.2 | 8,301 | 38% | 0.4 | 9.9 | | 9,722 | 45% | 0.5 | 9.8 | | | |
| 12940_12939 | TCSD | 399 | 11.8 | 11.7 | 14 | 48 | 23,668 | 6,078 | 26% | 0.4 | 10.3 | 8,297 | 35% | 0.4 | 10.0 | | 9,717 | 41% | 0.5 | 9.9 | | | |
| 12943_12940 | TCSD | 100 | 14.1 | 12.9 | 14 | 48 | 22,851 | 6,071 | 27% | 0.4 | 12.7 | 8,289 | 36% | 0.4 | 12.4 | | 9,709 | 42% | 0.5 | 12.3 | | | |
| 12944_12943 | TCSD | 347 | 10.4 | 12.3 | 14 | 48 | 19,609 | 5,680 | 29% | 0.4 | 8.9 | 7,810 | 40% | 0.4 | 8.6 | | 9,232 | 47% | 0.5 | 8.4 | | | |
| 12950_10764 | TCSD | 7 | 10.9 | 8.4 | 10 | 24 | 4,089 | 5,247 | 128% | 0.6 | 9.7 | 6,157 | 151% | 0.7 | 9.5 | | 7,572 | 185% | 0.8 | 9.3 | | | |
| 13680_11287 | TCSD | 322 | 12.1 | 11.5 | 14 | 24 | 8,948 | 2,183 | 24% | 0.4 | 11.4 | 2,472 | 28% | 0.4 | 11.3 | | 2,458 | 27% | 0.4 | 11.3 | | | |
| 13691_12903 | OC | 77 | 5.8 | 6.4 | 10 | 10 | 933 | 246 | 26% | 0.4 | 5.5 | 332 | 36% | 0.4 | 5.5 | | 332 | 36% | 0.4 | 5.5 | | | |
| 13696_12375 | OC | 286 | 3.3 | 10.3 | 14 | 12 | 1,001 | 323 | 32% | 0.4 | 2.9 | 426 | 43% | 0.5 | 2.9 | | 426 | 43% | 0.5 | 2.9 | | | |
| 13701_12366 | OC | 25 | 16.7 | 16.7 | 18 | 12 | 2,735 | 94 | 3% | 0.1 | 16.6 | 175 | 6% | 0.2 | 16.5 | | 175 | 6% | 0.2 | 16.5 | | | |
| 13810_12938 | TCSD | 185 | 13.4 | 12.7 | 14 | 48 | 22,112 | 6,098 | 28% | 0.4 | 11.9 | 8,351 | 38% | 0.4 | 11.6 | | 9,771 | 44% | 0.5 | 11.4 | | | |
| 13823_11347 | TCSD | 17 | 11.3 | 9.9 | 10 | 48 | 23,867 | 6,133 | 26% | 0.4 | 9.8 | 8,393 | 35% | 0.4 | 9.6 | | 9,813 | 41% | 0.5 | 9.4 | | | |
| 14088_11309 | OC | 94 | 23.6 | 21.3 | 18 | 15 | 1,674 | 1,167 | 70% | 0.6 | 22.9 | 1,350 | 81% | 0.6 | 22.9 | | 1,331 | 79% | 0.6 | 22.9 | | | |
| 14152_10961 | OC | 170 | 12.2 | 10.7 | 14 | 12 | 132 | 603 | 456% | 0.9 | 11.3 | 742 | 560% | 1.1 | 11.1 | | 710 | 537% | 1.0 | 11.2 | | | |
| 14154_14152 | OC | 108 | 15.2 | 13.7 | 14 | 12 | 162 | 606 | 374% | 1.1 | 14.2 | 734 | 453% | 1.3 | 13.9 | | 709 | 437% | 1.2 | 14.0 | | | |
| 14156_14154 | OC | 33 | 15.2 | 15.2 | 18 | 12 | 296 | 615 | 208% | 1.1 | 14.1 | 728 | 246% | 1.4 | 13.9 | | 711 | 240% | 1.3 | 13.9 | | | |
| 14158_14156 | OC | 58 | 16.2 | 15.7 | 18 | 12 | 223 | 614 | 276% | 1.2 | 15.0 | 727 | 326% | 1.5 | 14.7 | | 703 | 316% | 1.4 | 14.8 | | | |

**Appendix E-1. Existing and Future Modeling Results**

| Existing Pipe and Manhole Characteristics | | | | | | | | Existing Sewers - Existing Flows | | | | Existing Sewers - Buildout Peak Flows | | | | Upsized Sewer - Buildout Peak Flows | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pipe ID | Owner | Length (ft) | U/S MH Depth (ft) | Avg Pipe Depth (ft) | Average Rounded Depth (ft) | Existing Pipe Diameter (in) | Existing Capacity (gpm) | Peak Flow (gpm) | Current % Capacity Used[1] | U/S MH Current d/D [2] | Current U/S MH Freeboard (ft) [3] | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D [2] | Future U/S MH Freeboard (ft) [3] | Upsize Diameter (in) | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D [2] | Future U/S MH Freeboard (ft) [3] | Unit Cost ($/ft) | Current Total Cost ($) | Project Name |
| 14190_11779 | TCSD | 150 | 8.1 | 8.5 | 10 | 18 | 1,745 | 686 | 39% | 0.4 | 7.4 | 1,102 | 63% | 0.9 | 6.7 | | 1,090 | 62% | 0.6 | 7.2 | | | |
| 12064_12654 | OC | 141 | 8.0 | 8.6 | 10 | 8 | 898 | 172 | 19% | 0.3 | 7.8 | 232 | 26% | 0.4 | 7.8 | | 232 | 26% | 0.4 | 7.8 | | | |
| 12331_12330 | OC | 78 | 13.4 | 12.4 | 14 | 8 | 951 | 64 | 7% | 0.2 | 13.3 | 101 | 11% | 0.2 | 13.3 | | 101 | 11% | 0.2 | 13.3 | | | |
| 12330_12329 | OC | 160 | 11.4 | 11.8 | 14 | 8 | 1,169 | 65 | 6% | 0.2 | 11.3 | 113 | 10% | 0.2 | 11.3 | | 113 | 10% | 0.2 | 11.3 | | | |
| 12065_12064 | OC | 206 | 11.1 | 9.6 | 10 | 8 | 514 | 170 | 33% | 0.4 | 10.8 | 231 | 45% | 0.5 | 10.8 | | 231 | 45% | 0.5 | 10.8 | | | |
| 12649_12331 | OC | 375 | 12.5 | 13.0 | 14 | 8 | 683 | 63 | 9% | 0.2 | 12.4 | 100 | 15% | 0.3 | 12.3 | | 100 | 15% | 0.3 | 12.3 | | | |
| 12650_12649 | OC | 378 | 13.6 | 13.1 | 14 | 8 | 400 | 59 | 15% | 0.3 | 13.4 | 91 | 23% | 0.3 | 13.4 | | 91 | 23% | 0.3 | 13.4 | | | |
| 12654_12658 | OC | 224 | 9.1 | 9.0 | 10 | 8 | 776 | 177 | 23% | 0.3 | 8.9 | 237 | 31% | 0.4 | 8.8 | | 237 | 31% | 0.4 | 8.8 | | | |
| 18014_12657 | OC | 111 | 7.3 | 7.1 | 10 | 8 | 958 | 244 | 26% | 0.4 | 7.1 | 331 | 35% | 0.4 | 7.0 | | 331 | 35% | 0.4 | 7.0 | | | |
| 10323_18014 | OC | 286 | 8.5 | 7.9 | 10 | 8 | 1,016 | 209 | 21% | 0.3 | 8.3 | 274 | 27% | 0.4 | 8.3 | | 274 | 27% | 0.4 | 8.3 | | | |
| 12653_10323 | OC | 17 | 7.9 | 8.2 | 10 | 8 | 1,016 | 206 | 20% | 0.3 | 7.7 | 271 | 27% | 0.4 | 7.7 | | 271 | 27% | 0.4 | 7.7 | | | |
| 12651_12650 | OC | 347 | 11.0 | 12.3 | 14 | 8 | 1,028 | 4 | 0% | 0.0 | 11.0 | 4 | 0% | 0.0 | 11.0 | | 4 | 0% | 0.0 | 11.0 | | | |
| 13683_12652 | OC | 12 | 11.9 | 12.1 | 14 | 8 | 1,045 | 0 | 0% | 0.0 | 11.9 | 0 | 0% | 0.0 | 11.9 | | 0 | 0% | 0.0 | 11.9 | | | |
| 12652_12651 | OC | 21 | 12.3 | 11.7 | 14 | 8 | 1,036 | 1 | 0% | 0.0 | 12.3 | 1 | 0% | 0.0 | 12.3 | | 1 | 0% | 0.0 | 12.3 | | | |
| 12658_18013 | OC | 117 | 8.8 | 10.3 | 14 | 8 | 1,280 | 178 | 14% | 0.3 | 8.6 | 238 | 19% | 0.3 | 8.6 | | 238 | 19% | 0.3 | 8.6 | | | |
| 18013_12653 | OC | 218 | 11.8 | 9.9 | 10 | 8 | 1,133 | 182 | 16% | 0.3 | 11.7 | 242 | 21% | 0.3 | 11.6 | | 242 | 21% | 0.3 | 11.6 | | | |
| 18015_12065 | OC | 104 | 11.0 | 11.0 | 14 | 8 | 1,016 | 144 | 14% | 0.3 | 10.8 | 205 | 20% | 0.3 | 10.7 | | 205 | 20% | 0.3 | 10.7 | | | |
| 12329_18015 | OC | 131 | 12.2 | 11.6 | 14 | 8 | 466 | 124 | 27% | 0.4 | 12.0 | 171 | 37% | 0.4 | 11.9 | | 171 | 37% | 0.4 | 11.9 | | | |
| 14533_14534 | OC | 104 | 12.5 | 11.6 | 14 | 8 | 528 | 9 | 2% | 0.1 | 12.5 | 19 | 4% | 0.1 | 12.4 | | 19 | 4% | 0.1 | 12.4 | | | |
| 14534_14535 | OC | 166 | 10.7 | 10.1 | 14 | 8 | 443 | 10 | 2% | 0.1 | 10.7 | 21 | 5% | 0.1 | 10.6 | | 21 | 5% | 0.1 | 10.6 | | | |
| 14536_14671 | OC | 127 | 7.5 | 11.0 | 14 | 8 | 434 | 15 | 3% | 0.1 | 7.4 | 24 | 6% | 0.2 | 7.4 | | 24 | 6% | 0.2 | 7.4 | | | |
| 14671_14672 | OC | 290 | 14.5 | 13.3 | 14 | 8 | 416 | 17 | 4% | 0.1 | 14.4 | 31 | 8% | 0.2 | 14.4 | | 31 | 8% | 0.2 | 14.4 | | | |
| 14672_18015 | OC | 101 | 12.0 | 11.5 | 14 | 8 | 1,056 | 19 | 2% | 0.1 | 12.0 | 33 | 3% | 0.1 | 11.9 | | 33 | 3% | 0.1 | 11.9 | | | |
| 14535_14536 | OC | 227 | 9.4 | 8.5 | 10 | 8 | 442 | 13 | 3% | 0.1 | 9.4 | 23 | 5% | 0.2 | 9.3 | | 23 | 5% | 0.2 | 9.3 | | | |
| 14195_11781 | TCSD | 232 | 8.4 | 7.6 | 10 | 18 | 1,781 | 489 | 27% | 0.4 | 7.9 | 808 | 45% | 0.5 | 7.7 | | 808 | 45% | 0.5 | 7.7 | | | |
| 14206_11788 | OC | 83 | 12.1 | 12.7 | 14 | 12 | 1,164 | 1,424 | 122% | 1.4 | 10.7 | 1,469 | 126% | 2.3 | 9.8 | | 1,472 | 126% | 2.1 | 10.0 | | | |
| 14214_11784 | OC | 208 | 16.6 | 15.7 | 18 | 15 | 1,960 | 1,435 | 73% | 0.7 | 15.8 | 1,751 | 89% | 1.6 | 14.6 | | 1,685 | 86% | 0.8 | 15.6 | | | |
| 14288_11144 | OC | 291 | 8.3 | 10.5 | 14 | 10 | 1,098 | 102 | 9% | 0.2 | 8.2 | 102 | 9% | 0.2 | 8.2 | | 102 | 9% | 0.2 | 8.2 | | | |
| 14289_14288 | OC | 12 | 8.8 | 8.6 | 10 | 10 | 1,099 | 95 | 9% | 0.2 | 8.6 | 95 | 9% | 0.2 | 8.6 | | 95 | 9% | 0.2 | 8.6 | | | |
| 14304_11130 | TCSD | 354 | 8.2 | 14.4 | 18 | 24 | 24,076 | 2,327 | 10% | 0.2 | 7.8 | 2,646 | 11% | 0.2 | 7.8 | | 2,633 | 11% | 0.2 | 7.8 | | | |
| 14314_18006 | TCSD | 87 | 10.5 | 10.2 | 14 | 24 | 6,042 | 2,267 | 38% | 0.4 | 9.6 | 2,578 | 43% | 0.5 | 9.6 | | 2,565 | 42% | 0.5 | 9.6 | | | |
| 14323_11278 | TCSD | 43 | 10.7 | 11.3 | 14 | 24 | 8,113 | 2,263 | 28% | 0.4 | 9.9 | 2,570 | 32% | 0.4 | 9.8 | | 2,556 | 32% | 0.4 | 9.8 | | | |
| 14617_14642 | OC | 166 | 11.4 | 9.3 | 10 | 12 | 1,326 | 338 | 25% | 0.4 | 11.1 | 441 | 33% | 0.4 | 11.0 | | 441 | 33% | 0.4 | 11.0 | | | |
| 14642_12372 | OC | 289 | 7.1 | 5.1 | 6 | 12 | 985 | 340 | 35% | 0.4 | 6.7 | 444 | 45% | 0.5 | 6.6 | | 444 | 45% | 0.5 | 6.6 | | | |
| 14937_11296 | OC | 83 | 15.9 | 14.4 | 18 | 10 | 958 | 532 | 56% | 0.6 | 15.4 | 552 | 58% | 0.8 | 15.3 | | 552 | 58% | 0.8 | 15.3 | | | |
| 14938_14937 | OC | 318 | 12.0 | 14.0 | 14 | 10 | 1,201 | 530 | 44% | 0.5 | 11.6 | 550 | 46% | 0.5 | 11.6 | | 550 | 46% | 0.5 | 11.6 | | | |
| 14940_14938 | OC | 108 | 12.8 | 12.4 | 14 | 10 | 1,201 | 518 | 43% | 0.5 | 12.4 | 538 | 45% | 0.5 | 12.4 | | 538 | 45% | 0.5 | 12.4 | | | |
| 14941_14940 | OC | 78 | 9.0 | 10.9 | 14 | 10 | 1,480 | 514 | 35% | 0.4 | 8.7 | 534 | 36% | 0.4 | 8.7 | | 534 | 36% | 0.4 | 8.7 | | | |
| 14968_14969 | OC | 231 | 8.0 | 10.1 | 14 | 12 | 1,148 | 414 | 36% | 0.4 | 7.6 | 433 | 38% | 0.5 | 7.6 | | 433 | 38% | 0.5 | 7.6 | | | |
| 14969_14970 | OC | 341 | 12.2 | 14.2 | 18 | 12 | 979 | 449 | 46% | 0.5 | 11.7 | 468 | 48% | 0.5 | 11.7 | | 468 | 48% | 0.5 | 11.7 | | | |
| 14970_14971 | OC | 330 | 16.1 | 15.9 | 18 | 12 | 835 | 461 | 55% | 0.6 | 15.6 | 481 | 58% | 0.6 | 15.6 | | 481 | 58% | 0.6 | 15.6 | | | |
| 14971_14972 | OC | 112 | 15.7 | 14.6 | 18 | 12 | 626 | 483 | 77% | 0.6 | 15.1 | 503 | 80% | 0.7 | 15.1 | | 503 | 80% | 0.7 | 15.1 | | | |
| 14972_11334 | OC | 150 | 13.4 | 12.3 | 14 | 12 | 1,226 | 494 | 40% | 0.5 | 13.0 | 514 | 42% | 0.5 | 13.0 | | 514 | 42% | 0.5 | 13.0 | | | |
| 18006_11141 | TCSD | 102 | 9.9 | 9.6 | 10 | 24 | 5,031 | 2,270 | 45% | 0.4 | 9.1 | 2,582 | 51% | 0.4 | 9.0 | | 2,569 | 51% | 0.4 | 9.0 | | | |
| 18007_11290 | TCSD | 220 | 18.5 | 16.3 | 18 | 24 | 6,290 | 2,252 | 36% | 0.4 | 17.7 | 2,560 | 41% | 0.5 | 17.6 | | 2,547 | 40% | 0.5 | 17.6 | | | |
| 18009_11999 | OC | 233 | 6.3 | 11.4 | 14 | 12 | 3,485 | 574 | 16% | 0.3 | 6.1 | 692 | 20% | 0.3 | 6.0 | | 676 | 19% | 0.3 | 6.0 | | | |
| 18033_14323 | TCSD | 60 | 10.3 | 10.5 | 14 | 24 | 8,149 | 2,262 | 28% | 0.4 | 9.6 | 2,569 | 32% | 0.4 | 9.5 | | 2,556 | 31% | 0.4 | 9.5 | | | |
| 18034_14941 | OC | 58 | 7.5 | 8.2 | 10 | 10 | 1,483 | 511 | 34% | 0.4 | 7.1 | 531 | 36% | 0.4 | 7.1 | | 531 | 36% | 0.4 | 7.1 | | | |

**Appendix E-1. Existing and Future Modeling Results**

| Existing Pipe and Manhole Characteristics | | | | | | | | Existing Sewers - Existing Flows | | | | Existing Sewers - Buildout Peak Flows | | | | Upsized Sewer - Buildout Peak Flows | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pipe ID | Owner | Length (ft) | U/S MH Depth (ft) | Avg Pipe Depth (ft) | Average Rounded Depth (ft) | Existing Pipe Diameter (in) | Existing Capacity (gpm) | Peak Flow (gpm) | Current % Capacity Used[1] | U/S MH Current d/D [2] | Current U/S MH Freeboard (ft) [3] | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D [2] | Future U/S MH Freeboard (ft) [3] | Upsize Diameter (in) | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D [2] | Future U/S MH Freeboard (ft) [3] | Unit Cost ($/ft) | Current Total Cost ($) | Project Name |
| **South Model** | | | | | | | | | | | | | | | | | | | | | | | |
| 10056_10071 | OC | 287 | 11.1 | 14.2 | 18 | 8 | 398 | 539 | 135% | 12.4 | 2.8 | 538 | 135% | 12.5 | 2.8 | 10 | 638 | 88% | 0.8 | 10.5 | 677 | 194,127 | Division Street |
| 10057_10172 | OC | 142 | 11.9 | 10.7 | 14 | 8 | 807 | 789 | 98% | 2.1 | 10.4 | 790 | 98% | 2.2 | 10.4 | 10 | 910 | 62% | 0.6 | 11.4 | 514 | 72,918 | 13th Street |
| 10060_10170 | OC | 216 | 15.6 | 14.0 | 14 | 8 | 549 | 642 | 117% | 8.8 | 9.8 | 642 | 117% | 8.9 | 9.7 | 10 | 750 | 75% | 0.7 | 15.1 | 514 | 111,222 | 13th Street |
| 10063_10064 | OC | 144 | 17.5 | 17.0 | 18 | 8 | 488 | 585 | 120% | 9.9 | 10.9 | 585 | 120% | 10.0 | 10.8 | 10 | 690 | 78% | 0.7 | 16.9 | 677 | 97,388 | Division Street |
| 10064_10060 | OC | 110 | 16.6 | 16.1 | 18 | 8 | 572 | 592 | 103% | 9.1 | 10.5 | 592 | 103% | 9.1 | 10.5 | 10 | 697 | 67% | 0.6 | 16.1 | 677 | 74,337 | 13th Street |
| 10071_10063 | OC | 167 | 17.2 | 17.3 | 18 | 8 | 487 | 549 | 113% | 10.5 | 10.2 | 549 | 113% | 10.6 | 10.1 | 10 | 649 | 73% | 0.7 | 16.6 | 677 | 112,880 | Division Street |
| 10088_10185 | OC | 298 | 10.0 | 9.4 | 10 | 12 | 5,584 | 2,097 | 38% | 0.4 | 9.5 | 2,138 | 38% | 0.5 | 9.5 | | 2,138 | 38% | 0.5 | 9.5 | | | |
| 10089_13087 | OC | 291 | 8.5 | 8.0 | 10 | 8 | 912 | 536 | 59% | 0.6 | 8.1 | 538 | 59% | 0.6 | 8.1 | | 538 | 59% | 0.6 | 8.1 | | | |
| 10093_13910 | OC | 221 | 14.3 | 21.3 | 18 | 8 | 603 | 744 | 123% | 3.2 | 12.2 | 747 | 124% | 3.2 | 12.2 | | 747 | 124% | 3.3 | 12.2 | | | |
| 10122_10177 | OC | 291 | 7.1 | 11.1 | 14 | 10 | 1,181 | 861 | 73% | 0.7 | 6.5 | 861 | 73% | 0.7 | 6.5 | | 982 | 83% | 0.7 | 6.5 | | | |
| 10123_11365 | OC | 275 | 7.9 | 7.7 | 10 | 12 | 1,930 | 1,510 | 78% | 0.8 | 7.1 | 1,516 | 79% | 0.8 | 7.1 | | 1,635 | 85% | 0.8 | 7.0 | | | |
| 10124_10123 | OC | 266 | 12.7 | 10.3 | 14 | 12 | 2,123 | 1,476 | 70% | 0.6 | 12.1 | 1,481 | 70% | 0.6 | 12.1 | | 1,601 | 75% | 0.7 | 12.1 | | | |
| 10125_10124 | OC | 263 | 10.5 | 11.6 | 14 | 10 | 2,603 | 1,084 | 42% | 0.5 | 10.1 | 1,084 | 42% | 0.5 | 10.1 | | 1,215 | 47% | 0.5 | 10.0 | | | |
| 10126_10125 | OC | 33 | 10.7 | 10.6 | 14 | 10 | 1,122 | 1,053 | 94% | 0.8 | 10.0 | 1,053 | 94% | 0.8 | 10.0 | | 1,235 | 110% | 0.9 | 9.9 | | | |
| 10127_10126 | OC | 287 | 13.0 | 11.9 | 14 | 10 | 4,386 | 1,031 | 23% | 0.3 | 12.7 | 1,031 | 24% | 0.3 | 12.7 | | 1,151 | 26% | 0.4 | 12.7 | | | |
| 10128_10127 | OC | 234 | 12.0 | 12.5 | 14 | 10 | 2,738 | 1,001 | 37% | 0.5 | 11.6 | 1,001 | 37% | 0.5 | 11.6 | | 1,122 | 41% | 0.5 | 11.6 | | | |
| 10129_10128 | OC | 9 | 11.4 | 11.7 | 14 | 10 | 3,780 | 975 | 26% | 0.4 | 11.1 | 976 | 26% | 0.4 | 11.1 | | 1,096 | 29% | 0.4 | 11.0 | | | |
| 10131_10129 | OC | 200 | 10.8 | 11.1 | 14 | 10 | 2,468 | 963 | 39% | 0.5 | 10.4 | 963 | 39% | 0.5 | 10.4 | | 1,083 | 44% | 0.5 | 10.4 | | | |
| 10132_10131 | OC | 26 | 10.2 | 10.5 | 14 | 10 | 3,081 | 931 | 30% | 0.4 | 9.8 | 932 | 30% | 0.4 | 9.8 | | 1,052 | 34% | 0.4 | 9.8 | | | |
| 10152_10157 | OC | 248 | 5.7 | 7.1 | 10 | 8 | 2,089 | 375 | 18% | 0.3 | 5.5 | 376 | 18% | 0.3 | 5.5 | | 376 | 18% | 0.3 | 5.5 | | | |
| 10156_10259 | OC | 269 | 18.5 | 12.9 | 14 | 8 | 1,714 | 1,003 | 59% | 0.6 | 18.1 | 1,006 | 59% | 0.6 | 18.1 | | 1,006 | 59% | 0.6 | 18.1 | | | |
| 10157_10273 | OC | 272 | 8.5 | 9.0 | 10 | 8 | 1,782 | 1,449 | 81% | 0.7 | 8.0 | 1,452 | 81% | 0.7 | 8.0 | | 1,452 | 81% | 0.7 | 8.0 | | | |
| 10158_12403 | OC | 145 | 9.1 | 11.5 | 14 | 12 | 1,714 | 1,731 | 101% | 3.5 | 5.6 | 1,736 | 101% | 3.6 | 5.5 | | 1,853 | 108% | 2.2 | 6.9 | | | |
| 10170_10171 | OC | 203 | 12.3 | 9.3 | 10 | 8 | 572 | 705 | 123% | 7.4 | 7.3 | 706 | 123% | 7.4 | 7.3 | 10 | 816 | 79% | 0.7 | 11.7 | 372 | 75,618 | 13th Street |
| 10171_10057 | OC | 339 | 6.4 | 9.1 | 10 | 8 | 583 | 726 | 125% | 5.4 | 2.8 | 726 | 125% | 5.4 | 2.8 | 10 | 838 | 79% | 0.7 | 5.8 | 372 | 126,350 | 13th Street |
| 10172_10173 | OC | 100 | 9.5 | 9.4 | 10 | 8 | 1,071 | 795 | 74% | 0.7 | 9.1 | 796 | 74% | 0.7 | 9.1 | | 917 | 86% | 0.7 | 9.0 | | | |
| 10173_10122 | OC | 214 | 9.2 | 8.2 | 10 | 8 | 972 | 842 | 87% | 0.8 | 8.7 | 843 | 87% | 0.8 | 8.7 | | 963 | 99% | 0.9 | 8.7 | | | |
| 10175_10132 | OC | 39 | 9.4 | 9.8 | 10 | 10 | 2,455 | 917 | 37% | 0.4 | 9.1 | 917 | 37% | 0.4 | 9.1 | | 1,038 | 42% | 0.5 | 9.0 | | | |
| 10176_10175 | OC | 145 | 13.6 | 11.5 | 14 | 10 | 1,216 | 915 | 75% | 0.7 | 13.0 | 915 | 75% | 0.7 | 13.0 | | 1,035 | 85% | 0.8 | 12.9 | | | |
| 10177_10176 | OC | 48 | 15.1 | 14.3 | 18 | 10 | 981 | 891 | 91% | 0.8 | 14.5 | 892 | 91% | 0.8 | 14.5 | | 1,013 | 103% | 0.9 | 14.4 | | | |
| 10185_10186 | OC | 11 | 8.8 | 8.6 | 10 | 12 | 3,197 | 2,097 | 66% | 0.6 | 8.2 | 2,138 | 67% | 0.6 | 8.2 | | 2,138 | 67% | 0.6 | 8.2 | | | |
| 10186_10189 | OC | 273 | 8.4 | 9.4 | 10 | 18 | 14,310 | 2,115 | 15% | 0.3 | 8.0 | 2,155 | 15% | 0.3 | 8.0 | | 2,156 | 15% | 0.3 | 8.0 | | | |
| 10189_10380 | OC | 274 | 10.4 | 15.3 | 18 | 18 | 11,463 | 2,158 | 19% | 0.3 | 9.9 | 2,198 | 19% | 0.3 | 9.9 | | 2,198 | 19% | 0.3 | 9.9 | | | |
| 10190_13059 | OC | 271 | 9.1 | 8.9 | 10 | 24 | 22,100 | 5,563 | 25% | 0.4 | 8.4 | 5,632 | 25% | 0.4 | 8.4 | | 5,628 | 25% | 0.4 | 8.4 | | | |
| 10191_10190 | OC | 307 | 12.2 | 10.7 | 14 | 24 | 13,147 | 5,541 | 42% | 0.5 | 11.3 | 5,610 | 43% | 0.5 | 11.3 | | 5,606 | 43% | 0.5 | 11.3 | | | |
| 10194_10716 | OC | 273 | 10.4 | 10.5 | 14 | 18 | 5,904 | 2,231 | 38% | 0.4 | 9.8 | 2,272 | 38% | 0.5 | 9.8 | | 2,272 | 38% | 0.5 | 9.8 | | | |
| 10205_10206 | OC | 178 | 11.5 | 11.2 | 14 | 18 | 4,827 | 3,444 | 71% | 0.7 | 10.5 | 3,487 | 72% | 0.7 | 10.5 | | 3,487 | 72% | 0.7 | 10.5 | | | |
| 10206_10208 | OC | 125 | 10.9 | 10.4 | 14 | 18 | 3,774 | 3,454 | 92% | 0.8 | 9.7 | 3,498 | 93% | 0.8 | 9.7 | | 3,498 | 93% | 0.8 | 9.7 | | | |
| 10208_10215 | OC | 38 | 9.9 | 10.0 | 10 | 18 | 5,108 | 3,456 | 68% | 0.6 | 8.9 | 3,499 | 68% | 0.6 | 8.9 | | 3,499 | 68% | 0.6 | 8.9 | | | |
| 10215_10714 | OC | 130 | 10.1 | 9.4 | 10 | 24 | 22,828 | 5,420 | 24% | 0.3 | 9.4 | 5,491 | 24% | 0.3 | 9.4 | | 5,486 | 24% | 0.3 | 9.4 | | | |
| 10236_10665 | OC | 199 | 12.6 | 16.5 | 18 | 12 | 4,815 | 3,417 | 71% | 0.7 | 12.0 | 3,430 | 71% | 0.7 | 12.0 | | 3,544 | 74% | 0.7 | 11.9 | | | |
| 10237_10236 | OC | 78 | 9.6 | 11.1 | 14 | 12 | 4,885 | 3,405 | 70% | 0.6 | 9.0 | 3,417 | 70% | 0.7 | 9.0 | | 3,531 | 72% | 0.7 | 9.0 | | | |
| 10259_10157 | OC | 346 | 7.3 | 7.9 | 10 | 8 | 957 | 1,057 | 110% | 9.0 | 1.3 | 1,059 | 111% | 8.2 | 1.9 | 10 | 1,059 | 61% | 0.6 | 6.9 | 372 | 128,789 | 12th Street |
| 10261_10734 | TCSD | 121 | 8.2 | 8.7 | 10 | 18 | 5,187 | 4,872 | 94% | 0.8 | 7.0 | 6,604 | 127% | 5.8 | -0.5 | | 6,646 | 128% | 5.5 | 0.0 | | | |
| 10264_10269 | TCSD | 282 | 7.6 | 8.2 | 10 | 45 | 24,678 | 21,146 | 86% | 0.8 | 4.6 | 23,203 | 94% | 0.9 | 4.3 | | 23,285 | 94% | 0.9 | 4.3 | | | |
| 10265_10264 | TCSD | 27 | 7.8 | 7.7 | 10 | 45 | 48,253 | 21,154 | 44% | 0.7 | 5.0 | 23,216 | 48% | 0.8 | 4.6 | | 23,363 | 48% | 0.8 | 4.6 | | | |
| 10266_10668 | TCSD | 78 | 9.0 | 6.2 | 10 | 30 | 10,429 | 16,404 | 157% | 1.7 | 4.8 | 18,335 | 176% | 2.1 | 3.8 | | 18,413 | 177% | 2.1 | 3.9 | | | |
| 10267_10266 | TCSD | 269 | 13.2 | 11.1 | 14 | 30 | 10,668 | 16,402 | 154% | 2.2 | 7.6 | 18,333 | 172% | 2.9 | 5.9 | | 18,409 | 173% | 2.8 | 6.1 | | | |
| 10268_11382 | TCSD | 391 | 8.6 | 7.6 | 10 | 45 | 21,313 | 21,141 | 99% | 0.8 | 5.4 | 23,193 | 109% | 0.9 | 5.1 | | 23,272 | 109% | 0.9 | 5.1 | | | |
| 10269_10268 | TCSD | 79 | 8.7 | 8.6 | 10 | 45 | 24,473 | 21,138 | 86% | 0.8 | 5.6 | 23,196 | 95% | 0.9 | 5.3 | | 23,288 | 95% | 0.9 | 5.3 | | | |
| 10270_10271 | OC | 194 | 11.2 | 13.0 | 14 | 8 | 1,654 | 635 | 38% | 0.4 | 10.9 | 637 | 38% | 0.4 | 10.9 | | 637 | 38% | 0.4 | 10.9 | | | |
| 10271_10093 | OC | 138 | 14.9 | 14.6 | 18 | 8 | 1,402 | 708 | 50% | 0.5 | 14.5 | 710 | 51% | 0.5 | 14.5 | | 710 | 51% | 0.5 | 14.5 | | | |
| 10273_10237 | OC | 271 | 9.5 | 9.6 | 10 | 12 | 4,908 | 3,272 | 67% | 0.6 | 8.9 | 3,284 | 67% | 0.6 | 8.9 | | 3,398 | 69% | 0.6 | 8.9 | | | |
| 10312_11859 | OC | 260 | 9.1 | 8.0 | 10 | 10 | 806 | 1,025 | 127% | 4.1 | 5.7 | 1,029 | 128% | 4.2 | 5.6 | 12 | 1,190 | 91% | 0.8 | 8.3 | 490 | 127,524 | Hazelwood |
| 10334_11725 | OC | 307 | 14.5 | 19.2 | 18 | 15 | 1,457 | 567 | 39% | 0.4 | 14.0 | 582 | 40% | 0.5 | 14.0 | | 582 | 40% | 0.5 | 14.0 | | | |

**Appendix E-1. Existing and Future Modeling Results**

| Existing Pipe and Manhole Characteristics | | | | | | | | Existing Sewers - Existing Flows | | | | Existing Sewers - Buildout Peak Flows | | | | Upsized Sewer - Buildout Peak Flows | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pipe ID | Owner | Length (ft) | U/S MH Depth (ft) | Avg Pipe Depth (ft) | Average Rounded Depth (ft) | Existing Pipe Diameter (in) | Existing Capacity (gpm) | Peak Flow (gpm) | Current % Capacity Used[1] | U/S MH Current d/D [2] | Current U/S MH Freeboard (ft) [3] | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D [2] | Future U/S MH Freeboard (ft) [3] | Upsize Diameter (in) | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D [2] | Future U/S MH Freeboard (ft) [3] | Unit Cost ($/ft) | Current Total Cost ($) | Project Name |
| 10379_10194 | OC | 263 | 18.2 | 14.3 | 18 | 18 | 11,352 | 2,208 | 19% | 0.3 | 17.8 | 2,249 | 20% | 0.3 | 17.8 | | 2,249 | 20% | 0.3 | 17.8 | | | |
| 10380_13078 | OC | 267 | 20.2 | 20.3 | 18 | 18 | 11,451 | 2,174 | 19% | 0.3 | 19.7 | 2,215 | 19% | 0.3 | 19.7 | | 2,215 | 19% | 0.3 | 19.7 | | | |
| 10664_11402 | OC | 234 | 19.0 | 13.3 | 14 | 12 | 4,783 | 3,653 | 76% | 0.8 | 18.2 | 3,666 | 77% | 0.8 | 18.2 | | 3,780 | 79% | 0.7 | 18.3 | | | |
| 10665_10664 | OC | 36 | 20.4 | 19.7 | 18 | 12 | 2,503 | 3,624 | 145% | 2.0 | 18.4 | 3,637 | 145% | 2.0 | 18.4 | | 3,751 | 150% | 2.2 | 18.3 | | | |
| 10668_18000 | TCSD | 43 | 3.3 | 5.3 | 6 | 30 | 7,361 | 16,428 | 223% | 1.5 | 0.0 | 18,364 | 249% | 1.8 | 0.0 | | 18,445 | 251% | 1.8 | 0.0 | | | |
| 10669_10670 | TCSD | 55 | 8.1 | 7.8 | 10 | 36 | 10,562 | 16,431 | 156% | 1.0 | 5.1 | 18,401 | 174% | 1.2 | 4.7 | | 18,476 | 175% | 1.2 | 4.6 | | | |
| 10670_10265 | TCSD | 45 | 7.5 | 7.6 | 10 | 36 | 9,490 | 16,431 | 173% | 1.0 | 4.6 | 18,369 | 194% | 1.1 | 4.1 | | 18,465 | 195% | 1.1 | 4.1 | | | |
| 10671_10672 | TCSD | 248 | 3.2 | 3.2 | 6 | 16 | 5,545 | 4,873 | 88% | 0.8 | 2.1 | 6,581 | 119% | 9.0 | 0.0 | | 6,628 | 120% | 8.5 | 1.9 | | | |
| 10672_10673 | TCSD | 86 | 3.3 | 5.0 | 6 | 16 | 7,937 | 4,872 | 61% | 0.6 | 2.5 | 6,589 | 83% | 5.7 | -4.3 | | 6,633 | 84% | 5.8 | -4.5 | | | |
| 10673_10261 | TCSD | 59 | 6.7 | 7.4 | 10 | 16 | 6,425 | 4,876 | 76% | 0.7 | 5.8 | 6,593 | 103% | 6.5 | -2.0 | | 6,638 | 103% | 6.4 | -1.9 | | | |
| 10683_10689 | OC | 321 | 8.0 | 9.4 | 10 | 8 | 456 | 211 | 46% | 0.5 | 7.7 | 213 | 47% | 0.5 | 7.7 | | 213 | 47% | 0.5 | 7.7 | | | |
| 10689_10690 | OC | 180 | 10.8 | 12.1 | 14 | 18 | 2,519 | 3,169 | 126% | 1.0 | 9.3 | 3,211 | 127% | 1.1 | 9.2 | | 3,211 | 127% | 1.1 | 9.2 | | | |
| 10690_10691 | OC | 14 | 13.3 | 13.3 | 14 | 18 | 4,817 | 3,171 | 66% | 0.8 | 12.1 | 3,213 | 67% | 0.8 | 12.0 | | 3,213 | 67% | 0.8 | 12.0 | | | |
| 10691_10205 | OC | 161 | 13.4 | 12.5 | 14 | 18 | 2,863 | 3,194 | 112% | 0.9 | 12.1 | 3,235 | 113% | 0.9 | 12.1 | | 3,235 | 113% | 0.9 | 12.1 | | | |
| 10694_10689 | OC | 273 | 9.8 | 10.3 | 14 | 12 | 3,061 | 2,937 | 96% | 0.9 | 8.9 | 2,977 | 97% | 0.9 | 8.9 | | 2,977 | 97% | 0.9 | 8.9 | | | |
| 10695_10694 | OC | 253 | 11.4 | 10.6 | 14 | 12 | 2,457 | 2,919 | 119% | 4.5 | 6.9 | 2,959 | 120% | 4.6 | 6.8 | | 2,959 | 120% | 4.6 | 6.8 | | | |
| 10696_10695 | OC | 15 | 9.1 | 10.2 | 14 | 12 | 6,770 | 2,903 | 43% | 2.8 | 6.3 | 2,943 | 43% | 2.8 | 6.3 | | 2,944 | 43% | 2.7 | 6.3 | | | |
| 10697_10696 | OC | 268 | 9.2 | 9.1 | 10 | 12 | 3,046 | 2,901 | 95% | 3.1 | 6.1 | 2,941 | 97% | 3.3 | 6.0 | | 2,942 | 97% | 3.3 | 6.0 | | | |
| 10699_10697 | OC | 274 | 7.2 | 8.2 | 10 | 12 | 3,579 | 2,896 | 81% | 0.7 | 6.4 | 2,935 | 82% | 0.8 | 6.4 | | 2,935 | 82% | 0.8 | 6.4 | | | |
| 10700_10699 | OC | 8 | 7.1 | 7.1 | 10 | 12 | 3,584 | 2,835 | 79% | 0.7 | 6.4 | 2,874 | 80% | 0.7 | 6.4 | | 2,874 | 80% | 0.7 | 6.4 | | | |
| 10702_10700 | OC | 238 | 8.4 | 7.8 | 10 | 12 | 4,146 | 2,835 | 68% | 0.6 | 7.8 | 2,874 | 69% | 0.6 | 7.8 | | 2,874 | 69% | 0.6 | 7.8 | | | |
| 10704_10702 | OC | 26 | 8.3 | 8.4 | 10 | 12 | 4,494 | 2,804 | 62% | 0.6 | 7.7 | 2,843 | 63% | 0.6 | 7.7 | | 2,843 | 63% | 0.6 | 7.7 | | | |
| 10714_10715 | OC | 62 | 8.7 | 8.4 | 10 | 24 | 22,808 | 5,424 | 24% | 0.4 | 8.0 | 5,494 | 24% | 0.4 | 8.0 | | 5,490 | 24% | 0.4 | 8.0 | | | |
| 10715_13870 | OC | 37 | 8.1 | 13.1 | 14 | 24 | 67,601 | 5,497 | 8% | 0.2 | 7.7 | 5,565 | 8% | 0.2 | 7.7 | | 5,561 | 8% | 0.2 | 7.7 | | | |
| 10716_10215 | OC | 257 | 10.5 | 10.3 | 14 | 18 | 7,063 | 2,247 | 32% | 0.4 | 9.9 | 2,288 | 32% | 0.4 | 9.9 | | 2,288 | 32% | 0.4 | 9.9 | | | |
| 10722_10267 | TCSD | 378 | 9.2 | 11.2 | 14 | 24 | 7,165 | 5,090 | 71% | 2.3 | 4.5 | 6,981 | 97% | 4.0 | 1.3 | | 7,013 | 98% | 3.7 | 1.7 | | | |
| 10723_10722 | TCSD | 101 | 4.5 | 6.9 | 10 | 24 | 6,556 | 4,970 | 76% | 2.2 | 0.0 | 6,847 | 104% | 4.1 | -3.6 | | 6,881 | 105% | 3.8 | -3.1 | | | |
| 10727_10728 | TCSD | 223 | 10.5 | 10.1 | 14 | 24 | 6,336 | 4,956 | 78% | 2.0 | 6.4 | 6,824 | 108% | 4.2 | 2.0 | | 6,862 | 108% | 3.9 | 2.6 | | | |
| 10728_10723 | TCSD | 81 | 9.8 | 7.2 | 10 | 24 | 6,022 | 4,965 | 82% | 2.2 | 5.4 | 6,834 | 113% | 4.1 | 1.5 | | 6,868 | 114% | 3.9 | 2.1 | | | |
| 10729_10671 | TCSD | 309 | 3.2 | 3.2 | 6 | 16 | 7,159 | 4,895 | 68% | 0.6 | 2.4 | 6,567 | 92% | 10.4 | -10.7 | | 6,614 | 92% | 9.0 | -8.7 | | | |
| 10734_13881 | TCSD | 90 | 9.2 | 9.4 | 10 | 18 | 6,925 | 4,773 | 69% | 0.9 | 7.9 | 6,617 | 96% | 5.3 | 1.2 | | 6,660 | 96% | 4.9 | 1.9 | | | |
| 10736_10737 | TCSD | 250 | 3.1 | 3.1 | 6 | 16 | 7,895 | 4,957 | 63% | 0.6 | 2.3 | 6,767 | 86% | 4.5 | -2.9 | | 6,747 | 85% | 5.2 | -3.9 | | | |
| 10737_10729 | TCSD | 390 | 3.1 | 3.1 | 6 | 16 | 7,816 | 4,927 | 63% | 0.6 | 2.3 | 6,550 | 84% | 7.4 | -6.8 | | 6,596 | 84% | 8.0 | -7.7 | | | |
| 10795_10158 | OC | 326 | 9.4 | 9.3 | 10 | 12 | 1,549 | 1,576 | 102% | 4.0 | 5.4 | 1,581 | 102% | 4.1 | 5.3 | | 1,699 | 110% | 3.5 | 5.9 | | | |
| 10803_10829 | OC | 117 | 13.3 | 11.0 | 14 | 15 | 1,568 | 1,037 | 66% | 0.6 | 12.5 | 1,053 | 67% | 0.6 | 12.5 | | 1,053 | 67% | 0.6 | 12.5 | | | |
| 10804_10803 | OC | 406 | 8.2 | 10.7 | 14 | 15 | 1,568 | 1,022 | 65% | 0.6 | 7.4 | 1,038 | 66% | 0.6 | 7.4 | | 1,038 | 66% | 0.6 | 7.4 | | | |
| 10809_10810 | OC | 130 | 18.1 | 14.8 | 18 | 15 | 1,460 | 1,168 | 80% | 0.6 | 17.4 | 1,186 | 81% | 0.6 | 17.4 | | 1,186 | 81% | 0.6 | 17.4 | | | |
| 10810_10817 | OC | 233 | 11.4 | 12.4 | 14 | 15 | 4,073 | 1,183 | 29% | 0.4 | 10.9 | 1,201 | 29% | 0.4 | 10.9 | | 1,201 | 29% | 0.4 | 10.9 | | | |
| 10811_10809 | OC | 241 | 9.6 | 13.9 | 14 | 15 | 1,453 | 1,112 | 77% | 0.7 | 8.7 | 1,130 | 78% | 0.7 | 8.7 | | 1,130 | 78% | 0.7 | 8.7 | | | |
| 10817_10818 | OC | 210 | 13.4 | 12.7 | 14 | 15 | 6,747 | 1,235 | 18% | 0.3 | 13.1 | 1,253 | 19% | 0.3 | 13.1 | | 1,253 | 19% | 0.3 | 13.1 | | | |
| 10818_11454 | OC | 182 | 11.9 | 13.6 | 14 | 15 | 4,200 | 1,247 | 30% | 0.4 | 11.4 | 1,265 | 30% | 0.4 | 11.4 | | 1,265 | 30% | 0.4 | 11.4 | | | |
| 10826_10334 | OC | 332 | 11.3 | 12.9 | 14 | 15 | 1,463 | 548 | 37% | 0.4 | 10.7 | 563 | 38% | 0.4 | 10.7 | | 563 | 38% | 0.4 | 10.7 | | | |
| 10827_10826 | OC | 118 | 4.8 | 8.0 | 10 | 15 | 1,453 | 367 | 25% | 0.4 | 4.3 | 381 | 26% | 0.4 | 4.3 | | 381 | 26% | 0.4 | 4.3 | | | |
| 10828_10827 | OC | 41 | 5.2 | 5.0 | 6 | 15 | 1,365 | 360 | 26% | 0.4 | 4.7 | 373 | 27% | 0.4 | 4.7 | | 373 | 27% | 0.4 | 4.7 | | | |
| 10829_10830 | OC | 128 | 8.6 | 8.3 | 10 | 15 | 1,399 | 1,044 | 75% | 0.7 | 7.8 | 1,063 | 76% | 0.7 | 7.8 | | 1,063 | 76% | 0.7 | 7.8 | | | |
| 10830_10832 | OC | 111 | 7.9 | 7.0 | 10 | 15 | 1,470 | 1,051 | 72% | 0.7 | 7.1 | 1,069 | 73% | 0.7 | 7.1 | | 1,069 | 73% | 0.7 | 7.1 | | | |
| 10831_10804 | OC | 241 | 22.9 | 15.5 | 18 | 15 | 1,307 | 692 | 53% | 0.5 | 22.2 | 708 | 54% | 0.5 | 22.2 | | 708 | 54% | 0.5 | 22.2 | | | |
| 10832_10833 | OC | 90 | 6.1 | 5.5 | 6 | 15 | 1,460 | 1,057 | 72% | 0.7 | 5.3 | 1,075 | 74% | 0.7 | 5.3 | | 1,075 | 74% | 0.7 | 5.3 | | | |
| 10833_10811 | OC | 113 | 4.8 | 7.2 | 10 | 15 | 1,486 | 1,065 | 72% | 0.7 | 4.0 | 1,082 | 73% | 0.7 | 4.0 | | 1,082 | 73% | 0.7 | 4.0 | | | |
| 10863_10864 | OC | 57 | 5.2 | 5.7 | 6 | 12 | 3,866 | 1,219 | 32% | 0.4 | 4.8 | 1,242 | 32% | 0.4 | 4.8 | | 1,242 | 32% | 0.4 | 4.8 | | | |
| 10864_10866 | OC | 94 | 6.1 | 5.7 | 6 | 12 | 3,505 | 1,284 | 37% | 0.5 | 5.7 | 1,306 | 37% | 0.5 | 5.7 | | 1,306 | 37% | 0.5 | 5.7 | | | |
| 10866_11582 | OC | 139 | 5.3 | 5.6 | 6 | 12 | 4,796 | 1,314 | 27% | 0.4 | 4.9 | 1,336 | 28% | 0.4 | 4.9 | | 1,336 | 28% | 0.4 | 4.9 | | | |
| 10868_11848 | OC | 36 | 5.0 | 6.1 | 10 | 10 | 1,717 | 645 | 38% | 0.4 | 4.7 | 651 | 38% | 0.4 | 4.7 | | 651 | 38% | 0.4 | 4.7 | | | |
| 10869_10863 | OC | 266 | 7.1 | 6.1 | 10 | 12 | 2,652 | 933 | 35% | 0.4 | 6.6 | 938 | 35% | 0.4 | 6.6 | | 938 | 35% | 0.4 | 6.6 | | | |
| 10918_11863 | OC | 120 | 11.4 | 10.6 | 14 | 10 | 1,230 | 996 | 81% | 5.3 | 7.0 | 999 | 81% | 5.4 | 6.9 | 12 | 1,160 | 58% | 0.6 | 10.8 | 632 | 75,758 | Hazelwood |
| 10926_13206 | OC | 41 | 8.0 | 12.0 | 14 | 10 | 5,370 | 1,615 | 30% | 0.4 | 7.7 | 1,619 | 30% | 0.4 | 7.7 | | 1,790 | 33% | 0.4 | 7.7 | | | |

## Appendix E-1. Existing and Future Modeling Results

| Existing Pipe and Manhole Characteristics | | | | | | | | Existing Sewers - Existing Flows | | | | Existing Sewers - Buildout Peak Flows | | | | Upsized Sewer - Buildout Peak Flows | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pipe ID | Owner | Length (ft) | U/S MH Depth (ft) | Avg Pipe Depth (ft) | Average Rounded Depth (ft) | Existing Pipe Diameter (in) | Existing Capacity (gpm) | Peak Flow (gpm) | Current % Capacity Used[1] | U/S MH Current d/D[2] | Current U/S MH Freeboard (ft)[3] | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D[2] | Future U/S MH Freeboard (ft)[3] | Upsize Diameter (in) | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D[2] | Future U/S MH Freeboard (ft)[3] | Unit Cost ($/ft) | Current Total Cost ($) | Project Name |
| 10927_10926 | OC | 232 | 7.3 | 7.7 | 10 | 10 | 2,267 | 1,586 | 70% | 0.7 | 6.7 | 1,590 | 70% | 0.7 | 6.7 | | 1,760 | 78% | 0.8 | 6.6 | | | |
| 10928_10927 | OC | 261 | 8.0 | 7.6 | 10 | 10 | 1,362 | 1,281 | 94% | 0.9 | 7.3 | 1,284 | 94% | 0.9 | 7.3 | 12 | 1,460 | 66% | 0.6 | 7.4 | 396 | 103,447 | Hazelwood |
| 10930_10928 | OC | 89 | 8.2 | 8.1 | 10 | 10 | 904 | 1,269 | 140% | 1.9 | 6.6 | 1,273 | 141% | 2.6 | 6.0 | 12 | 1,460 | 99% | 0.8 | 7.4 | 396 | 35,100 | Hazelwood |
| 10991_13051 | OC | 218 | 8.1 | 7.9 | 10 | 10 | 664 | 903 | 136% | 8.5 | 0.9 | 906 | 137% | 8.7 | 0.8 | 12 | 1,067 | 99% | 1.5 | 6.6 | 490 | 106,766 | Hazelwood |
| 10992_10991 | OC | 109 | 11.4 | 9.7 | 10 | 10 | 654 | 870 | 133% | 9.0 | 3.9 | 874 | 134% | 9.2 | 3.7 | 12 | 1,034 | 97% | 1.5 | 9.9 | 490 | 53,202 | Hazelwood |
| 10993_10992 | OC | 295 | 8.4 | 9.9 | 10 | 8 | 837 | 226 | 27% | 2.8 | 6.5 | 232 | 28% | 3.0 | 6.3 | | 231 | 28% | 0.4 | 8.1 | | | |
| 11041_10993 | OC | 305 | 10.4 | 9.4 | 10 | 8 | 570 | 212 | 37% | 0.4 | 10.1 | 218 | 38% | 0.4 | 10.1 | | 218 | 38% | 0.5 | 10.1 | | | |
| 11044_10992 | OC | 179 | 10.2 | 10.8 | 14 | 8 | 390 | 676 | 173% | 13.8 | 1.0 | 675 | 173% | 14.0 | 0.9 | 10 | 797 | 113% | 2.2 | 8.4 | 514 | 92,088 | Hazelwood |
| 11046_11044 | OC | 431 | 11.8 | 11.0 | 14 | 8 | 502 | 669 | 133% | 17.7 | 0.0 | 668 | 133% | 17.7 | 0.0 | 10 | 788 | 87% | 1.9 | 10.2 | 514 | 221,253 | Hazelwood |
| 11047_18025 | OC | 227 | 10.6 | 10.4 | 14 | 8 | 511 | 253 | 49% | 13.5 | 1.7 | 265 | 52% | 13.6 | 1.6 | | 265 | 52% | 0.5 | 10.3 | | | |
| 11105_13188 | OC | 32 | 11.5 | 11.9 | 14 | 18 | 10,648 | 880 | 8% | 0.2 | 11.2 | 2,792 | 26% | 0.4 | 10.9 | | 2,786 | 26% | 0.4 | 10.9 | | | |
| 11106_11105 | OC | 115 | 7.3 | 9.4 | 10 | 8 | 443 | 873 | 197% | 42.0 | -20.7 | 949 | 214% | 46.8 | PS | | 948 | 214% | 46.7 | PS | | | |
| 11365_11366 | OC | 43 | 7.6 | 9.9 | 10 | 12 | 7,229 | 1,513 | 21% | 0.3 | 7.3 | 1,519 | 21% | 0.3 | 7.3 | | 1,638 | 23% | 0.3 | 7.2 | | | |
| 11366_11367 | OC | 22 | 12.3 | 12.8 | 14 | 12 | 6,130 | 1,515 | 25% | 0.4 | 12.0 | 1,520 | 25% | 0.4 | 12.0 | | 1,639 | 27% | 0.4 | 11.9 | | | |
| 11367_18008 | OC | 172 | 13.2 | 14.7 | 18 | 12 | 3,997 | 1,526 | 38% | 0.4 | 12.8 | 1,531 | 38% | 0.5 | 12.8 | | 1,649 | 41% | 0.5 | 12.8 | | | |
| 11382_11383 | TCSD | 204 | 6.5 | 7.2 | 10 | 45 | 21,074 | 21,133 | 100% | 0.8 | 3.4 | 23,186 | 110% | 0.9 | 3.2 | | 23,268 | 110% | 0.9 | 3.2 | | | |
| 11383_11384 | TCSD | 200 | 7.8 | 6.4 | 10 | 45 | 23,202 | 23,974 | 103% | 0.8 | 4.7 | 25,994 | 112% | 0.9 | 4.5 | | 26,064 | 112% | 0.9 | 4.5 | | | |
| 11384_11385 | TCSD | 242 | 4.9 | 6.7 | 10 | 45 | 22,984 | 23,981 | 104% | 0.8 | 1.9 | 26,001 | 113% | 0.9 | 1.7 | | 26,071 | 113% | 0.9 | 1.7 | | | |
| 11385_11387 | TCSD | 247 | 8.5 | 8.5 | 10 | 45 | 23,347 | 23,992 | 103% | 0.7 | 5.7 | 26,012 | 111% | 0.8 | 5.6 | | 26,083 | 112% | 0.8 | 5.6 | | | |
| 11387_11389 | TCSD | 280 | 8.4 | #N/A | #N/A | 54 | 38,198 | 23,994 | 63% | 0.5 | 6.0 | 26,012 | 68% | 0.6 | 5.9 | | 26,087 | 68% | 0.6 | 5.9 | | | |
| 11395_11397 | OC | 139 | 10.8 | 15.8 | 18 | 15 | 3,036 | 3,640 | 120% | 1.6 | 8.7 | 3,640 | 120% | 1.6 | 8.7 | | 3,986 | 131% | 1.9 | 8.3 | | | |
| 11396_11395 | OC | 20 | 9.0 | 9.9 | 10 | 12 | 5,039 | 3,541 | 70% | 1.4 | 7.6 | 3,542 | 70% | 1.4 | 7.6 | | 3,888 | 77% | 1.9 | 7.1 | | | |
| 11397_11383 | OC | 140 | 20.8 | 14.3 | 18 | 18 | 7,405 | 3,694 | 50% | 0.6 | 19.8 | 3,694 | 50% | 0.7 | 19.7 | | 4,040 | 55% | 0.8 | 19.6 | | | |
| 11402_11396 | OC | 250 | 7.6 | 8.3 | 10 | 12 | 2,549 | 3,518 | 138% | 7.6 | 0.0 | 3,515 | 138% | 7.6 | 0.0 | 15 | 3,850 | 83% | 0.7 | 6.7 | 443 | 110,616 | 12th Street |
| 11426_11444 | OC | 86 | 7.6 | 8.7 | 10 | 8 | 650 | 447 | 69% | 11.4 | 0.0 | 447 | 69% | 11.4 | 0.0 | | 528 | 81% | 0.7 | 7.2 | | | |
| 11427_11426 | OC | 165 | 7.7 | 7.7 | 10 | 8 | 428 | 447 | 105% | 11.6 | 0.0 | 447 | 104% | 11.6 | 0.0 | | 522 | 122% | 1.8 | 6.5 | | | |
| 11444_10056 | OC | 39 | 9.8 | 10.5 | 14 | 8 | 526 | 503 | 96% | 12.4 | 1.5 | 503 | 96% | 12.4 | 1.5 | 10 | 597 | 62% | 0.6 | 9.3 | 514 | 19,941 | Division Street |
| 11445_11446 | OC | 7 | 8.0 | 9.1 | 10 | 12 | 9,950 | 2,063 | 21% | 0.3 | 7.7 | 2,104 | 21% | 0.3 | 7.7 | | 2,104 | 21% | 0.3 | 7.7 | | | |
| 11446_10088 | OC | 231 | 10.2 | 10.1 | 14 | 12 | 5,787 | 2,078 | 36% | 0.4 | 9.8 | 2,119 | 37% | 0.4 | 9.8 | | 2,119 | 37% | 0.4 | 9.8 | | | |
| 11452_11486 | OC | 204 | 4.7 | 9.6 | 10 | 15 | 1,440 | 1,272 | 88% | 0.8 | 3.7 | 1,290 | 90% | 0.8 | 3.7 | | 1,290 | 90% | 0.8 | 3.7 | | | |
| 11453_11452 | OC | 80 | 7.0 | 5.9 | 6 | 15 | 1,433 | 1,259 | 88% | 0.8 | 6.1 | 1,277 | 89% | 0.8 | 6.1 | | 1,277 | 89% | 0.8 | 6.1 | | | |
| 11454_11453 | OC | 120 | 15.2 | 11.1 | 14 | 15 | 1,499 | 1,254 | 84% | 0.8 | 14.3 | 1,272 | 85% | 0.8 | 14.3 | | 1,272 | 85% | 0.8 | 14.3 | | | |
| 11457_11445 | OC | 286 | 8.5 | 8.2 | 10 | 18 | 12,388 | 2,063 | 17% | 0.3 | 8.1 | 2,103 | 17% | 0.3 | 8.0 | | 2,103 | 17% | 0.3 | 8.0 | | | |
| 11458_11501 | OC | 239 | 7.8 | 7.6 | 10 | 12 | 4,379 | 1,714 | 39% | 0.5 | 7.4 | 1,750 | 40% | 0.5 | 7.4 | | 1,750 | 40% | 0.5 | 7.4 | | | |
| 11467_11457 | OC | 186 | 9.4 | 8.9 | 10 | 18 | 9,387 | 1,949 | 21% | 0.3 | 8.9 | 1,988 | 21% | 0.3 | 8.9 | | 1,988 | 21% | 0.3 | 8.9 | | | |
| 11484_11506 | OC | 375 | 7.5 | 8.0 | 10 | 12 | 3,668 | 1,319 | 36% | 0.4 | 7.1 | 1,338 | 36% | 0.4 | 7.1 | | 1,338 | 36% | 0.4 | 7.1 | | | |
| 11485_11484 | OC | 211 | 7.0 | 7.2 | 10 | 12 | 3,237 | 1,296 | 40% | 0.5 | 6.5 | 1,315 | 41% | 0.5 | 6.5 | | 1,315 | 41% | 0.5 | 6.5 | | | |
| 11486_11485 | OC | 175 | 14.5 | 10.7 | 14 | 15 | 1,347 | 1,283 | 95% | 0.7 | 13.7 | 1,301 | 97% | 0.7 | 13.7 | | 1,301 | 97% | 0.7 | 13.7 | | | |
| 11501_11503 | OC | 253 | 7.4 | 8.2 | 10 | 12 | 4,231 | 1,730 | 41% | 0.5 | 7.0 | 1,766 | 42% | 0.5 | 6.9 | | 1,766 | 42% | 0.5 | 6.9 | | | |
| 11503_11508 | OC | 279 | 9.0 | 9.0 | 10 | 12 | 3,123 | 1,747 | 56% | 0.6 | 8.4 | 1,783 | 57% | 0.6 | 8.4 | | 1,783 | 57% | 0.6 | 8.4 | | | |
| 11506_11531 | OC | 255 | 8.4 | 8.7 | 10 | 12 | 3,956 | 1,686 | 43% | 0.5 | 8.0 | 1,722 | 44% | 0.5 | 7.9 | | 1,722 | 44% | 0.5 | 7.9 | | | |
| 11508_11467 | OC | 165 | 9.1 | 9.2 | 10 | 12 | 4,052 | 1,757 | 43% | 0.5 | 8.6 | 1,794 | 44% | 0.5 | 8.6 | | 1,794 | 44% | 0.5 | 8.6 | | | |
| 11514_11427 | OC | 239 | 8.1 | 7.9 | 10 | 8 | 622 | 492 | 79% | 10.7 | 1.0 | 494 | 79% | 10.6 | 1.0 | | 494 | 79% | 0.7 | 7.6 | | | |
| 11515_11516 | OC | 215 | 8.5 | 11.3 | 14 | 8 | 1,409 | 312 | 22% | 0.3 | 8.3 | 313 | 22% | 0.3 | 8.3 | | 313 | 22% | 0.3 | 8.3 | | | |
| 11516_11536 | OC | 180 | 14.1 | 12.8 | 14 | 8 | 816 | 463 | 57% | 3.1 | 12.1 | 465 | 57% | 2.9 | 12.2 | | 465 | 57% | 0.6 | 13.8 | | | |
| 11518_11515 | OC | 262 | 8.3 | 8.4 | 10 | 8 | 1,017 | 298 | 29% | 0.4 | 8.1 | 299 | 29% | 0.4 | 8.1 | | 299 | 29% | 0.4 | 8.1 | | | |
| 11531_11458 | OC | 209 | 9.1 | 8.4 | 10 | 12 | 3,312 | 1,699 | 51% | 0.5 | 8.5 | 1,735 | 52% | 0.6 | 8.5 | | 1,735 | 52% | 0.6 | 8.5 | | | |
| 11536_11514 | OC | 212 | 11.5 | 9.8 | 10 | 8 | 841 | 477 | 57% | 6.5 | 7.2 | 479 | 57% | 6.4 | 7.2 | | 479 | 57% | 0.6 | 11.1 | | | |
| 11546_11547 | OC | 230 | 8.9 | 9.0 | 10 | 12 | 108 | 2,168 | 2006% | 5.8 | 3.1 | 2,194 | 2030% | 5.9 | 3.0 | 15 | 2,194 | 1119% | 1.8 | 6.6 | 443 | 101,788 | Linn Avenue |
| 11547_11570 | OC | 252 | 9.1 | 9.0 | 10 | 12 | 4,804 | 2,185 | 45% | 0.5 | 8.7 | 2,210 | 46% | 0.0 | 8.6 | | 2,210 | >100% | 0.0 | 8.6 | | | |
| 11549_13972 | OC | 35 | 6.9 | 6.0 | 10 | 12 | 5,089 | 2,663 | 52% | 0.5 | 6.4 | 2,701 | 53% | 0.5 | 6.4 | | 2,701 | 53% | 0.5 | 6.4 | | | |
| 11550_10704 | OC | 282 | 4.9 | 6.6 | 10 | 12 | 5,164 | 2,802 | 54% | 0.6 | 4.4 | 2,841 | 55% | 0.6 | 4.4 | | 2,841 | 55% | 0.6 | 4.4 | | | |
| 11560_11595 | OC | 265 | 8.0 | 7.7 | 10 | 8 | 1,964 | 671 | 34% | 0.4 | 7.7 | 671 | 34% | 0.4 | 7.7 | | 671 | 34% | 0.4 | 7.7 | | | |
| 11564_11549 | OC | 462 | 6.9 | 6.9 | 10 | 12 | 4,406 | 2,660 | 60% | 0.6 | 6.3 | 2,699 | 61% | 0.6 | 6.3 | | 2,699 | 61% | 0.6 | 6.3 | | | |
| 11569_11832 | OC | 343 | 9.9 | 11.0 | 14 | 12 | 2,571 | 2,584 | 100% | 6.7 | 3.2 | 2,620 | 102% | 7.3 | 2.7 | 15 | 2,619 | 56% | 0.6 | 9.2 | 596 | 204,517 | Linn Avenue |
| 11570_13748 | OC | 33 | 8.8 | 8.5 | 10 | 12 | 2,459 | 2,268 | 92% | 6.7 | 2.2 | 2,306 | 94% | 7.3 | 1.6 | | 2,303 | 94% | 0.8 | 8.0 | | | |

## Appendix E-1. Existing and Future Modeling Results

| Existing Pipe and Manhole Characteristics | | | | | | | | Existing Sewers - Existing Flows | | | | Existing Sewers - Buildout Peak Flows | | | | Upsized Sewer - Buildout Peak Flows | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pipe ID | Owner | Length (ft) | U/S MH Depth (ft) | Avg Pipe Depth (ft) | Average Rounded Depth (ft) | Existing Pipe Diameter (in) | Existing Capacity (gpm) | Peak Flow (gpm) | Current % Capacity Used[1] | U/S MH Current d/D[2] | Current U/S MH Freeboard (ft)[3] | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D[2] | Future U/S MH Freeboard (ft)[3] | Upsize Diameter (in) | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D[2] | Future U/S MH Freeboard (ft)[3] | Unit Cost ($/ft) | Current Total Cost ($) | Project Name |
| 11581_11546 | OC | 223 | 7.1 | 8.0 | 10 | 12 | 4,891 | 2,153 | 44% | 0.5 | 6.6 | 2,177 | 45% | 0.5 | 6.6 | | 2,177 | 45% | 0.5 | 6.6 | | | |
| 11582_11583 | OC | 223 | 5.9 | 5.4 | 6 | 12 | 5,659 | 1,328 | 23% | 0.3 | 5.5 | 1,351 | 24% | 0.3 | 5.5 | | 1,351 | 24% | 0.3 | 5.5 | | | |
| 11583_11596 | OC | 295 | 4.9 | 7.2 | 10 | 12 | 3,218 | 1,347 | 42% | 0.5 | 4.5 | 1,371 | 43% | 0.5 | 4.5 | | 1,371 | 43% | 0.5 | 4.5 | | | |
| 11593_11581 | OC | 197 | 6.5 | 6.8 | 10 | 12 | 4,406 | 2,139 | 49% | 0.5 | 6.0 | 2,163 | 49% | 0.5 | 6.0 | | 2,163 | 49% | 0.5 | 6.0 | | | |
| 11594_11593 | OC | 148 | 6.4 | 6.5 | 10 | 12 | 4,128 | 2,112 | 51% | 0.5 | 5.9 | 2,135 | 52% | 0.5 | 5.9 | | 2,135 | 52% | 0.5 | 5.9 | | | |
| 11595_13012 | OC | 50 | 7.3 | 8.6 | 10 | 8 | 1,964 | 674 | 34% | 0.4 | 7.1 | 674 | 34% | 0.4 | 7.1 | | 674 | 34% | 0.4 | 7.1 | | | |
| 11596_13012 | OC | 49 | 9.5 | 9.7 | 10 | 12 | 4,528 | 1,408 | 31% | 0.4 | 9.1 | 1,431 | 32% | 0.4 | 9.1 | | 1,431 | 32% | 0.4 | 9.1 | | | |
| 11602_11637 | TCSD | 253 | 3.7 | 3.2 | 6 | 12 | 2,437 | 876 | 36% | 0.5 | 3.2 | 899 | 37% | 0.5 | 3.2 | | 886 | 36% | 0.5 | 3.2 | | | |
| 11603_10736 | TCSD | 302 | 4.2 | 3.6 | 6 | 16 | 8,108 | 4,960 | 61% | 0.6 | 3.4 | 6,879 | 85% | 0.8 | 3.2 | | 6,994 | 86% | 0.8 | 3.1 | | | |
| 11606_11603 | OC | 55 | 10.7 | 7.4 | 10 | 18 | 7,758 | 4,192 | 54% | 0.5 | 9.8 | 6,158 | 79% | 0.7 | 9.6 | | 6,224 | 80% | 0.7 | 9.6 | | | |
| 11618_11620 | TCSD | 22 | 3.9 | 4.2 | 6 | 12 | 5,466 | 956 | 17% | 0.3 | 3.6 | 976 | 18% | 0.3 | 3.6 | | 965 | 18% | 0.3 | 3.6 | | | |
| 11620_11602 | TCSD | 86 | 4.5 | 4.1 | 6 | 12 | 1,809 | 961 | 53% | 0.6 | 4.0 | 983 | 54% | 0.6 | 3.9 | | 971 | 54% | 0.6 | 3.9 | | | |
| 11621_11603 | TCSD | 119 | 3.2 | 3.7 | 6 | 12 | 4,099 | 794 | 19% | 0.3 | 2.9 | 815 | 20% | 0.3 | 2.9 | | 805 | 20% | 0.3 | 2.9 | | | |
| 11637_11621 | TCSD | 195 | 2.7 | 3.0 | 6 | 12 | 3,493 | 820 | 23% | 0.4 | 2.4 | 842 | 24% | 0.4 | 2.3 | | 831 | 24% | 0.4 | 2.4 | | | |
| 11638_11618 | OC | 169 | 4.1 | 4.0 | 6 | 12 | 1,644 | 945 | 57% | 0.6 | 3.5 | 968 | 59% | 0.6 | 3.5 | | 959 | 58% | 0.6 | 3.5 | | | |
| 11639_11638 | OC | 242 | 3.8 | 4.0 | 6 | 12 | 865 | 1,355 | 157% | 22.8 | -19.0 | 1,356 | 157% | 23.2 | PS | | 1,358 | 157% | 25.8 | PS | | | |
| 11711_11713 | OC | 339 | 14.3 | 10.3 | 14 | 15 | 3,117 | 310 | 10% | 0.2 | 14.0 | 323 | 10% | 0.2 | 14.0 | | 323 | 10% | 0.2 | 14.0 | | | |
| 11713_10828 | OC | 351 | 6.4 | 5.8 | 6 | 15 | 1,470 | 332 | 23% | 0.3 | 6.0 | 346 | 24% | 0.3 | 6.0 | | 346 | 24% | 0.3 | 6.0 | | | |
| 11724_10831 | OC | 109 | 22.6 | 22.7 | 18 | 15 | 1,450 | 677 | 47% | 0.5 | 22.0 | 692 | 48% | 0.5 | 22.0 | | 692 | 48% | 0.5 | 22.0 | | | |
| 11725_11724 | OC | 307 | 24.0 | 23.3 | 18 | 15 | 1,447 | 587 | 41% | 0.5 | 23.4 | 601 | 42% | 0.5 | 23.4 | | 601 | 42% | 0.5 | 23.4 | | | |
| 11832_11845 | OC | 41 | 12.1 | 12.4 | 14 | 12 | 324 | 2,587 | 798% | 5.5 | 6.6 | 2,624 | 809% | 5.8 | 6.3 | 15 | 2,623 | 446% | 0.9 | 11.0 | 596 | 24,341 | Linn Avenue |
| 11845_11564 | OC | 315 | 12.7 | 9.8 | 10 | 12 | 2,347 | 2,607 | 111% | 4.4 | 8.3 | 2,644 | 113% | 4.7 | 8.0 | 15 | 2,644 | 62% | 0.6 | 12.0 | 443 | 139,464 | Linn Avenue |
| 11848_10869 | OC | 172 | 7.2 | 7.1 | 10 | 10 | 1,719 | 915 | 53% | 0.5 | 6.8 | 920 | 54% | 0.6 | 6.7 | | 920 | 54% | 0.6 | 6.7 | | | |
| 11856_10930 | OC | 122 | 15.9 | 12.1 | 14 | 10 | 1,629 | 1,240 | 76% | 0.7 | 15.3 | 1,243 | 76% | 0.8 | 15.3 | | 1,487 | 90% | 0.8 | 15.4 | | | |
| 11857_11856 | OC | 23 | 15.3 | 15.6 | 18 | 10 | 698 | 1,234 | 177% | 1.1 | 14.4 | 1,238 | 177% | 1.1 | 14.4 | 12 | 1,662 | 146% | 0.9 | 14.5 | 796 | 18,052 | Hazelwood |
| 11858_11857 | OC | 132 | 10.9 | 13.1 | 14 | 10 | 867 | 1,194 | 138% | 2.4 | 8.9 | 1,199 | 138% | 2.4 | 8.9 | 12 | 1,367 | 97% | 0.9 | 10.1 | 632 | 83,522 | Hazelwood |
| 11859_11858 | OC | 105 | 7.0 | 9.0 | 10 | 10 | 1,214 | 1,189 | 98% | 2.5 | 4.9 | 1,192 | 98% | 2.6 | 4.9 | 12 | 1,353 | 69% | 0.6 | 6.4 | 490 | 51,370 | Hazelwood |
| 11862_10312 | OC | 355 | 9.7 | 9.4 | 10 | 10 | 804 | 1,013 | 126% | 6.1 | 4.6 | 1,017 | 126% | 6.2 | 4.5 | 12 | 1,178 | 90% | 0.8 | 8.9 | 490 | 173,929 | Hazelwood |
| 11863_11862 | OC | 30 | 9.8 | 9.8 | 10 | 10 | 1,481 | 998 | 67% | 5.8 | 5.0 | 1,002 | 68% | 5.9 | 4.9 | 12 | 1,161 | 48% | 0.6 | 9.3 | 490 | 14,549 | Hazelwood |
| 12171_10271 | OC | 39 | 7.3 | 11.1 | 14 | 8 | 2,956 | 64 | 2% | 0.1 | 7.2 | 64 | 2% | 0.1 | 7.2 | | 64 | 2% | 0.1 | 7.2 | | | |
| 12401_10273 | OC | 184 | 4.9 | 7.2 | 10 | 12 | 1,780 | 1,799 | 101% | 1.6 | 3.2 | 1,804 | 101% | 1.8 | 3.0 | 15 | 1,919 | 59% | 0.6 | 4.1 | 443 | 81,202 | 12th Street |
| 12402_12401 | OC | 367 | 3.4 | 4.1 | 6 | 12 | 1,522 | 1,788 | 117% | 3.0 | 0.4 | 1,792 | 118% | 3.2 | 0.3 | 15 | 1,907 | 69% | 0.6 | 2.6 | 237 | 86,858 | 12th Street |
| 12403_12402 | OC | 114 | 13.8 | 8.6 | 10 | 12 | 1,708 | 1,763 | 103% | 3.3 | 10.5 | 1,768 | 104% | 3.4 | 10.4 | | 1,884 | 110% | 1.6 | 12.2 | | | |
| 12791_12792 | OC | 130 | 10.3 | 7.9 | 10 | 20 | 16,184 | 4,161 | 26% | 0.4 | 9.7 | 6,132 | 38% | 0.4 | 9.5 | | 6,199 | 38% | 0.4 | 9.5 | | | |
| 12792_12793 | OC | 141 | 5.6 | 6.1 | 10 | 22 | 21,870 | 4,177 | 19% | 0.3 | 5.0 | 6,149 | 28% | 0.4 | 4.9 | | 6,216 | 28% | 0.4 | 4.9 | | | |
| 12793_11606 | OC | 194 | 6.7 | 8.7 | 10 | 22 | 23,039 | 4,187 | 18% | 0.3 | 6.1 | 6,158 | 27% | 0.4 | 6.0 | | 6,225 | 27% | 0.4 | 6.0 | | | |
| 13012_11594 | OC | 110 | 9.8 | 8.1 | 10 | 12 | 3,437 | 2,090 | 61% | 0.6 | 9.2 | 2,113 | 61% | 0.6 | 9.2 | | 2,113 | 61% | 0.6 | 9.2 | | | |
| 13051_10918 | OC | 331 | 7.8 | 9.6 | 10 | 10 | 619 | 918 | 148% | 7.4 | 1.7 | 921 | 149% | 7.5 | 1.6 | 12 | 1,084 | 108% | 1.4 | 6.4 | 490 | 162,156 | Hazelwood |
| 13061_10265 | OC | 86 | 9.9 | 8.8 | 10 | 24 | 50,456 | 5,626 | 11% | 0.2 | 9.4 | 5,695 | 11% | 0.2 | 9.4 | | 5,692 | 11% | 0.2 | 9.4 | | | |
| 13066_12171 | OC | 276 | 7.0 | 7.1 | 10 | 10 | 3,452 | 61 | 2% | 0.1 | 6.9 | 61 | 2% | 0.1 | 6.9 | | 61 | 2% | 0.1 | 6.9 | | | |
| 13078_10379 | OC | 279 | 20.4 | 19.3 | 18 | 18 | 11,453 | 2,192 | 19% | 0.3 | 19.9 | 2,233 | 19% | 0.3 | 19.9 | | 2,233 | 19% | 0.3 | 19.9 | | | |
| 13086_10089 | OC | 285 | 12.3 | 10.4 | 14 | 8 | 1,342 | 392 | 29% | 0.4 | 12.0 | 393 | 29% | 0.4 | 12.0 | | 393 | 29% | 0.4 | 12.0 | | | |
| 13087_10270 | OC | 247 | 7.4 | 9.3 | 10 | 8 | 1,780 | 552 | 31% | 0.4 | 7.2 | 553 | 31% | 0.4 | 7.2 | | 553 | 31% | 0.4 | 7.2 | | | |
| 13088_13086 | OC | 275 | 7.0 | 9.6 | 10 | 8 | 1,817 | 356 | 20% | 0.3 | 6.8 | 357 | 20% | 0.3 | 6.8 | | 357 | 20% | 0.3 | 6.8 | | | |
| 13089_13088 | OC | 217 | 7.8 | 7.4 | 10 | 8 | 1,648 | 324 | 20% | 0.3 | 7.6 | 324 | 20% | 0.3 | 7.6 | | 324 | 20% | 0.3 | 7.6 | | | |
| 13090_13920 | OC | 291 | 7.3 | 9.6 | 10 | 8 | 1,510 | 274 | 18% | 0.3 | 7.1 | 274 | 18% | 0.3 | 7.1 | | 274 | 18% | 0.3 | 7.1 | | | |
| 13100_13090 | OC | 266 | 7.2 | 7.2 | 10 | 8 | 824 | 227 | 28% | 0.4 | 6.9 | 227 | 28% | 0.4 | 6.9 | | 227 | 28% | 0.4 | 6.9 | | | |
| 13188_13189 | OC | 317 | 12.3 | 12.7 | 14 | 18 | 5,121 | 800 | 16% | 0.3 | 11.9 | 2,631 | 51% | 0.5 | 11.5 | | 2,631 | 51% | 0.5 | 11.5 | | | |
| 13189_13190 | OC | 337 | 13.1 | 14.7 | 18 | 18 | 5,123 | 824 | 16% | 0.3 | 12.7 | 2,670 | 52% | 0.5 | 12.3 | | 2,671 | 52% | 0.5 | 12.3 | | | |
| 13190_13191 | OC | 342 | 16.2 | 14.8 | 18 | 18 | 5,611 | 1,924 | 34% | 0.4 | 15.6 | 3,640 | 65% | 0.6 | 15.3 | | 3,795 | 68% | 0.6 | 15.3 | | | |
| 13191_13192 | OC | 359 | 13.3 | 12.1 | 14 | 18 | 5,185 | 1,740 | 34% | 0.4 | 12.7 | 3,532 | 68% | 0.6 | 12.4 | | 3,633 | 70% | 0.6 | 12.4 | | | |
| 13192_13193 | OC | 189 | 10.8 | 12.1 | 14 | 18 | 5,153 | 1,675 | 33% | 0.4 | 10.2 | 3,476 | 67% | 0.6 | 9.9 | | 3,578 | 69% | 0.6 | 9.9 | | | |
| 13193_13194 | OC | 353 | 13.4 | 13.6 | 14 | 18 | 5,108 | 1,691 | 33% | 0.4 | 12.8 | 3,497 | 68% | 0.6 | 12.5 | | 3,613 | 71% | 0.7 | 12.4 | | | |
| 13194_13195 | OC | 241 | 13.8 | 12.4 | 14 | 18 | 5,219 | 1,682 | 32% | 0.4 | 13.2 | 3,499 | 67% | 0.6 | 12.9 | | 3,615 | 69% | 0.6 | 12.8 | | | |
| 13195_13196 | OC | 233 | 11.1 | 10.9 | 14 | 18 | 5,163 | 1,661 | 32% | 0.4 | 10.5 | 3,488 | 68% | 0.6 | 10.1 | | 3,605 | 70% | 0.7 | 10.1 | | | |
| 13196_13197 | OC | 29 | 10.8 | 11.3 | 14 | 18 | 6,914 | 1,665 | 24% | 0.4 | 10.3 | 3,490 | 50% | 0.5 | 10.0 | | 3,608 | 52% | 0.6 | 10.0 | | | |

**Appendix E-1. Existing and Future Modeling Results**

| Existing Pipe and Manhole Characteristics | | | | | | | | Existing Sewers - Existing Flows | | | | Existing Sewers - Buildout Peak Flows | | | | Upsized Sewer - Buildout Peak Flows | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pipe ID | Owner | Length (ft) | U/S MH Depth (ft) | Avg Pipe Depth (ft) | Average Rounded Depth (ft) | Existing Pipe Diameter (in) | Existing Capacity (gpm) | Peak Flow (gpm) | Current % Capacity Used[1] | U/S MH Current d/D [2] | Current U/S MH Freeboard (ft) [3] | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D [2] | Future U/S MH Freeboard (ft) [3] | Upsize Diameter (in) | Peak Flow (gpm) | Future % Capacity Used[1] | U/S MH Future d/D [2] | Future U/S MH Freeboard (ft) [3] | Unit Cost ($/ft) | Current Total Cost ($) | Project Name |
| 13197_13198 | OC | 339 | 11.8 | 14.4 | 18 | 21 | 7,501 | 1,708 | 23% | 0.3 | 11.2 | 3,531 | 47% | 0.5 | 11.0 | | 3,664 | 49% | 0.5 | 10.9 | | | |
| 13198_13199 | OC | 330 | 17.1 | 16.6 | 18 | 21 | 7,931 | 1,676 | 21% | 0.3 | 16.5 | 3,526 | 44% | 0.5 | 16.2 | | 3,648 | 46% | 0.5 | 16.2 | | | |
| 13199_13200 | OC | 148 | 16.2 | 15.2 | 18 | 21 | 9,130 | 1,686 | 18% | 0.3 | 15.7 | 3,560 | 39% | 0.5 | 15.4 | | 3,658 | 40% | 0.5 | 15.4 | | | |
| 13200_13201 | OC | 334 | 14.1 | 13.6 | 14 | 21 | 7,664 | 1,671 | 22% | 0.3 | 13.6 | 3,560 | 46% | 0.5 | 13.3 | | 3,641 | 48% | 0.5 | 13.2 | | | |
| 13201_13202 | OC | 14 | 13.1 | 12.8 | 14 | 21 | 5,703 | 1,649 | 29% | 0.4 | 12.5 | 3,544 | 62% | 0.6 | 12.1 | | 3,615 | 63% | 0.6 | 12.1 | | | |
| 13202_13203 | OC | 30 | 12.5 | 11.6 | 14 | 21 | 8,175 | 1,649 | 20% | 0.3 | 11.9 | 3,545 | 43% | 0.5 | 11.7 | | 3,615 | 44% | 0.5 | 11.6 | | | |
| 13203_13204 | OC | 92 | 10.7 | 10.3 | 14 | 21 | 17,323 | 1,758 | 10% | 0.2 | 10.3 | 3,689 | 21% | 0.3 | 10.1 | | 3,722 | 21% | 0.3 | 10.1 | | | |
| 13204_13205 | OC | 195 | 10.0 | 10.7 | 14 | 21 | 21,865 | 1,771 | 8% | 0.2 | 9.6 | 3,706 | 17% | 0.3 | 9.5 | | 3,735 | 17% | 0.3 | 9.5 | | | |
| 13205_13206 | OC | 137 | 11.3 | 13.7 | 14 | 21 | 14,239 | 1,810 | 13% | 0.3 | 10.9 | 3,762 | 26% | 0.4 | 10.7 | | 3,774 | 27% | 0.4 | 10.7 | | | |
| 13206_13207 | OC | 217 | 16.0 | 14.0 | 14 | 26 | 12,289 | 3,390 | 28% | 0.4 | 15.2 | 5,392 | 44% | 0.5 | 15.0 | | 5,551 | 45% | 0.5 | 15.0 | | | |
| 13207_13208 | OC | 151 | 11.9 | 9.5 | 10 | 26 | 32,051 | 3,397 | 11% | 0.2 | 11.4 | 5,400 | 17% | 0.3 | 11.3 | | 5,558 | 17% | 0.3 | 11.3 | | | |
| 13208_13209 | OC | 168 | 7.1 | 6.4 | 10 | 18 | 32,314 | 3,401 | 11% | 0.2 | 6.8 | 5,404 | 17% | 0.3 | 6.7 | | 5,563 | 17% | 0.3 | 6.7 | | | |
| 13209_13210 | OC | 178 | 5.7 | 5.4 | 6 | 18 | 13,552 | 3,402 | 25% | 0.4 | 5.2 | 5,406 | 40% | 0.5 | 5.0 | | 5,565 | 41% | 0.5 | 5.0 | | | |
| 13210_13211 | OC | 359 | 5.2 | 5.1 | 6 | 18 | 12,531 | 3,407 | 27% | 0.4 | 4.6 | 5,413 | 43% | 0.5 | 4.5 | | 5,572 | 44% | 0.5 | 4.5 | | | |
| 13211_14114 | OC | 105 | 5.1 | 5.0 | 6 | 18 | 13,032 | 3,406 | 26% | 0.4 | 4.6 | 5,412 | 42% | 0.5 | 4.4 | | 5,571 | 43% | 0.5 | 4.4 | | | |
| 13212_13213 | OC | 51 | 4.3 | 5.1 | 6 | 20 | 17,320 | 3,412 | 20% | 0.3 | 3.7 | 5,418 | 31% | 0.4 | 3.6 | | 5,577 | 32% | 0.4 | 3.6 | | | |
| 13213_13214 | OC | 227 | 6.0 | 7.9 | 10 | 20 | 13,852 | 3,549 | 26% | 0.4 | 5.4 | 5,541 | 40% | 0.5 | 5.2 | | 5,683 | 41% | 0.5 | 5.2 | | | |
| 13214_14109 | OC | 168 | 9.9 | 8.5 | 10 | 20 | 15,358 | 3,556 | 23% | 0.3 | 9.4 | 5,543 | 36% | 0.4 | 9.2 | | 5,685 | 37% | 0.4 | 9.2 | | | |
| 13215_14108 | OC | 14 | 3.9 | 4.0 | 6 | 20 | 19,153 | 3,572 | 19% | 0.3 | 3.4 | 5,556 | 29% | 0.4 | 3.3 | | 5,694 | 30% | 0.4 | 3.3 | | | |
| 13216_13217 | OC | 293 | 6.8 | 5.6 | 6 | 20 | 16,821 | 3,613 | 21% | 0.3 | 6.3 | 5,583 | 33% | 0.4 | 6.2 | | 5,707 | 34% | 0.4 | 6.1 | | | |
| 13217_13218 | OC | 318 | 4.3 | 4.7 | 6 | 20 | 17,819 | 3,623 | 20% | 0.3 | 3.8 | 5,594 | 31% | 0.4 | 3.6 | | 5,711 | 32% | 0.4 | 3.6 | | | |
| 13218_13219 | OC | 313 | 5.0 | 5.6 | 6 | 20 | 15,202 | 3,631 | 24% | 0.3 | 4.5 | 5,601 | 37% | 0.4 | 4.3 | | 5,713 | 38% | 0.4 | 4.3 | | | |
| 13219_12791 | OC | 168 | 6.1 | 8.2 | 10 | 20 | 12,599 | 3,652 | 29% | 0.4 | 5.5 | 5,619 | 45% | 0.5 | 5.3 | | 5,726 | 45% | 0.5 | 5.3 | | | |
| 13748_11569 | OC | 32 | 8.3 | 9.1 | 10 | 12 | 2,476 | 2,273 | 92% | 6.7 | 1.6 | 2,310 | 93% | 7.2 | 1.0 | | 2,308 | 93% | 0.8 | 7.4 | | | |
| 13870_13871 | OC | 20 | 18.1 | 17.8 | 18 | 24 | 67,591 | 5,498 | 8% | 0.2 | 17.7 | 5,567 | 8% | 0.2 | 17.7 | | 5,563 | 8% | 0.2 | 17.7 | | | |
| 13871_10191 | OC | 133 | 17.4 | 14.8 | 18 | 24 | 67,605 | 5,523 | 8% | 0.2 | 17.0 | 5,592 | 8% | 0.2 | 17.0 | | 5,588 | 8% | 0.2 | 17.0 | | | |
| 13881_10727 | TCSD | 167 | 9.6 | 10.1 | 14 | 18 | 6,916 | 4,791 | 69% | 1.6 | 7.3 | 6,641 | 96% | 5.5 | 1.5 | | 6,681 | 97% | 5.0 | 2.1 | | | |
| 13910_10156 | OC | 26 | 28.3 | 23.4 | 18 | 8 | 605 | 747 | 123% | 0.9 | 27.7 | 749 | 124% | 0.9 | 27.7 | | 749 | 124% | 0.9 | 27.7 | | | |
| 13920_13089 | OC | 25 | 11.8 | 9.8 | 10 | 8 | 1,509 | 310 | 21% | 0.3 | 11.6 | 310 | 21% | 0.3 | 11.6 | | 310 | 21% | 0.3 | 11.6 | | | |
| 13972_13973 | OC | 30 | 5.2 | 6.5 | 10 | 12 | 5,083 | 2,665 | 52% | 0.5 | 4.6 | 2,704 | 53% | 0.5 | 4.6 | | 2,704 | 53% | 0.5 | 4.6 | | | |
| 13973_11550 | OC | 260 | 7.8 | 6.4 | 10 | 12 | 5,089 | 2,719 | 53% | 0.5 | 7.3 | 2,758 | 54% | 0.6 | 7.3 | | 2,758 | 54% | 0.6 | 7.3 | | | |
| 14108_13216 | OC | 342 | 4.0 | 5.4 | 6 | 20 | 19,136 | 3,590 | 19% | 0.3 | 3.5 | 5,565 | 29% | 0.4 | 3.4 | | 5,699 | 30% | 0.4 | 3.4 | | | |
| 14109_13215 | OC | 180 | 7.0 | 5.5 | 6 | 20 | 15,356 | 3,566 | 23% | 0.3 | 6.4 | 5,548 | 36% | 0.4 | 6.3 | | 5,687 | 37% | 0.4 | 6.3 | | | |
| 14114_13212 | OC | 258 | 4.9 | 4.6 | 6 | 18 | 13,032 | 3,412 | 26% | 0.4 | 4.3 | 5,418 | 42% | 0.5 | 4.1 | | 5,577 | 43% | 0.5 | 4.1 | | | |
| 14146_10868 | OC | 451 | 13.0 | 9.0 | 10 | 10 | 1,719 | 615 | 36% | 0.4 | 12.6 | 619 | 36% | 0.4 | 12.6 | | 619 | 36% | 0.4 | 12.6 | | | |
| 18000_10669 | TCSD | 183 | 7.4 | 7.7 | 10 | 33 | 10,940 | 16,433 | 150% | 1.3 | 3.8 | 18,365 | 168% | 1.5 | 3.1 | | 18,449 | 169% | 1.5 | 3.1 | | | |
| 18008_10795 | OC | 27 | 16.2 | 12.8 | 14 | 12 | 4,003 | 1,554 | 39% | 2.8 | 13.4 | 1,560 | 39% | 2.9 | 13.3 | | 1,678 | 42% | 2.4 | 13.8 | | | |
| 18019_13061 | OC | 230 | 8.6 | 9.2 | 10 | 24 | 11,872 | 5,621 | 47% | 0.5 | 7.5 | 5,690 | 48% | 0.5 | 7.5 | | 5,687 | 48% | 0.5 | 7.5 | | | |
| 18025_11046 | OC | 173 | 10.2 | 11.0 | 14 | 8 | 568 | 249 | 44% | 15.4 | 0.0 | 256 | 45% | 15.4 | 0.0 | | 300 | 53% | 0.5 | 9.9 | | | |

*1. The percentage of capacity used is a ratio of the modeled peak flow in the sewer to the calculated capacity of the existing sewer using Manning's equation. Cells with 100 percent or more of the existing capacity used are flagged in red.*

*2. d/D is a ratio of the modeled water surface depth in the upstream manhole (d) to the diameter of the existing sewer (D). A d/D ratio greater than 1 indicates surcharging in the model results and is highlighted in red.*

*3. The upstream freeboard is the depth in feet from the rim of the upstream manhole to the water surface elevation in the MH. Manholes with less than 5 feet of freeboard are highlighted in red. This value is not reported for pump station locations, which are indicated with a PS.*

## Appendix E-2. Surcharging Sewers to Observe

| Existing Pipe and Manhole Characteristics | | | | | Existing Sewers - Existing Flows | | | | | Observance No. 1 | | | | Observance No. 2 | | | | Observance No. 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pipe ID | Length (ft) | U/S MH Depth (ft) | Existing Pipe Diameter (in) | Existing Capacity (gpm) | Peak Flow (gpm) | Current % Capacity Used[1] | U/S MH Current d/D [2] | Current U/S MH Freeboard (ft) [3] | Capital Improvement Project Number/Name | Date/Time | Observed U/S MH Freeboard (ft) [3] | 24-hour Rainfall Depth (in) | Observer Name | Date/Time | Observed U/S MH Freeboard (ft) [3] | 24-hour Rainfall Depth (in) | Observer Name | Date/Time | Observed U/S MH Freeboard (ft) [3] | 24-hour Rainfall Depth (in) | Observer Name |
| 11787_14206 | 131 | 8.7 | 12 | 1,144 | 1,402 | 123% | 3.2 | 5.4 | | | | | | | | | | | | | |
| 12627_12621 | 215 | 9.4 | 12 | 1,256 | 1,365 | 109% | 1.6 | 7.8 | | | | | | | | | | | | | |
| 10056_10071 | 287 | 11.1 | 8 | 398 | 539 | 135% | 12.4 | 2.8 | (3) Division Street | | | | | | | | | | | | |
| 10158_12403 | 145 | 9.1 | 12 | 1,714 | 1,731 | 101% | 3.5 | 5.6 | | | | | | | | | | | | | |
| 10170_10171 | 203 | 12.3 | 8 | 572 | 705 | 123% | 7.4 | 7.3 | (2) 13th Street | | | | | | | | | | | | |
| 10171_10057 | 339 | 6.4 | 8 | 583 | 726 | 125% | 5.4 | 2.8 | (2) 13th Street | | | | | | | | | | | | |
| 10259_10157 | 346 | 7.3 | 8 | 957 | 1,057 | 110% | 9.0 | 1.3 | (1) 12th Street | | | | | | | | | | | | |
| 10312_11859 | 260 | 9.1 | 10 | 806 | 1,025 | 127% | 4.1 | 5.7 | (5) Hazelwood | | | | | | | | | | | | |
| 10695_10694 | 253 | 11.4 | 12 | 2,457 | 2,919 | 119% | 4.5 | 6.9 | | | | | | | | | | | | | |
| 10696_10695 | 15 | 9.1 | 12 | 6,770 | 2,903 | 43% | 2.8 | 6.3 | | | | | | | | | | | | | |
| 10697_10696 | 268 | 9.2 | 12 | 3,046 | 2,901 | 95% | 3.1 | 6.1 | | | | | | | | | | | | | |
| 10795_10158 | 326 | 9.4 | 12 | 1,549 | 1,576 | 102% | 4.0 | 5.4 | | | | | | | | | | | | | |
| 10918_11863 | 120 | 11.4 | 10 | 1,230 | 996 | 81% | 5.3 | 7.0 | (5) Hazelwood | | | | | | | | | | | | |
| 10930_10928 | 89 | 8.2 | 10 | 904 | 1,269 | 140% | 1.9 | 6.6 | (5) Hazelwood | | | | | | | | | | | | |
| 10991_13051 | 218 | 8.1 | 10 | 664 | 903 | 136% | 8.5 | 0.9 | (5) Hazelwood | | | | | | | | | | | | |
| 10992_10991 | 109 | 11.4 | 10 | 654 | 870 | 133% | 9.0 | 3.9 | (5) Hazelwood | | | | | | | | | | | | |
| 10993_10992 | 295 | 8.4 | 8 | 837 | 226 | 27% | 2.8 | 6.5 | | | | | | | | | | | | | |
| 11044_10992 | 179 | 10.2 | 8 | 390 | 676 | 173% | 13.8 | 1.0 | (5) Hazelwood | | | | | | | | | | | | |
| 11046_11044 | 431 | 11.8 | 8 | 502 | 669 | 133% | 17.7 | 0.0 | (5) Hazelwood | | | | | | | | | | | | |
| 11047_18025 | 227 | 10.6 | 8 | 511 | 253 | 49% | 13.5 | 1.7 | | | | | | | | | | | | | |
| 11396_11395 | 20 | 9.0 | 12 | 5,039 | 3,541 | 70% | 1.4 | 7.6 | | | | | | | | | | | | | |
| 11402_11396 | 250 | 7.6 | 12 | 2,549 | 3,518 | 138% | 7.6 | 0.0 | (1) 12th Street | | | | | | | | | | | | |
| 11426_11444 | 86 | 7.6 | 8 | 650 | 447 | 69% | 11.4 | 0.0 | | | | | | | | | | | | | |
| 11427_11426 | 165 | 7.7 | 8 | 428 | 447 | 105% | 11.6 | 0.0 | | | | | | | | | | | | | |
| 11444_10056 | 39 | 9.8 | 8 | 526 | 503 | 96% | 12.4 | 1.5 | (3) Division Street | | | | | | | | | | | | |
| 11514_11427 | 239 | 8.1 | 8 | 622 | 492 | 79% | 10.7 | 1.0 | | | | | | | | | | | | | |
| 11536_11514 | 212 | 11.5 | 8 | 841 | 477 | 57% | 6.5 | 7.2 | | | | | | | | | | | | | |
| 11546_11547 | 230 | 8.9 | 12 | 108 | 2,168 | 2006% | 5.8 | 3.1 | (4) Linn Avenue | | | | | | | | | | | | |
| 11569_11832 | 343 | 9.9 | 12 | 2,571 | 2,584 | 100% | 6.7 | 3.2 | (4) Linn Avenue | | | | | | | | | | | | |
| 11570_13748 | 33 | 8.8 | 12 | 2,459 | 2,268 | 92% | 6.7 | 2.2 | | | | | | | | | | | | | |
| 11832_11845 | 41 | 12.1 | 12 | 324 | 2,587 | 798% | 5.5 | 6.6 | (4) Linn Avenue | | | | | | | | | | | | |
| 11859_11858 | 105 | 7.0 | 10 | 1,214 | 1,189 | 98% | 2.5 | 4.9 | (5) Hazelwood | | | | | | | | | | | | |
| 11862_10312 | 355 | 9.7 | 10 | 804 | 1,013 | 126% | 6.1 | 4.6 | (5) Hazelwood | | | | | | | | | | | | |
| 11863_11862 | 30 | 9.8 | 10 | 1,481 | 998 | 67% | 5.8 | 5.0 | (5) Hazelwood | | | | | | | | | | | | |
| 12401_10273 | 184 | 4.9 | 12 | 1,780 | 1,799 | 101% | 1.6 | 3.2 | (1) 12th Street | | | | | | | | | | | | |
| 12402_12401 | 367 | 3.4 | 12 | 1,522 | 1,788 | 117% | 3.0 | 0.4 | (1) 12th Street | | | | | | | | | | | | |
| 13051_10918 | 331 | 7.8 | 10 | 619 | 918 | 148% | 7.4 | 1.7 | (5) Hazelwood | | | | | | | | | | | | |
| 13748_11569 | 32 | 8.3 | 12 | 2,476 | 2,273 | 92% | 6.7 | 1.6 | | | | | | | | | | | | | |
| 18019_13061 | 230 | 8.6 | 24 | 11,872 | 5,621 | 47% | 0.5 | 7.5 | | | | | | | | | | | | | |
| 18025_11046 | 173 | 10.2 | 8 | 568 | 249 | 44% | 15.4 | 0.0 | | | | | | | | | | | | | |

*Notes:*

*1. The percentage of capacity used is a ratio of the modeled peak flow in the sewer to the calculated capacity of the existing sewer using Manning's equation. Cells with 100 percent or more of the existing capacity used are flagged in red.*

*2. d/D is a ratio of the modeled water surface depth in the upstream manhole (d) to the diameter of the existing sewer (D). A d/D ratio greater than 1 indicates surcharging in the model results and is highlighted in red.*

*3. The upstream freeboard is the depth in feet from the rim of the upstream manhole to the water surface elevation in the MH. Manholes with less than 5 feet of freeboard are highlighted in light red.*

# Appendix F Overview of Current and Proposed Regulations

Appendix F

# Overview of Current and Proposed Regulations

This document provides an overview of current and proposed regulations that impact the City of Oregon City's (City) management of the sanitary sewer collection system and provides recommendations for compliance.

## Background

The Clean Water Act (CWA) prohibits discharges of pollutants to waters of the U.S. unless authorized by a National Pollutant Discharge Elimination System (NPDES) permit. Unpermitted discharges from the sanitary sewer system to the waters of the U.S. constitute a violation of the CWA. For many utilities and cities, their NPDES permits identify requirements for operating and maintaining the municipal wastewater conveyance and treatment systems.

The current NPDES permit is held by the Tri-City Service District (TCSD) for the Tri-City Water Pollution Control Plant (TPCP) with an expiration date of April 15, 2016. The permit mentions three specific requirements regulating the management and the operation and maintenance (O&M) of the sanitary collection system. The stated provisions are as follows:

- All overflows are prohibited
- Requires program to identify and reduce inflow and infiltration (I/I) into the collection system
- Permittee must prepare and implement an Emergency Response and Public Notification Plan

The above requirements apply specifically to TCSD since it is the holder of the permit. An Intergovernmental Agreement (IGA) has been established between TCSD and the City. It is through this agreement that elements of the permit could flow down to the City. However, as currently written, none of the above noted requirements are mentioned in the IGA. The City should be aware that the IGA can be updated at the request of TCSD.

Additional legislation has been proposed that could significantly increase compliance requirements included in future NPDES permits. Many of these requirements are a part of the proposed sanitary sewer overflow (SSO) regulations, specifically, the capacity, management, operation, and maintenance (CMOM) provisions. When and if enacted, the new requirements will dictate more of the day-to-day operation of the conveyance system than those currently in place. The next section describes them in more detail.

## CMOM

In 2001, the U.S. Environmental Protection Agency (USEPA) proposed legislation to significantly reduce the number and volume of SSOs throughout the U.S. The USEPA determined that such actions were required to improve water quality. The proposed requirements would improve the performance of sanitary sewer systems such that there would be fewer and smaller SSO events. In short, the proposed requirements would affect nearly all aspects of sanitary sewer management and operation. As proposed, each permit holder would be required to develop a CMOM plan comprised of the nine primary elements described in Table F-1. The activities are primarily a best management practice approach to controlling SSOs. When implemented, each permit holder's CMOM plan would improve the performance of the collection system resulting in much reduced number and volume of SSOs, fewer customer complaints, improved efficiency of O&M activities, and increased longevity of the collection system infrastructure.

**Table F-1. CMOM Program Elements**

| Element | Purpose | Description |
|---|---|---|
| Goals | To provide direction on all aspects of managing the collection system. | Goals should be specific, realistic, achievable, and measureable.<br>• Determine linear footage of sewers to be inspected annually.<br>• Determine number of manholes to be upgraded annually.<br>• Upgrade maintenance management system.<br>• Develop Fats, Oils, and Grease (FOG) Program.<br>• Set limits on number of SSOs per year. |
| Organization | To structure the organization for efficient operation and management of the collection system. | • Write organization and governing body description.<br>• Prepare organization chart.<br>• Write job descriptions.<br>• Define lines of communication. |
| Legal authority | To establish the legal authority allowing the City to direct all critical aspects of sanitary sewer management. | The City has the legal authority to do the following:<br>• Control rates.<br>• Regulate the volume and strength of discharges.<br>• Manage FOG.<br>• Maintain and replace service laterals. |
| O&M activities | To operate and maintain the sanitary sewer collection system in a way that achieves optimum sewer performance. | • Identify the O&M activities required to maintain sewers, manholes, pump stations, force mains, and service laterals.<br>• Establish frequencies for performing the required activities that optimize sewer performance. |
| Design and performance provisions | To establish minimum requirements for collection system design, construction, inspection, and final acceptance. | • Determine minimum requirements for design.<br>• Determine minimum requirements for construction materials.<br>• Clearly define inspection requirements and train inspectors. |
| Overflow Emergency Response Plan | To establish response capabilities for responding to sewer emergencies. | • Clearly define emergency procedures.<br>• Provide equipment and personnel training.<br>• Install operating alarm system.<br>• Create public notification plan. |
| Capacity assurance | To identify where hydraulic deficiencies may occur in the sanitary sewer collection system. | • Map collection system completely and accurately.<br>• Model the collection system including sewers and pump stations.<br>• Identify potential hydraulic deficiencies and create a plan for addressing the deficiencies.<br>• Identify potential operational problem areas and create a schedule for cleaning affected sewers.<br>• Create action plan for addressing areas with excessive infiltration/inflow. |
| Annual self auditing | To evaluate where improvements are required in managing the sanitary collection system through annual auditing. | • Compare collection system performance with goals established to identify where improvements may be required.<br>• Conduct annual self-evaluation and practice continuous improvement. |

The USEPA's promulgation of the CMOM requirements has stalled; however, elements of the proposed requirements have made their way into NPDES permits and environmental programs throughout the country. Within USEPA Region 10, some of the CMOM requirements have been written into recently-renewed NPDES permits. California has adopted many of the CMOM provisions and they are being included in renewed NPDES permits. In Oregon, only a few of the provisions have shown up in recent permit updates. For example, the City of Salem's permit requires the following activities related to sanitary sewer management:

- A plan for reducing inflow.
- Identification of all potential overflow points associated with a 5-year storm event.
- Establishment of legal authority as required to control inflow.
- Requirement to establish a Management, Operation, and Maintenance Program with similar requirements to those that have been defined for a CMOM program.

It is understood that Salem's requirements may be a special case. It is believed that the Oregon Department of Environmental Quality (DEQ) added these additional requirements to help the City of Salem address specific deficiencies in its collection system. At this time, these additional requirements are not being added to all new permits being issued, but DEQ could implement them if cities/utilities are having problems with SSOs.

## USEPA on SSOs

The USEPA's interpretation of the CWA is that any SSO is a violation and exceptions are not allowed. According to the USEPA, the exceptions written into many of the NPDES permits issued by DEQ are not allowed, including defining SSO exceptions based on storm events (i.e., 5-year, 24-hour winter storm event). DEQ's position has been that eliminating all SSOs is "technologically impracticable because even well-designed and operated systems can experience SSOs" (excerpt from DEQ letter to USEPA, November 29, 2011). Furthermore, DEQ's "alternate approach" suggested that the number and volume of SSOs can be reduced and water quality can be improved without requirements that place municipalities in violation of their permits and exposure to third-party lawsuits. In 2012, the alternate approach suggested by DEQ was rejected by USEPA. Consequently, DEQ has withdrawn the alternate approach concept and now is promoting USEPA's Integrated Approach.

## DEQ on SSOs

In late 2010, DEQ issued the *Internal Management Directive Sanitary Sewer Overflows (SSOs)*, (November 2010) (*IMD*). The *IMD* provides direction to DEQ staff on what enforcement action to take when an NPDES permit holder experiences an SSO. The *IMD* lays out enforcement procedures based on the following premises:

1. All SSOs are violations.
2. Since not all SSO violations are equally culpable or injurious to public health, enforcement discretion can be used to address less culpable violations.

In addition, the *IMD* helps to clarify certain permit requirements, including the following:

- Revised SSO reporting requirements, 2009
- SSO reporting follow-up requirements
- Emergency Response and Public Notification Plans
- Taking enforcement action

The *IMD's* instructions on SSO enforcement focus on whether the SSO event is "beyond the reasonable control of the permittee." If the SSO event is beyond the reasonable control of the permittee, a warning letter is issued. Otherwise, the permittee could receive a pre-enforcement notice (PEN). A PEN notifies the violator that it is being referred for formal enforcement action. Table F-2 is an excerpt from the *IMD* that clarifies "reasonable control."

| Table F-2. SSO Reasonable Control Criteria From DEQ's *IMD* |
|---|
| **An SSO is (to) be considered to be beyond reasonable control if Any of the following are true:** |
| 1. The event was caused by a force majeure event. Force majeure events are those events which can be neither anticipated nor controlled. They include war, sabotage, unusual vandalism, and extremes act of nature. |
| 2. The SSO was caused by a storm event larger than what the system was designed to handle, as per Oregon Administrative Rules (OAR) 340-041-0009(6) and (7). |
| 3. The SSO was caused by hydrologic conditions that exceeded those described in a bacteria management plan approved by the Oregon Environmental Quality Commission, as per OAR 340-041-0009(6) and (7). |
| 4. The SSO was caused by an act of vandalism that could not have been reasonably anticipated or prevented by ordinary measures such as a padlock, cover, or fence. |
| 5. The SSO was the result of an act or omission of a third party not acting as an agent of the permittee. |
| 6. The SSO occurred despite the fact that the permittee is implementing a good CMOM program. DEQ has not developed guidance on what constitutes a good CMOM program, and therefore permit staff are directed to USEPA's guidance on the subject. |
| **Alternatively, an SSO is considered to be beyond reasonable control if All of the following are true:** |
| 1. The system had an adequate level of redundancy against breakdowns and power failures. Appendix F lists examples of the level of redundancy that DEQ expects permittees to design for and maintain. |
| 2. The SSO was not the result of an action or actions initiated by the permittee such as pipe cleaning, pipe repair, or reservoir cleaning. |
| 3. The SSO was not the result of an action or actions by contractors working for the permittee. Examples include pump-around failures or plugs left in lines. Such actions are avoidable. |
| 4. The SSO was not the result of poor or lagging maintenance, or an unreasonable failure to inspect. Examples of such SSOs include those caused by grease plugs, root intrusion, or debris occurring in lines that have not been adequately inspected or cleaned. |

Implementing a good CMOM program can provide a "beyond reasonable control" defense for an SSO event. Conversely, not having a good CMOM program, such as for inspection and cleaning, may void the "beyond reasonable control" defense.

## USEPA's Integrated Approach

The USEPA has embraced an integrated planning approach to stormwater and wastewater management. The purpose of this new approach is to assist municipalities with meeting all of their regulatory requirements by having each develop a plan that prioritizes activities and programs for maximum efficiency of water quality improvement and regulatory compliance. Also, the integrated approach places a strong emphasis on sustainable solutions, such as green infrastructure that will protect human health, improve water quality, and support other activities that will enhance the community. The integrated approach does not reduce regulatory requirements or water quality standards. Instead, it is intended to assist municipalities with prioritizing focus for regulatory compliance. The integrated approach is voluntary and may not be the best approach for every municipality, but the USEPA believes that it will most help those communities with many competing regulatory challenges.

The USEPA's overarching principles for implementing the integrated approach (as stated in its *Integrated Municipal Stormwater and Wastewater Planning Approach Framework*, May, 2012) are as follows:

1. *This effort will maintain existing regulatory standards that protect public health and water quality.*
2. *This effort will allow a municipality to balance CWA requirements in a manner that addresses the most pressing public health and environmental protection issues first.*

3. *The responsibility to develop an integrated plan rests with the municipality that chooses to pursue this approach. Where a municipality has developed an initial plan, EPA and/or the State will determine appropriate actions, which may include developing requirements and schedules in enforceable documents.*
4. *Innovative technologies, including green infrastructure, are important tools that can generate many benefits, and may be fundamental aspects of municipalities' plans for integrated solutions.*

Brown and Caldwell (BC) recommends the City investigate how adopting an integrated approach to regulatory planning would benefit the community. Since the City does not have pressing SSO-related problems, BC does not believe that adoption of an integrated approach would offer much benefit or would provide much impact on how the City manages and operates the wastewater collection system. The integrated approach may offer value in addressing other regulatory requirements.

BC recommends the City consider implementing some of the CMOM principles since they can lead to improved sanitary collection system performance and lengthen the service life of infrastructure investments. In this way, the CMOM principles fully support sustainability concepts and the asset management objective of overall least cost of ownership.

## Developing a CMOM Program

Table F-1 identifies the eight proposed components of a well-structured CMOM program. BC recommends the City consider adoption of some of the most pertinent CMOM concepts since they will improve the performance of the sanitary sewer collection system. Several work sessions could be held with key stakeholders to evaluate the strengths and weaknesses of current sanitary sewer collection system management practices with regard to the recommended CMOM activities. Then, a CMOM strategy development team could identify the new activities to be adopted and the estimated costs for implementing the identified activities. Finally, the list could be prioritized based on benefit and cost considerations. The cost to develop and implement these components will vary considerably depending on the City's interest and focus.

# Appendix G: Rehabilitation and Replacement Technologies

Appendix G

# Rehabilitation and Replacement Technologies

A variety of corrective action technologies are available for application to the City of Oregon City's (City) sewer rehabilitation and replacement needs. This document describes the various technologies and presents cost information on those that are most appropriate for City use.

## Open-Cut Pipe Materials

A number of pipe materials can be used to replace the City's existing sewers. Many of the structural defects observed in municipal sewers are due to available pipe materials, their susceptibility to corrosion and infiltration, and/or poor construction techniques. Brown and Caldwell (BC) recommends that candidate pipe materials satisfy the following criteria:

- They are resistant to the corrosive environment often found in sanitary sewers.
- They are resistant to erosion due to the conveyance of sand and grit.
- They have structural support adequate to support the expected design loads.
- They have joints that are watertight as required to prevent infiltration and the resulting loss of bedding and backfill material.
- They are readily available commercially.

Based on these criteria, several materials are recommended for the rigid and flexible classes of pipe.

## Rigid Pipe Materials

Three rigid pipe materials meet the above criteria for replacement pipe:

- reinforced concrete pipe (RCP) with plastic corrosion-resistant liner
- vitrified clay pipe (VCP) with fiberglass joints and rubber gaskets
- polymer concrete pipe

## Flexible Pipe Materials

Three flexible pipe materials meet the above criteria for replacement pipe:

- high-density polyethylene (HDPE) pipe
- poly-vinyl chloride (PVC) pipe, ≤ 24 inches in diameter
- centrifugally-cast fiberglass reinforced polymer mortar pipe, or Hobas®

All of the above are suitable options for the City. The selection of the project-specific appropriate pipe material(s) should be made during preliminary design.

# Rehabilitation Technologies

A number of technologies are available for rehabilitating gravity sewers. Rehabilitation technologies can be fully structural (i.e., even if the existing pipe lost all its structural strength, the rehabilitation method could still support all live and dead loads) or non-structural (i.e., the existing host pipe must bear all structural loads). Some non-structural rehabilitation techniques extend the pipe's remaining life by stabilizing the pipe, either internally or externally.

The following paragraphs describe technologies for full pipe segment rehabilitation, point repair rehabilitation, and non-structural (stabilization) rehabilitation.

# Full Pipe Segment Rehabilitation Technologies

Full pipe segment rehabilitation technologies are considered when the existing defects are located extensively throughout the pipe such that point or spot repairs are not feasible. Technologies that were considered for City use include cured-in-place pipe (CIPP), pipe bursting, spiral pipe renewal (SPR), sliplining, and pipe wrap.

## CIPP

CIPP is a technology that has been in use in North America for almost 40 years. Rehabilitation is done by installing an uncured tube that is saturated with resin into an existing pipe. The existing pipe is used as a form as the tube is expanded against it and the resin is cured. All CIPP liners have four essential components: a flexible tube, a thermosetting resin that impregnates the tube, a method to install and expand the impregnated tube, and a method to cure (i.e., harden) the resin. The end result is a corrosion-resistant, jointless pipe that conforms to the geometry of the existing host pipe. CIPP can be installed with little to no excavation and it can be a fully structural repair or a non-structural repair, depending on design parameters. Of the various trenchless rehabilitation techniques, CIPP generally results in the least amount of internal diameter reduction due to its thin-walled, semi-tight-fit nature.

Installation of CIPP can be performed in difficult locations on almost any size pipe. However, pipes greater than 27 to 30 inches in diameter typically require the removal of the manhole top slab or cone to be rehabilitated with CIPP. Typical vehicle access requirements include large box trucks, boiler trucks, and possibly scaffolding constructed directly over the manhole. The pipe must be dry during installation, so bypass pumping is required. Installation time could take from a few hours to a week, depending on location and size. Figure G-1 shows examples of CIPP installation.

This technology is recommended for City consideration in the rehabilitation of sewers with adequate sewer capacity.

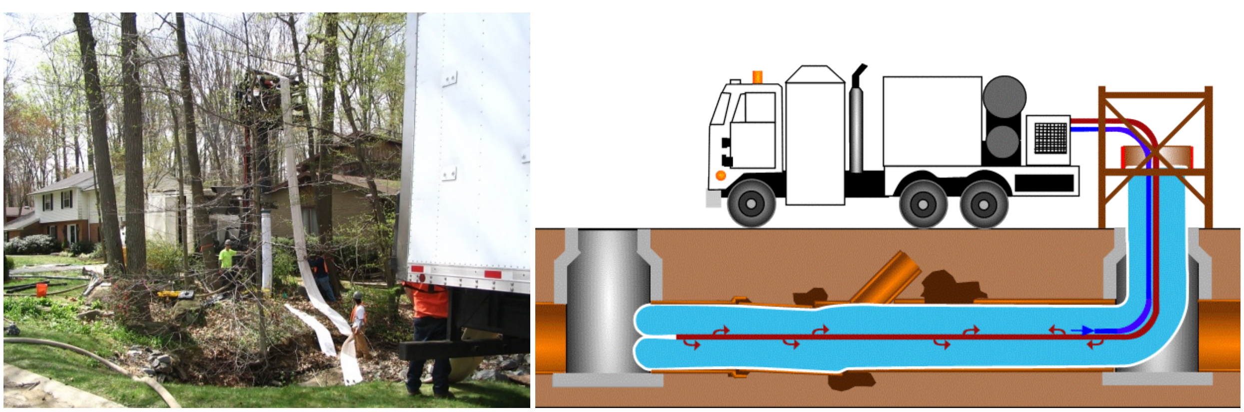


**Figure G-1. Examples of CIPP installation**

## Pipe Bursting

Pipe bursting is a technology that involves the pulling of a bursting head to break apart or slice the existing pipe. As the head is pulled through the host pipe, a continuously-fused HDPE or PVC pipe is fed into the pipe directly behind the bursting head. The new pipe can be either the same size or slightly larger than the original. The end result is a fully structural, corrosion-resistant, jointless pipe that replaces the existing host pipe. Figure G-2 shows examples of pipe bursting installation.

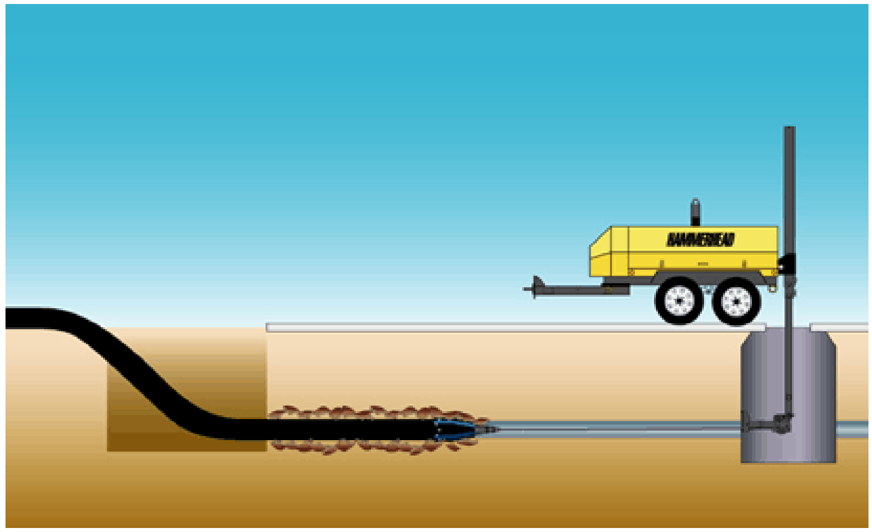


**Figure G-2. Examples of pipe bursting installation**

Pipe bursting requires some excavation and vehicle access. The new pipe must be inserted at one end using an excavated insertion pit, normally at the upstream manhole, which allows the new pipe to be pulled into the existing pipe without exceeding the HDPE or PVC pipe bending radii. The technology is generally limited to existing pipes 24 inches in diameter or smaller. In addition, the entire length of new pipe must be fully fused and laid out prior to insertion of the pipe, meaning that a long laydown area immediately adjacent to the insertion pit is required. The pipe must be dry during installation, so bypass pumping is required. Installation can take from a few hours to several days, depending on location and size. Suitability of ground conditions, potential for heave disturbing surface improvements or affecting pipeline grade, condition of host pipe including sags, and required diameter are all considerations for the design phase.

This technology is recommended for City consideration in the rehabilitation of sewers with adequate, or near-adequate, capacity.

## SPR

SPR is a trenchless technology that involves the winding of a continuous strip of PVC or HDPE within an existing pipe. It can be performed on a wide range of existing pipe sizes, since the host pipe is used as a form for the wound pipe. The strips are interlocked and because SPR is not a tight-fit technology, the resulting annulus is filled with grout. Concerns regarding the structural capability of the PVC product have resulted in the development of HDPE with embedded steel reinforcement. The HDPE product is welded together in the field, whereas the PVC product uses a mechanical joint. The HDPE product has a thicker profile and reduces the internal diameter significantly more than does the PVC product. In general, use of SPR results in a much larger loss of hydraulic capacity than do some other techniques such as CIPP. However, the end result is a corrosion-resistant pipe that replaces the existing host pipe and can be installed with little excavation.

The winding machine is of significant size and requires the removal of a manhole at one end for larger pipes. The grout and pumps must be in the vicinity for filling the annular space between the newly wound pipe and host pipe. One major benefit of SPR is the ability to install the pipe during active flow conditions. However, the newer more structurally sound HDPE material requires field welding, so bypass pumping is recommended. Installation can take from a few hours to several days, depending on location and size. Figure G-3 shows examples of SPR installation.

While the SPR technique is used in some areas of the country, BC is not aware of its use in Oregon or the Northwest. Consequently, it is unlikely that local contractors are experienced in its application. This technology is not recommended for City consideration for rehabilitating sewers at this time. In the future, if contractor experience is found or developed within the area, the City should consider this technology as one of the rehabilitation alternatives.

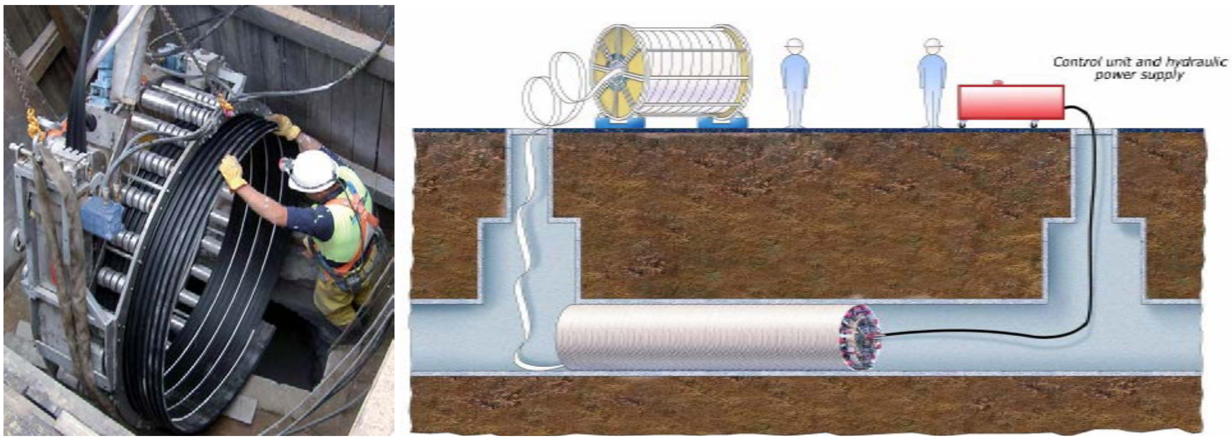



**Figure G-3. Examples of SPR installation**

## Sliplining

Sliplining is a technology that involves the jacking or pulling of a smaller pipe inside the existing pipe. The pipe that is either jacked or pulled through the existing pipe must be able to withstand the forces exerted during the installation process. Common pipe materials used are fusible HDPE or PVC, fiberglass-reinforced pipe such as Hobas, and VCP. Because sliplining is not a tight-fit technology, the resulting annulus is filled with grout. Sliplining generally reduces the internal diameter of the pipe more than any other rehabilitation technology. The end result is a fully structural corrosion-resistant pipe that replaces the existing host pipe and can be installed with limited excavation.

Excavation is limited to an insertion pit that is required at one end of the pipe slated for rehabilitation. The grout and pumps must be in the vicinity for filling the annular space between the newly inserted pipe and host pipe. In addition, a laydown area must be provided for the new pipe and jacking/pulling equipment. Except in low flow cases, bypass pumping is required. Installation can take from a few hours to a week, depending on location and size. Figure G-4 shows examples of sliplining installation.

This technology is recommended for City consideration only in the rehabilitation of sewers with excess capacity.

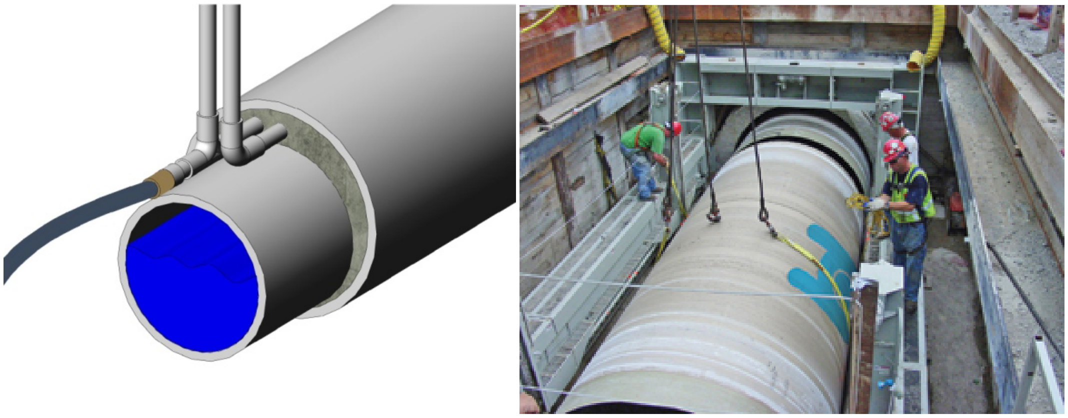


Figure G-4. Examples of sliplining installation

## Pipe Wrap

Pipe wrap is a new technology based on a technique used to reinforce above-grade structures such as bridges and building walls. A thin carbon-fiber-reinforced fabric is saturated with corrosion-resistant epoxy resin and is glued to the interior of the pipe. Existing pipe surface preparation and primer are required to obtain a bond between the resin-saturated fabric and the existing pipe. Man-entry is required for installation of pipe wrap; consequently, its use is limited to sewers 48 inches in diameter and larger. The resin fabric is less than 0.1 inch thick and therefore reduces the flow capacity only slightly.

Given the workability of the material and the man-entry installation, no excavation is required. Because the fabric is saturated with resin in the field, a small setup area is required to wet the fabric strips. The pipe must be dry during installation, so bypass pumping is required. Installation can take from a few days to several weeks, depending on location and size. However, given the unproven nature of the product and the lack of successful installations in the Northwest, pipe wrap is not recommended for City consideration at this time. This technology may become more viable in the future. Figure G-5 shows examples of pipe wrap installation.


Figure G-5. Examples of pipe wrap installation

## Point Repair Rehabilitation Technologies

Spot or point repairs are recommended where defects are localized or not distributed throughout long sections of the sewer. All of the technologies presented in this section are recommended for City consideration in repairing sewers.

### Cured-in-Place Point Repair

Spot or point repairs can be made using the same cured-in-place technology that is used for entire pipe segment rehabilitation. A flexible tube is impregnated with resin and inserted into the host pipe, but with point repairs the tube is shorter in length. Point repairs benefit from their trenchless nature, but because they are shorter and require significantly less material than full-length pipe segment CIPP, construction equipment and materials are greatly reduced. Bypass pumping is still required. Figure G-6 shows examples of cured-in-place point repair.

**Figure G-6. Examples of cured-in-place point repair**

### Mechanical Point Repair (Link Pipe®)

Spot or point repairs can be made using a stainless steel or PVC sleeve that results in a close-fitting repair. For smaller diameter trunk lines (i.e., less than 30 inches) a stainless steel sleeve is used. The sleeve is positioned into place and the annular space is filled with grout. O-rings seal each end of the sleeve to the host pipe with ports located in the center of the sleeve used for filling the grout. For larger diameter trunk lines (i.e., 36 inches or greater) a hinged PVC repair is used. Hydraulic jacks are used to expand the PVC sleeve and O-rings are used to seal the edges. Grout is pumped into the annular space.

The end result is a structural, corrosion-resistant repair that can be installed with little to no excavation. Construction access involves the box truck, closed-circuit television (CCTV) truck, and potentially heavy equipment for the larger diameter repairs that require manhole cone or top slab removal. In all but the largest of pipe diameters, bypass pumping is not required. Figure G-7 shows examples of Link Pipe® installation.

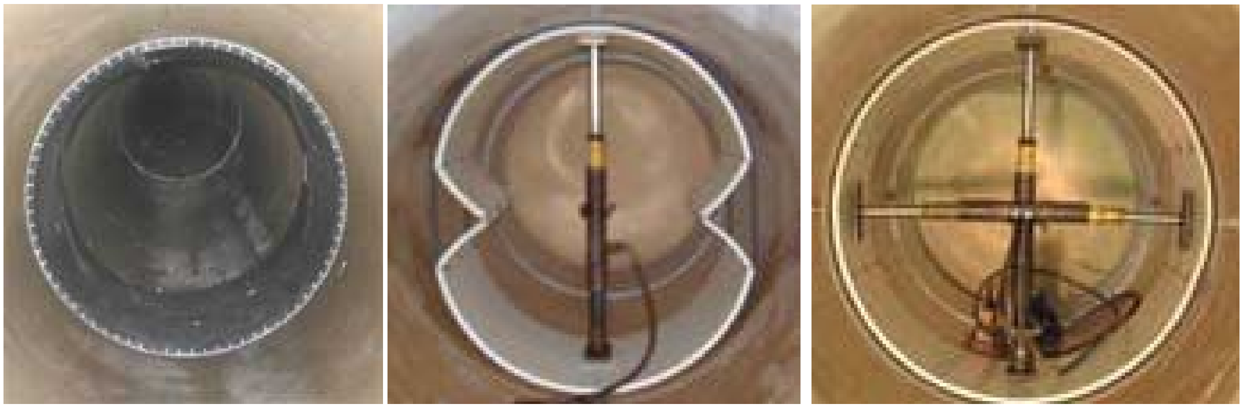


**Figure G-7. Examples of Link-Pipe® installation**

*(left: stainless steel sleeve; middle and right: PVC link-pipe)*

# Non-Structural (Stabilization) Rehabilitation Technologies

Non-structural rehabilitation technologies focus on slowing or preventing further degradation of the pipe. Applicable technologies include injection grouting for stabilizing pipe bedding and backfill against soil loss and magnesium hydroxide application to slow hydrogen sulfide degradation.

## Test and Seal (Injection Grouting)

Sewers with high levels of infiltration risk the loss of pipe bedding and backfill due to erosion into the pipe. Loss of pipe bedding can lead to pipe settlement and a resulting increase in pipe and joint cracks, fractures, and breaks. The characteristics of the soil are critical to the degree of soil loss experienced. Silts and fine sands experience the greatest amount of degradation. If not detected early, soil loss can lead to catastrophic failures, as shown in Figure G-8. The test and seal technology helps to locate and then seal leaky sewers.

The basic principle of grouting pipe lines is to test the joints by hydraulically applying a positive pressure to the joints, monitoring the pressure in the void, and monitoring the test medium flow rate. The test medium is usually air. The intent of joint testing is to identify sewer pipe joints that are not watertight and that can be sealed successfully by injecting chemical grout into the soils encompassing the pipe joint. Chemical grouts have little to no structural strength. They provide stabilization of pipe bedding and prevention of infiltration and the potential loss of fine-grained soils through leaking pipe joints.

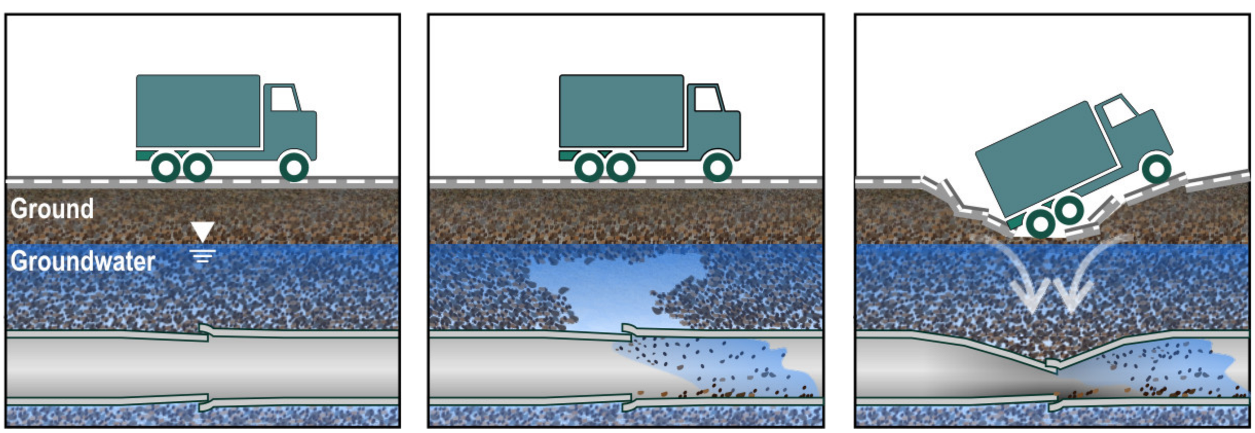



**Figure G-8. Structural failure mechanism caused by infiltration at joints**

Injection of grout is most effective when it is applied from an internal packer device that is placed inside the sewer pipe. The major support equipment includes a box truck that contains the hoses, chemical grout, air compressor, and CCTV equipment. Normally, the pipe can receive limited flow during this operation, such that bypass pumping may not be required except when flows are above the camera lens. In large diameter pipes, the size of the required packers is too large for standard manhole frame openings. In this case, the packers can be disassembled and then reassembled in the manhole if manhole component removal is undesirable.

Similarly, heavy infiltration can occur at manholes and cause loss of bedding around the manhole structure and influent/effluent pipes. This infiltration can be addressed via man-entry into the manhole, drilling a small hole into the manhole wall, and injecting chemical grout. Heavy vehicle access or excavation is not required, and the work can be done in live sewers with no bypass pumping. Figure G-9 depicts typical packer injection grouting installation.

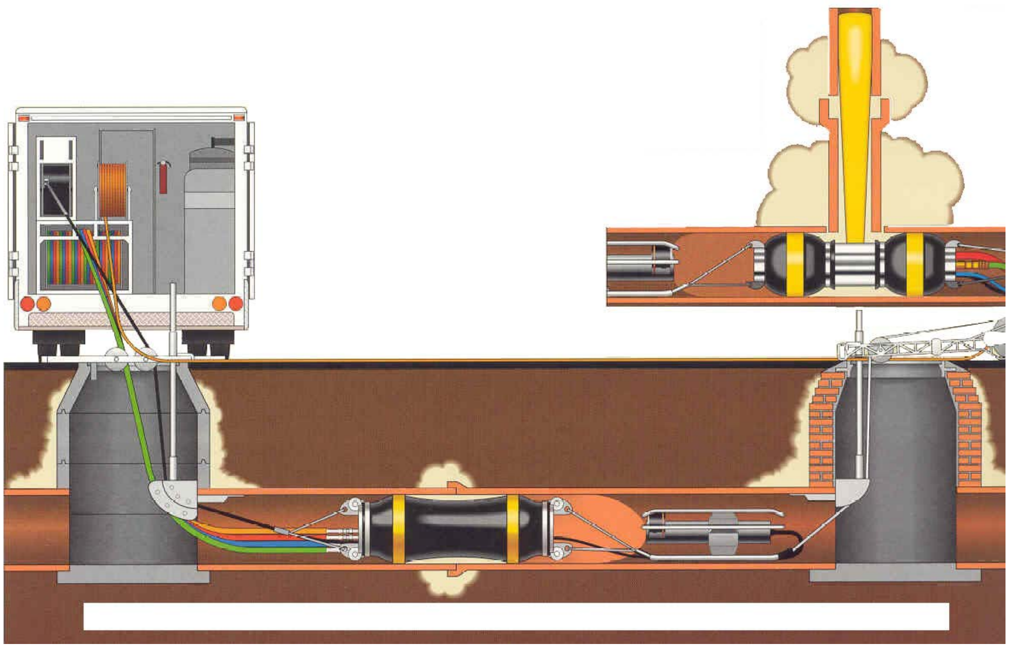


**Figure G-9. Typical packer injection grouting installation**

## Magnesium Hydroxide Spraying

For corrosion issues, one way to slow the rate of corrosion is repeated magnesium hydroxide spraying on the exposed portions of the concrete sewer pipe. Magnesium hydroxide neutralizes acids that corrode the concrete and greatly slows the rate of corrosion, resulting in increased pipe life. Magnesium hydroxide should be applied at times of lowest flow to maximize the surface area exposed to corrosive gases. For City sewers, that would mean nighttime flows during the driest summer months. Magnesium hydroxide is spray-applied from a boat or crawler in the pipe, depending on flow conditions. No bypass pumping is required, and access to the upstream pipe manhole is preferable. A box truck similar in size to a grout truck is the only access required. Magnesium hydroxide spraying has been used successfully in other municipalities such as Phoenix and Los Angeles for recurring maintenance to extend pipe life. However, this technology has seen limited use in the Northwest. Therefore, there may not be contractors in this area who are familiar with its application. BC does not recommend consideration of this technology for use at this time. Figure G-10 illustrates the rate of corrosion as impacted by surface pH.

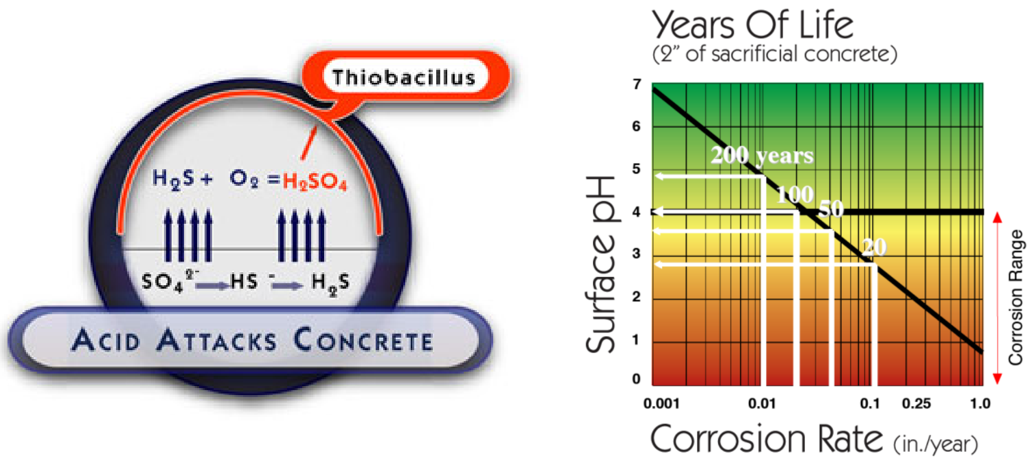



**Figure G-10. Rate of corrosion as impacted by surface pH**

### Other Maintenance Activities

Regular maintenance is a proven way to extend pipe life. Accumulation of debris, roots, and grease can lead to hydraulic restrictions which can cause surcharging and stress on the pipe. Surcharging of older clay and concrete pipes that do not have watertight joints can lead to disturbance of the surrounding soils, potential loss of bedding and pipe support, and further deterioration.

## Summary of Rehabilitation Technologies

Table G-1 summarizes the various options available for full pipe segment, pipe repair, and non-structural corrective actions.

**Table G-1. Rehabilitation Options**

| Technology | Available pipe diameters | Structural | Bypass pumping required | Excavation required | Local contractors | Loss of hydraulic capacity | Appropriate for City sewers |
|---|---|---|---|---|---|---|---|
| Open-cut | All | Y | Y | Major | Y | N | Y |
| CIPP | All | Y | Y | Minor | Y | Minor | Y |
| Pipe bursting | ≤ 24 inches | Y | Y | Moderate | Y | N | Y |
| SPR | All | Y | N | Minor | N | Moderate | N |
| Sliplining | All | Y | Y | Moderate | Y | Major | Y |
| Pipe wrap | ≥ 48 inches | Unknown | Y | N | N | Minor | N |
| Link-pipe | All | Y | N | N | Y | Minor | Y |
| Magnesium hydroxide | All | N | N | N | Y | N | N |
| Test and seal | All (limited packer availability in > 42 inches) | N | N | N | Y | N | Y |

Many of the above-described rehabilitation technologies are available as candidates for use on the City's sewers. For smaller diameter sewers (≤ 24 inches), cured-in-place and pipe bursting are the most frequently used and least costly technologies currently available. A cost savings of approximately 50 percent is typical when comparing the rehabilitation technologies presented in this document to open cut replacement costs.

Sewer capacity often influences rehabilitation and replacement decisions. Consequently, the Sanitary Sewer Master Plan should be referenced during the predesign phase of a project to ensure that the hydraulic capacity of a given sewer is considered as part of an informed rehabilitation and replacement decision-making process.

## Other Inspection/Evaluation Technologies

While CCTV inspection is the primary technology used by most municipalities to inspect the sewer system, a number of other technologies exist that can be used to augment a CCTV inspection program. Typically, these would be used for specialized inspections where CCTV inspections do not perform well. Examples include the following: laser profiling, sonar, and ground-penetrating radar. The focus of this discussion will be on laser profiling.

Laser profiling is recommended in pipes where an accurate measurement of the pipe's internal diameter and shape are critical to the rehabilitation decision-making and design process. Although it is a relatively new technology, laser profiling has a number of practical applications in assessing sewer condition, including accurately determining the location and geometry of defects, verifying the level of deformation in flexible and non-flexible pipes, and determining the size of cracks in rigid pipes.

Figures G-11 through G-13 show images from a laser profiling inspection performed on a cast-in-place RCP. The pipe was constructed in the 1910s and is approximately 25 feet deep. As shown in Figure G-11, the pipe looks deformed, but it is difficult to assess the degree of deformity. In this case, information on the true dimensions of the pipe was critical since sliplining rehabilitation was being considered.

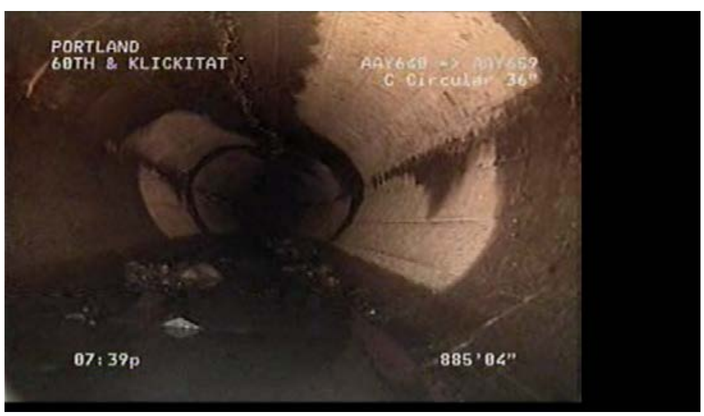



**Figure G-11. Video image from laser profile inspection**

Figure G-12 shows the laser projection on the wall of the pipe as captured by the inspection equipment's video camera. As shown on the screen capture, the true diameter of the pipe is determined for both the X and Y axes.

As shown in Figure G-13, the actual profile of the pipe is projected against the original shape. At one location on this pipeline, the 36-inch internal diameter pipe had only a 30-inch vertical (Y-axis) dimension.

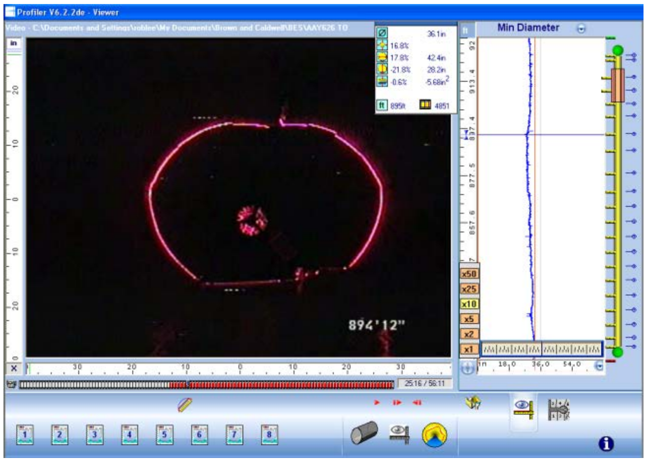


**Figure G-12. Laser projection from laser profile inspection**

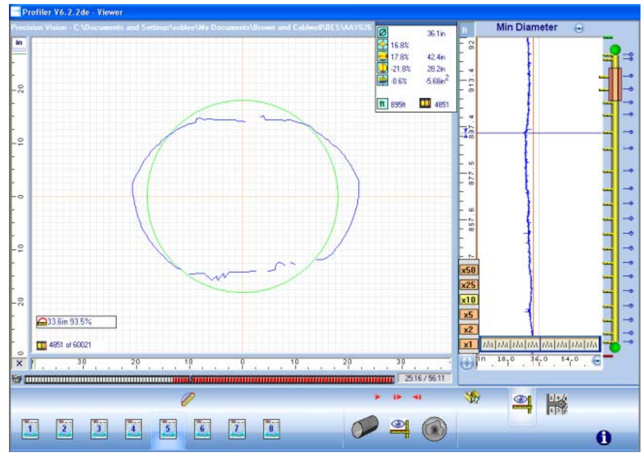
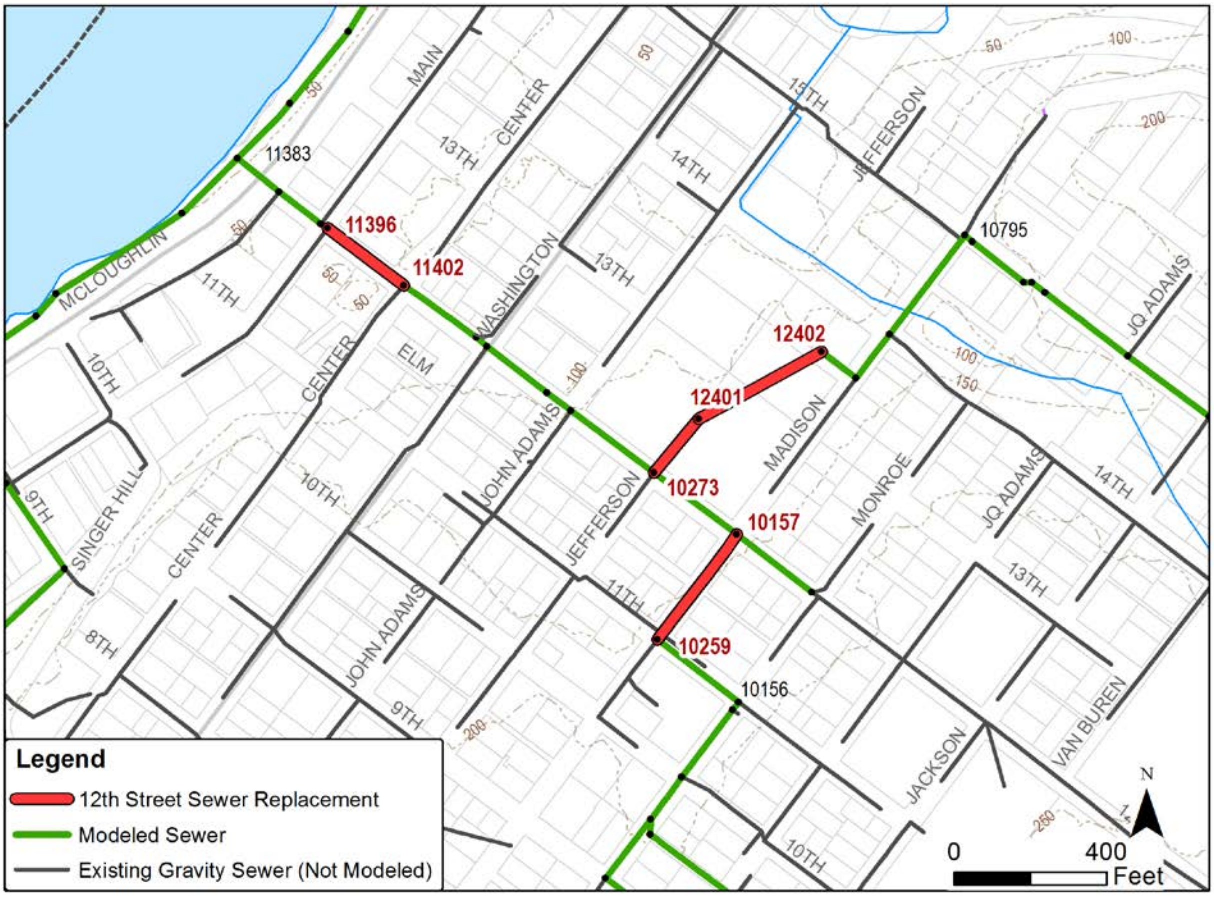


**Figure G-13. Laser profile inspection results**

For the City, use of laser profile technology is recommended for consideration only in specialized cases and for large-diameter lines.

# Appendix H: Sewer Replacement Project Sheets



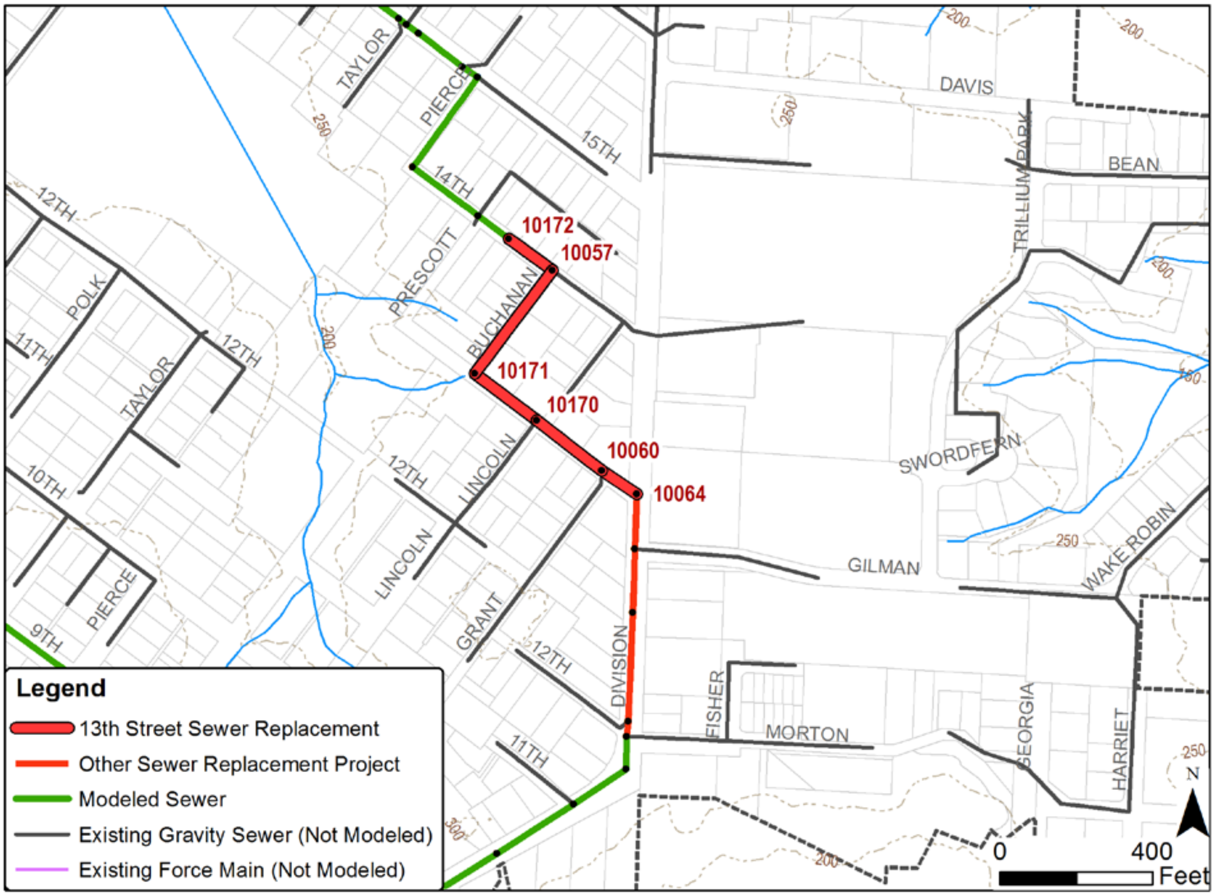

| Project Name | 12th Street Sewer Replacement |
|---|---|

**Project Description**

This project includes replacement of 250 linear feet of existing gravity sewer in public right-of-way on 12th Street from Center Street to Main Street. This project also includes replacement of 346 linear feet of existing gravity sewer in public right-of-way on Madison Street from 11th to 12th Street and 550 linear feet of existing gravity sewer in Barclay Park from manhole 12402 to 12th Street.

**Project Data Table**

| Name | Length (ft) | Existing diameter (in) | Upsized diameter (in) | Cost (2013 $) |
|---|---|---|---|---|
| 11402_11396 | 250 | 12 | 15 | 110,616 |
| 10259_10157 | 346 | 8 | 10 | 128,789 |
| 12402_12401 | 367 | 12 | 15 | 86,858 |
| 12401_10273 | 184 | 12 | 15 | 81,202 |
| Capital Project Implementation Cost Total | | | | 407,466 |

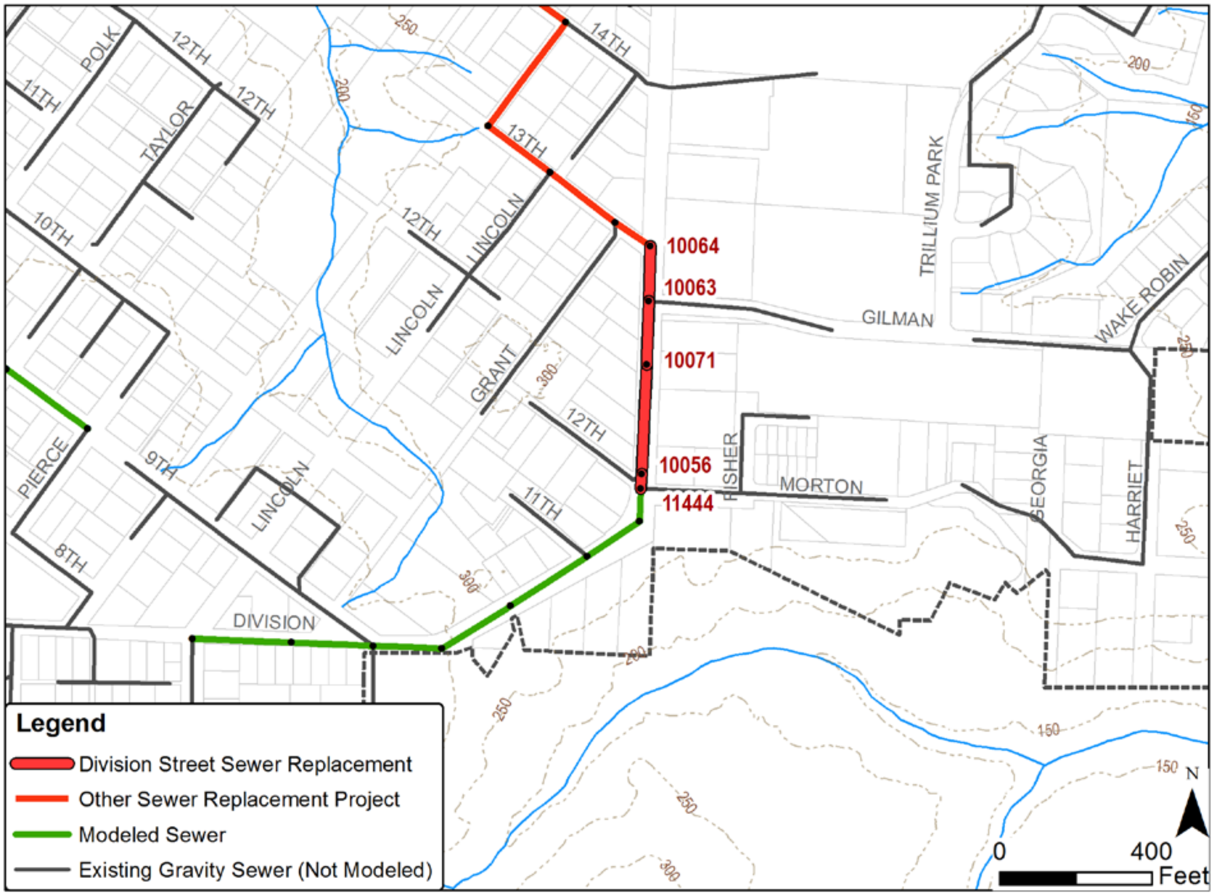



**Project Name** 13th Street Sewer Replacement

**Project Description**

This project includes replacement of 1,011 linear feet of existing gravity sewer in the public right-of-way from MH 10064 on Division Street along 13th Street and Buchanan Street to MH 10172 on 14th Street.

| Project Data Table | | | | |
|---|---|---|---|---|
| Name | Length (ft) | Existing diameter (in) | Upsized diameter (in) | Cost (2013 $) |
| 10057_10172 | 142 | 8 | 10 | 72,918 |
| 10171_10057 | 339 | 8 | 10 | 126,350 |
| 10170_10171 | 203 | 8 | 10 | 75,618 |
| 10060_10170 | 216 | 8 | 10 | 111,222 |
| 10064_10060 | 110 | 8 | 10 | 74,337 |
| Capital Project Implementation Cost Total | | | | 460,446 |



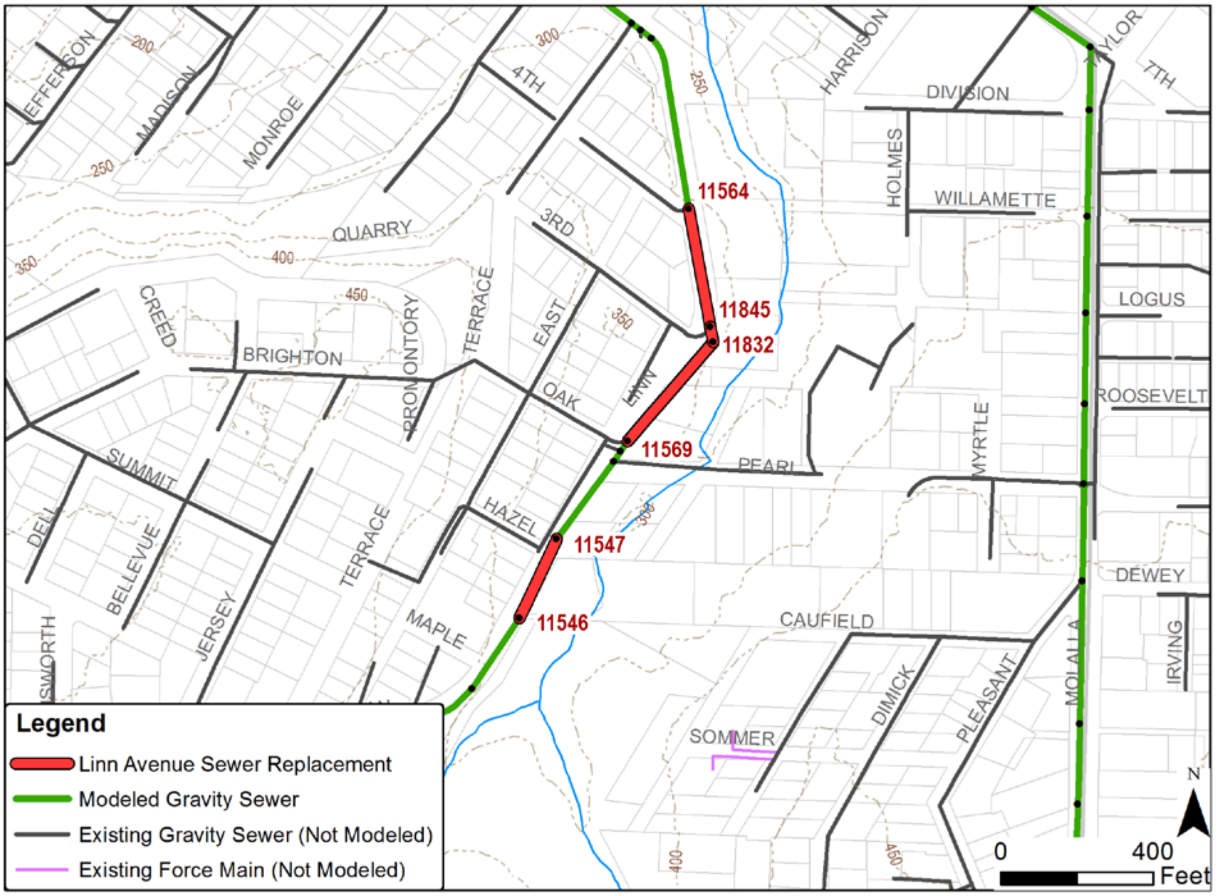

| Project Name | Division Street Sewer Replacement |
|---|---|

**Project Description**

This project includes replacement of 636 linear feet of existing gravity sewer in the public right-of-way on Division Street from 12th Street to 13th Street.

**Project Data Table**

| Name | Length (ft) | Existing diameter (in) | Upsized diameter (in) | Cost (2013 $) |
|---|---|---|---|---|
| 10063_10064 | 144 | 8 | 10 | 97,388 |
| 10071_10063 | 167 | 8 | 10 | 112,880 |
| 10056_10071 | 287 | 8 | 10 | 194,127 |
| 11444_10056 | 39 | 8 | 10 | 19,941 |
| Capital Project Implementation Cost Total | | | | 424,336 |

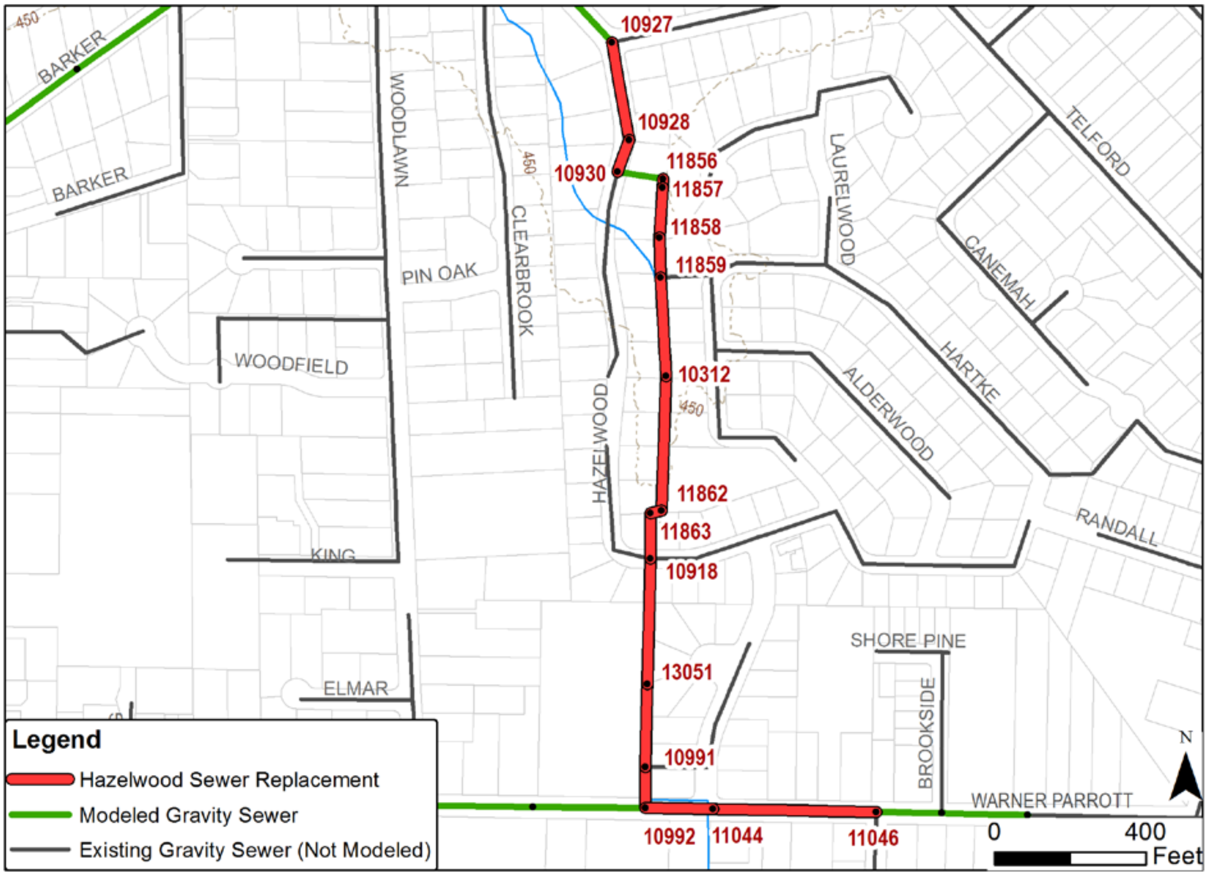



| Project Name | Linn Avenue Sewer Replacement |
|---|---|

**Project Description**

This project includes replacement of 929 linear feet of existing gravity sewer in the public right-of-way on Linn Avenue from Maple to 4th Street.

| Project Data Table | | | | |
|---|---|---|---|---|
| Name | Length (ft) | Existing Diameter (in) | Upsized diameter (in) | Cost (2013 $) |
| 11845_11564 | 315 | 12 | 15 | 139,464 |
| 11832_11845 | 41 | 12 | 15 | 24,341 |
| 11569_11832 | 343 | 12 | 15 | 204,517 |
| 11546_11547 | 230 | 12 | 15 | 101,788 |
| Capital Project Implementation Cost Total | | | | 470,110 |



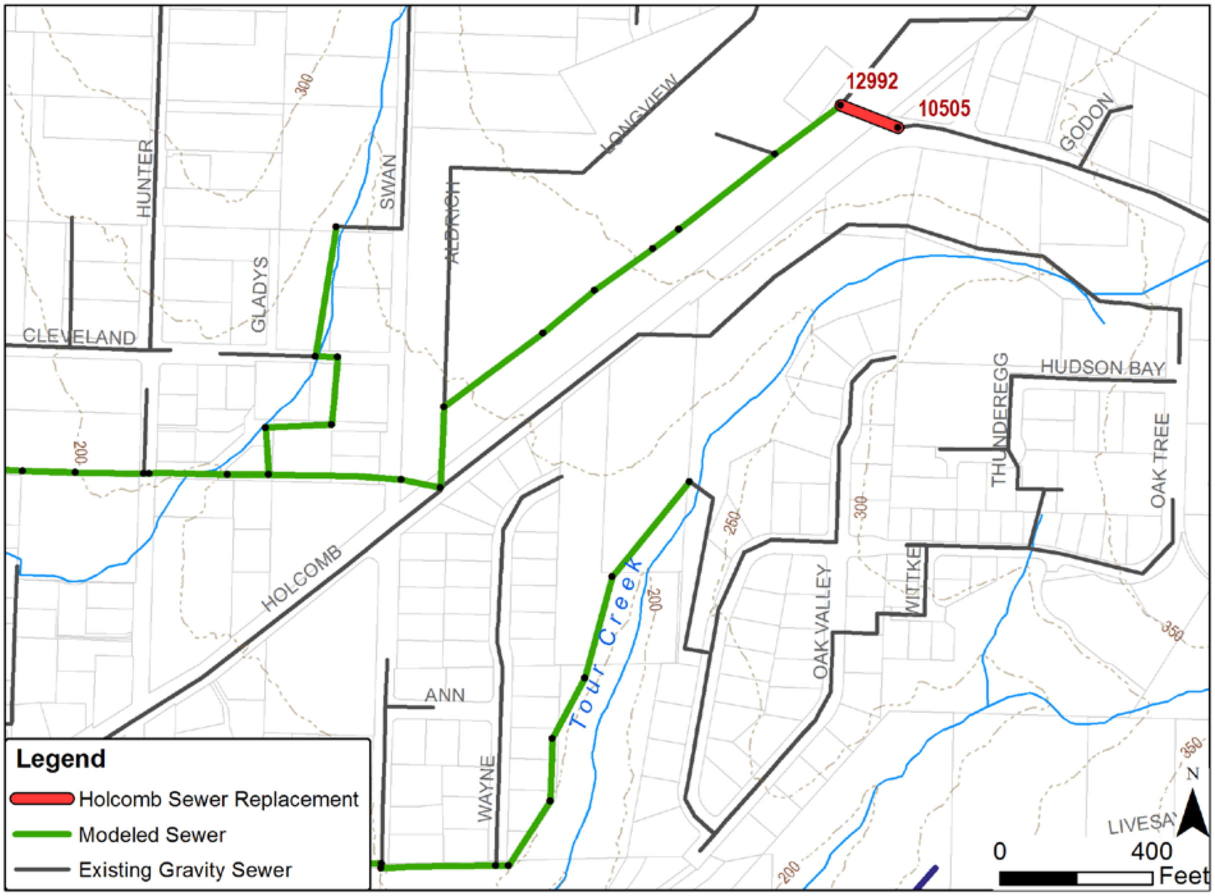

| Project Name | Hazelwood Drive Sewer Replacement |
|---|---|

**Project Description**

This project includes replacement of 610 linear feet existing gravity sewer in the public right-of-way from MH 11046 to MH 10992 on Warner Parrott Road. This project also includes replacement of 1,683 linear feet of gravity sewer on private property from MH 10992 on Warner Parrott Road to MH 11856, east of Hazelwood Drive. This segment is between residential lots and shares an alignment with the creek. Construction costs and feasibility of this portion of the CIP should be evaluated further in preliminary design due to its location. The final segment of this project includes replacement of 350 linear feet of existing gravity sewer in the public right-of-way on Hazelwood Drive from MH 10930 to MH 10927.

**Project Data Table**

| Name | Length (ft) | Existing diameter (in) | Upsized diameter (in) | Cost (2013 $) |
|---|---|---|---|---|
| 10928_10927 | 261 | 10 | 12 | 103,447 |
| 10930_10928 | 89 | 10 | 12 | 35,100 |
| 11857_11856 | 23 | 10 | 12 | 18,052 |
| 11858_11857 | 132 | 10 | 12 | 83,522 |
| 11859_11858 | 105 | 10 | 12 | 51,370 |
| 10312_11859 | 260 | 10 | 12 | 127,524 |
| 11862_10312 | 355 | 10 | 12 | 173,929 |
| 11863_11862 | 30 | 10 | 12 | 14,549 |
| 10918_11863 | 120 | 10 | 12 | 75,758 |
| 13051_10918 | 331 | 10 | 12 | 162,156 |
| 10991_13051 | 218 | 10 | 12 | 106,766 |
| 10992_10991 | 109 | 10 | 12 | 53,202 |
| 11044_10992 | 179 | 8 | 10 | 92,088 |
| 11046_11044 | 431 | 8 | 10 | 221,253 |
| Capital Project Implementation Cost Total | | | | 1,318,715 |




| Project Name | Holcomb Boulevard Sewer Replacement |
|---|---|

**Project Description**

This project includes replacement of 161 linear feet of existing gravity sewer at Holcomb Boulevard and S. Longview Way.

| Project Data Table | | | | |
|---|---|---|---|---|
| Name | Length (ft) | Existing diameter (in) | Upsized diameter (in) | Cost (2013 $) |
| 10505_12992 | 161 | 8 | 10 | 60,107 |
| Capital Project Implementation Cost Total | | | | 60,107 |

# Appendix I: Glen Oak Road Analysis

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# Technical Memorandum

Prepared for: City of Oregon City, Oregon

Project Title: City of Oregon City Sanitary Sewer Master Plan

Project No.: 142029

**Technical Memorandum**

Subject: Glen Oak Road Sewer Extensions

Date: June 30, 2014

To: Erik Wahrgren, City of Oregon City

From: James Hansen, BC-Portland

Technical Reviewer: Justin Twenter, BC-Seattle

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# Section 1: Introduction

In 2012, the City of Oregon City (City) retained Brown and Caldwell to assist with the development of a new sanitary sewer master plan (SSMP). The new SSMP will identify requirements within the existing sanitary collection system for improving existing and future sanitary sewer service and for providing services to new areas as they are developed and annexed by the City. One of these areas is the proposed Beavercreek Road Concept Area that will require a number of sanitary sewer system improvements. As shown in Figure 1, there are only two sewers that currently serve this area. One is available in Beavercreek Road toward the north end of the concept area and another is available in Glen Oak Road toward the south and west ends of the concept area. This technical memorandum (TM) evaluates the impacts of flows on the existing downstream sewer collection system from three different routing alternatives.

# Section 2: Analysis Methodology

Hydraulic analyses were conducted using Storm Water Management Model (SWMM) urban hydrology and conveyance system hydraulics software. The model constructed for use in analyzing the City's sanitary sewer collection system for the SSMP effort was expanded so that the alternatives defined by this TM could be analyzed.

The SWMM model used in the development of the SSMP included approximately the western one-third of the sanitary sewer in Glen Oak Road. The model included manhole (MH)-12903 and the sewers connecting it to MH-12370 in Oregon Route 213 as shown in Figure 1. Flows generated along the north and south sides of Glen Oak Road were introduced into the model at appropriate manholes along the model extents.

In the expanded model, the Glen Oak Road sewer was extended to the intersection with Beavercreek Road (MH-12652) to represent how the sewer exists today such that future sewer extension options could be evaluated.

## 2.1 Modeling Parameters

The modeling parameters used for this analysis are the same as those used in preparing the SSMP. Refer to the SSMP for a detailed description of these parameters. In summary, modeling was performed for two planning horizons: existing conditions (2013) and future conditions (at full-build out). Wet weather flows are based on the 1- in 10-year storm event (recurrence interval) which is equivalent to rainfall of 3.5 inches in 24 hours.

## 2.2 Assessment Criteria

This section discusses the criteria used to determine the adequacy of existing and future collection system infrastructure.

Two criteria are used to evaluate whether pipes are too small to convey the design flow. The first, the percent of capacity used, is a ratio of maximum predicted flow (Q) to pipe capacity (Qm) expressed as a percentage. The maximum predicted flow, Q, is the calculated peak flow in each pipe from the model. The pipe capacity (Qm) is the theoretical pipe capacity according to Manning's equation, which assumes unpressurized flow (no surcharging). A percentage of greater than 100 indicates that the pipe is carrying more flow than is theoretically possible for unpressurized flow for a given pipe slope, diameter, and internal roughness. A percent capacity of greater than 100 is an indication of a surcharged pipe.

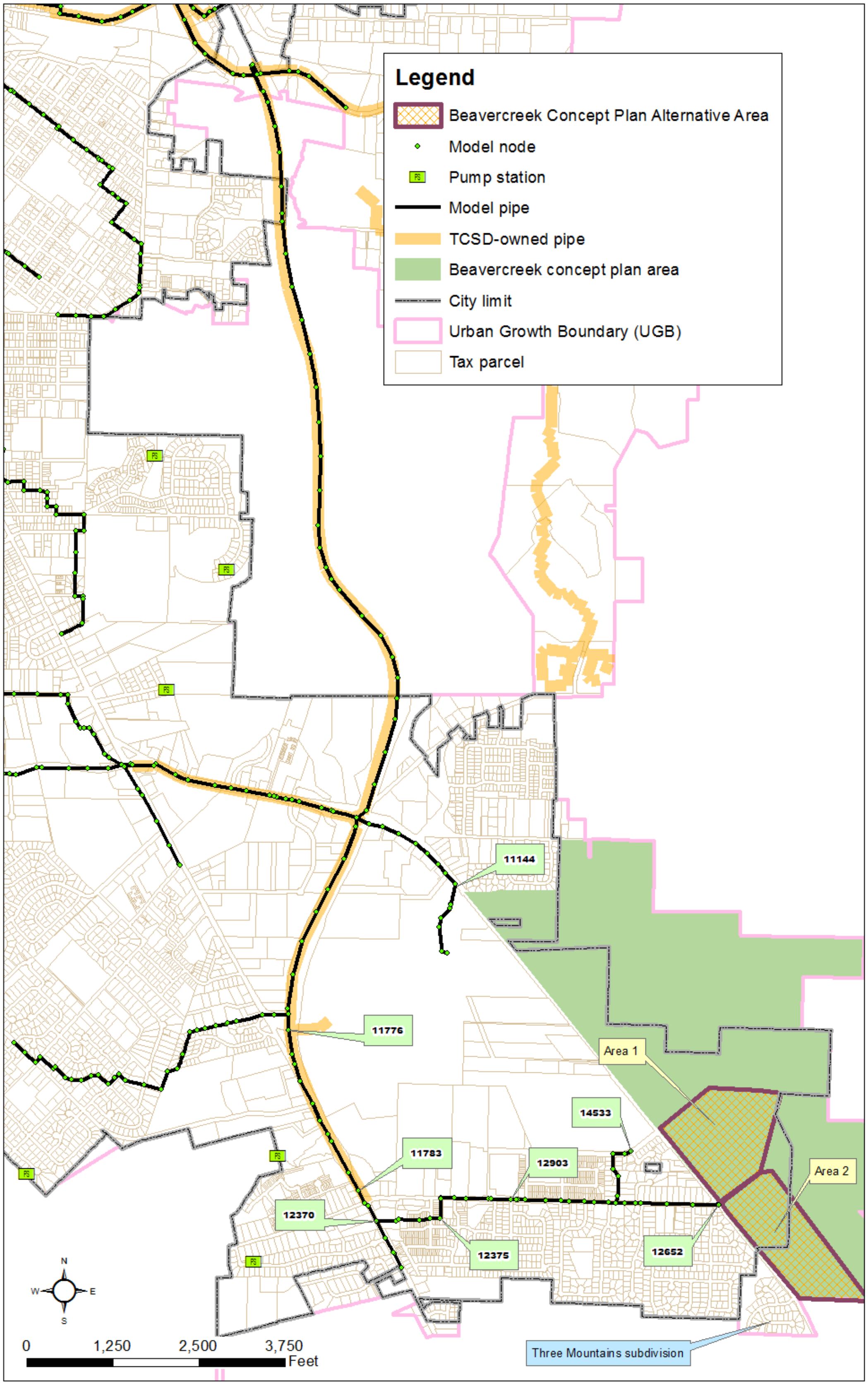


Figure 1. Modeling of Glen Oak Road

However, the percent capacity criterion cannot be used alone to determine pipe capacity due to the way that SWMM-based models report their data. In some situations, peak flows reported by the model exist for extremely short periods of time, sometimes only for seconds. Consequently, some of these peak flow values should not be used as the basis for pipe replacement. The second criterion, the ratio of depth of water to pipe diameter (d/D) is often more reliable. Use of the d/D ratio is described in more detail below.

In an unpressurized pipe, or a pipe with open-channel flow characteristics, the hydraulic grade line (HGL) is the elevation of the water surface within the pipe, or the d value. In a pipe that is surcharged (pressurized flow), the HGL is defined by the elevation to which water would rise in an open pipe, or manhole, as shown in Figure 2. In hydraulic terms, the HGL is equal to the pressure head measured above the invert of the pipe.

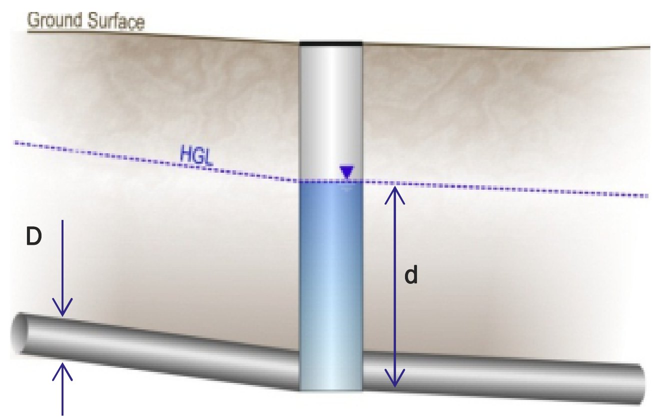


**Figure 2. HGL for surcharged condition**

The recommended approach for determining which pipes need to be upsized is to consider the amount and frequency of surcharging. For example, if minor surcharging (less than 1 to 2 feet) were to occur only during large storm events (i.e., the 1- in 10-year storm) and the surcharging did not impact property or create a sanitary sewer overflow (SSO), City staff should not consider upsizing the pipe. However, if the frequency or amount of surcharging were to increase and endanger property or overflow, then the pipe should be upsized.

Pipes that surcharge frequently should be upsized since frequent surcharging has the potential to reduce their structural stability due to loss of pipe support from fine-grain soils washing into the sewer. Similarly, if the amount of surcharging is more than 1 or 2 feet, City staff should consider the amount of remaining freeboard (i.e., distance between water surface in manhole and ground surface, or to the elevation of basements in the area) with regard to the risk of SSOs or basement backups. This approach will help to ensure that the City has adequate capacity for conveying the design flows without spending more capital dollars than necessary.

In general, most sewers with d/D ratios of between 1 and 3 are not identified for replacement. City staff should monitor these sewers during large storm events to quantify the amount of surcharging that actually occurs. If the observed surcharging increases to the point of risking property or becoming an SSO, then the pipe or pipes should be upsized. Some pipes with minor surcharging are identified for replacement even though their d/D ratio is less than 1 foot. Upsizing of these pipes will help to reduce more significant surcharging in the upstream system.

## 2.3 Flow Routing Alternatives

The impacts of three flow routing alternatives were evaluated to determine impacts on the downstream sanitary collection system. Following are the alternatives:

- Routing Alternative A (Base)—All Beavercreek Road Concept Area flows are directed to a new sewer extension to be connected to existing MH-11144 and then extended to the south in Beavercreek Road.
- Routing Alternative B—Area 2 is routed to the existing sewer in Glen Oak Road (MH-12652) while Area 1 and all of the other remaining portions of the Beavercreek Road Concept Area are routed toward a new sewer extension the same as above.
- Routing Alternative C—Areas 1 and 2 shown in Figure 3 are routed to the existing sewer in Glen Oak Road with Area 1 connected to MH-14533 and Area 2 connected to MH-12652.

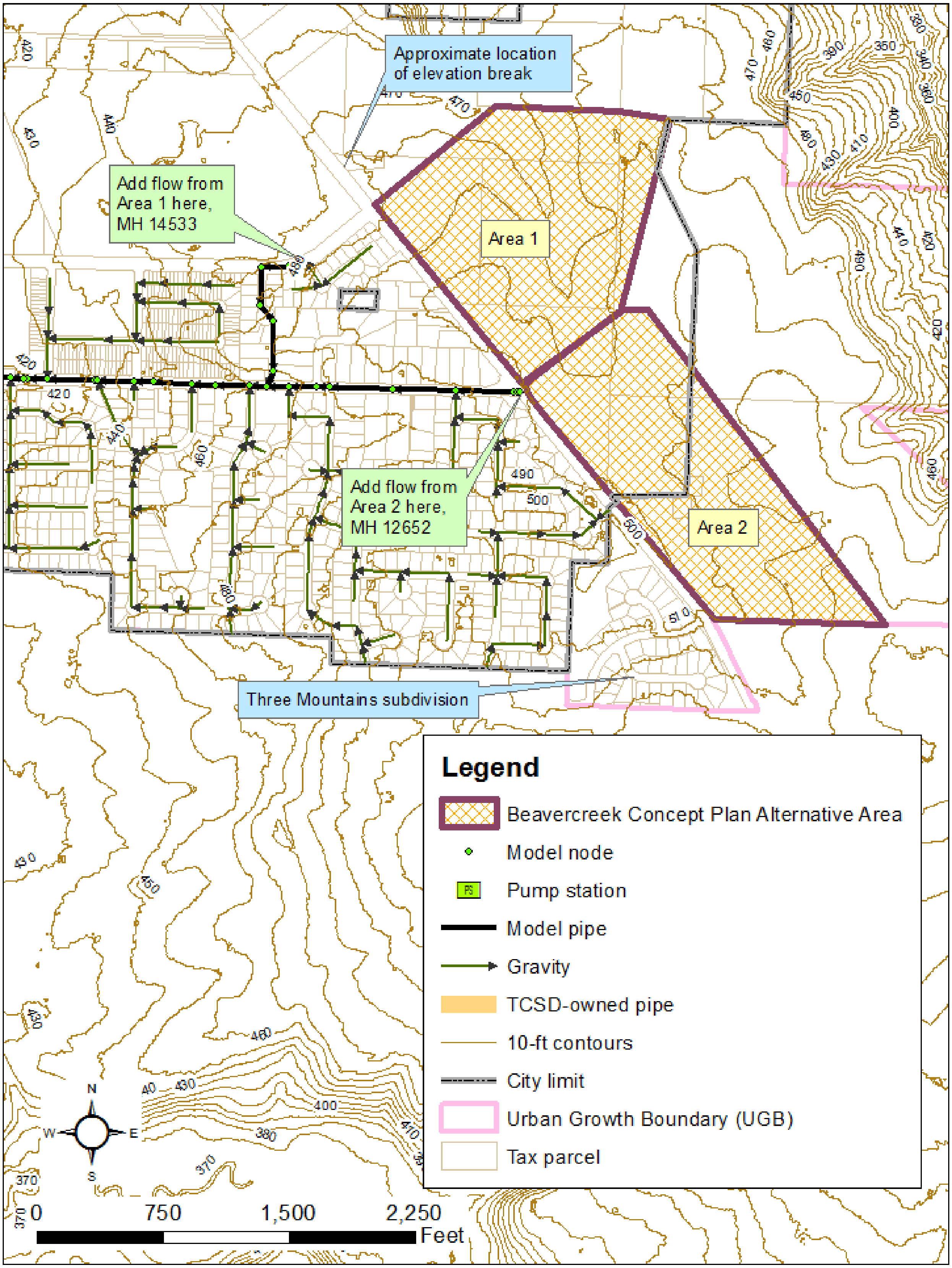


Figure 3. Areas 1 and 2 within Beavercreek concept area

The modeled flows for the base alternative are listed in Table 1. For this alternative, all Beavercreek Road Concept Area-generated flows are routed to new and existing sewers along Beavercreek Road. Other basin flows are generated from the existing and planned development on the north and south sides of Glen Oak Road. Since the model introduces flows at several manhole, flow rates for just three manhole locations are listed in order to simplify reporting.

| Table 1. Base Alternative Flows, gpm | | |
|---|---|---|
| Location | Existing conditions | Future conditions |
| MH-12903 | 283 | 369 |
| MH-12370 | 474 | 683 |
| MH-11776 | 720 | 1,143 |

Flow rates for Areas 1 and 2 are based on the planned development for the Beavercreek Road Concept Area as provided by the City. Unit flow rates of gallons per minute (gpm) are dependent on the type of zoning and assumptions on inflow and infiltration as described in the SSMP. The future condition flow rates for Areas 1 and 2 are listed in Table 2. In summary, Area 1 introduces approximately 123 gpm to the Glen Oak sanitary sewer and Area 2 introduces about 298 gpm.

| Table 2. Areas 1 and 2 Future Flows, gpm | | |
|---|---|---|
| Area | Flow introduced at MH | Future conditions |
| 1 | MH-14533 | 123 |
| 2 | MH-12652 | 298 |

For the purposes of this TM, flows from the Three Mountains subdivision are included in the Glen Oak Road sewer for each alternative. Homes within the Three Mountains subdivision are currently on individual septic systems. In the future, it is envisioned that the area will be connected to the public sewer.

Table 3 summarizes the modeled flows in the Glen Oak Road sewer for the three routing alternatives.

| Table 3. Future Flows in Glen Oak Road for Routing Alternatives | | | |
|---|---|---|---|
| Location | Routing alternatives, gpm | | |
| | Alternative A | Alternative B | Alternative C |
| MH-12903 | 369 | 667 | 792 |
| MH-12370 | 683 | 979 | 1,097 |
| MH-11776 | 1,139 | 1,389 | 1,542 |

# Section 3: Results

This section presents the results of the analysis effort, including a description of surcharged pipes, locations for potential SSOs (flooding), undersized pipes and costs to upsize pipes for the three routing alternatives.

## 3.1 Routing Alternative A

Predicted surcharging in the downstream sanitary collection system for Routing Alternative A is shown in Figures A-1 through A-3 in Attachment A. As shown, there is surcharging in the collection system downstream of MH-11776. Figure A-2 shows there is no surcharging in the Glen Oak Road vicinity. Figure A4 shows that the model predicts surcharging that will produce SSOs farther down in the collection system. These system overflows are located within sewers owned and operated by the Tri-City Service District (TCSD). The TCSD collection system starts at MH-12368 and extends downstream to the Tri-City Water Pollution Control Plant (owned by TCSD/Clackamas County).

Routing Alternative A does not require upsizing of any City-owned sewers along Glen Oak Road or immediately downstream. Downstream TCSD sewers are undersized for the projected future flows as shown in Figure A-5. The hydraulic restrictions in the downstream TCSD sewers do not directly impact flow conditions in Glen Oak Road at the Alternative A flow rate.

## 3.2 Routing Alternative B

For Routing Alternative B, future flows from Area 2 within the Beavercreek Concept Area are routed to the east end of Glen Oak Road and introduced at MH-12652. Predicted surcharging in the downstream sanitary collection system for the Routing Alternative B is shown in Figures B-1 through B-3 in Attachment B. As shown, there is surcharging in the west end of Glen Oak Road. Figure B-3 shows the surcharging is within 5 feet of ground surface at MH-12371 and MH-12372. This condition could lead to sanitary flow backups into basements if homes with basements are located in the area. This condition indicates this sewer and/or downstream sewers need to be upsized to reduce the amount of surcharging.

Figure B-4 shows no model predicted SSOs in the Glen Oak Road area. The model predicts SSOs farther down in the collection system along Oregon Route 213, similar to what is shown for Alternative A.

Alternative B does not require upsizing of any City-owned sewers along Glen Oak Road or immediately downstream. Downstream (north of MH-11776) TCSD sewers are undersized for the projected future flows as shown in Figure A-5. These hydraulic restrictions in the downstream TCSD sewers impact flow conditions in Glen Oak Road for the higher flow rates associated with Alternative B. Upsizing the downstream TCSD sewers would eliminate the surcharge within 5 feet of the ground surface simulated at MH-12371 and MH-12372 in Glen Oak Road. Alternatively, an inflow/infiltration (I/I) abatement program would be required to reduce the flow rate. The cost of upsizing the TCSD sewers is not included in this estimate.

## 3.3 Routing Alternative C

For Routing Alternative C, future flows from Areas 1 and 2 within the Beavercreek Concept Area are routed to the east end of Glen Oak Road. Flows from Area 1 are introduced into the model at MH-14533 (Meyers Road) and flows from Area 2 are inserted at MH-12652. Predicted surcharging in the downstream sanitary collection system for Routing Alternative C is shown in Figures C-1 through C-3 in Attachment C. As shown, there is extensive surcharging in the collection system downstream of MH-11785 including the west end of Glen Oak Road. Figure C-3 shows the surcharging is within 5 feet of ground surface at four manholes along Glen Oak Road. This condition could result in sewer backups into basements located in the area. The modeling indicates this sewer and/or downstream sewers should be upsized to reduce the amount of surcharging.

Figure C-4 shows that the model predicts surcharging that will produce SSOs at MH-12371 as well as farther down in the collection system as shown with the Routing Alternative A. The upsizing of at least two TCSD sewers just north of the intersection of Oregon Route 213 and Glen Oak Road, as shown in Figure C-5, will be required to reduce the surcharging upstream of MH-12370 to within acceptable levels without the need to upsize City-owned sewers. The estimated cost to upsize the TCSD sewers is $537,000.

As with Alternative B, TCSD sewers downstream of MH-11776 are undersized for the projected future flows as shown in Figure A-5 and/or and I/I abatement program is required to reduce the flow rate. The hydraulic restrictions in the downstream TCSD sewers impact flow conditions in Glen Oak Road. The cost of these additional upsized sewers is not included in this estimate.

## 3.4 Beavercreek Road Sewer Extension

Development within the Beavercreek Road Concept Area will require that a number of new sewers and pump stations be constructed. At some point in the development process, a new sewer will be required along Beavercreek Road. At the north end, this new sewer will connect to MH-11144 (at the intersection of Inskeep Drive and Beavercreek Road). The options for providing sewer service to the southerly extents of the Beavercreek Road Concept Area will depend on how the City routes flows from Areas 1 and 2 of the Beavercreek Concept Area as well as the currently unsewered area (Three Mountains subdivision) just outside of the existing city boundary. The topography slopes toward the north such that construction of a gravity sewer along the full length of Beavercreek Road is physically possible and practical.

The distance from the Three Mountains subdivision to MH-11144 is approximately 7,700 feet with a drop in ground surface elevation of about 100 feet. Initial sizing of this sewer finds that it will consist of approximately 5,039 feet of 12-inch pipe and 2,661 feet of 15-inch pipe. Estimated cost for these improvements is $4,016,000. The estimate is based on Alternative A. Diverting flows from Area 1 and/or Area 2 to the Glen Oak Road sewer theoretically would allow for somewhat smaller pipes along Beavercreek Road but this is not recommended. Installing conservatively designed sewer along this important thoroughfare could limit future development possibilities while offering very limited savings.

# Section 4: Conclusion and Recommendations

Routing Alternative A routes all flows from the Beavercreek Concept Area to a sewer in Beavercreek Road. With this alternative, no upgrades are required for the Glen Oak Road sewer. At some point in the development process a new sewer will be required along most of Beavercreek Road.

Routing Alternative B allows Area 2 to be developed before the construction of a new sewer in Beavercreek Road. The increase in flows associated with this alternative will increase the surcharging along Glen Oak Road. Upsizing TCSD sewers further downstream will need to be done to manage the surcharging. The required upsizing is common to all three alternatives. Therefore, the cost of the upsizing is not included. Implementation of Alternative B will not preclude the need for a new sewer along most of Beavercreek Road to serve the Beavercreek Road Concept areas outside of Area 2.

Routing Alternative C allows for Areas 1 and 2 to be developed before the construction of a new sewer in Beavercreek Road. However, the increase in flows associated with this alternative will increase the surcharging along Glen Oak Road. Two TCSD sewers will need to be upsized to manage the surcharging. The estimated cost of the TCSD upgrades is $537,000. Implementation of Alternative C will not preclude the need for a new sewer along most of Beavercreek Road to serve the Beavercreek Road Concept areas outside of Areas 1 and 2.

Ideally, a sewer would be constructed starting at MH-11144 to meet the needs of development in the north end of the concept area. Then as growth continues toward the south, the sewer in Beavercreek Road would be extended to keep in front of the development. Since it is uncertain how growth will occur, the City could consider constructing the Beavercreek Road sewer so that it will be available to developers as growth occurs in the Beavercreek Concept Area. As connections are made, the City would need to be reimbursed through system development charges.

Routing Alternatives A and B could be a quick fix for routing flows from Areas 1 and 2 with resources required for improvements in the TCSD system. The alternatives would essentially divert measures that could be used to help complete sewer improvements in Beavercreek Road which would better serve the full extent of the City's urban growth boundary.

Alternative A is in the best interest of the City since it requires flows from Areas 1 and 2 to be routed through a new sewer extension constructed in Beavercreek Road. This new sewer will be required for serving the entire Beavercreek Road Concept Area, not just Areas 1 and 2.

# Attachment A: Routing Alternative A

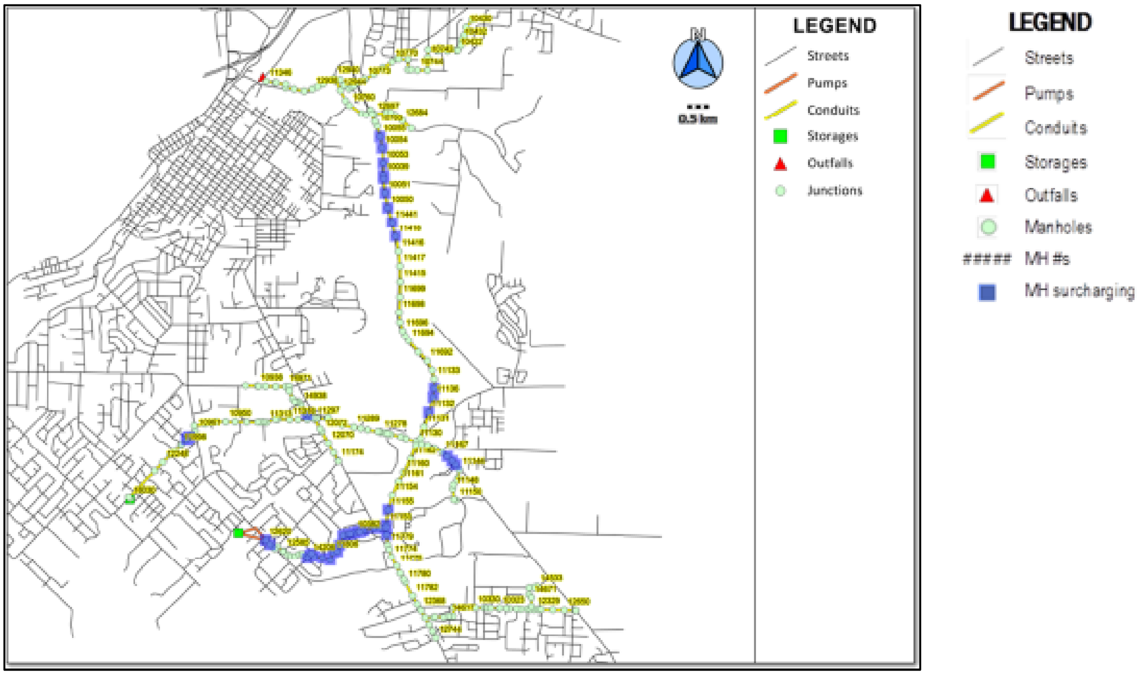


Figure A-1. Surcharging – Alternative A

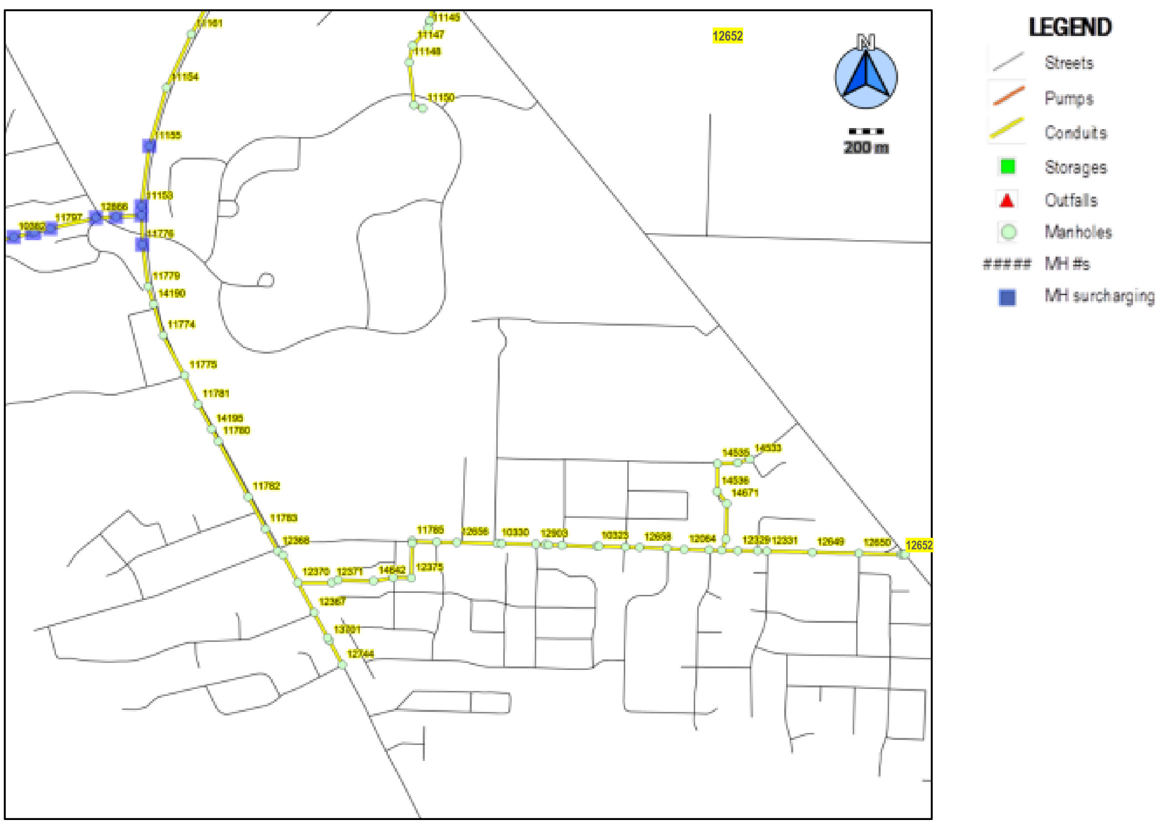


Figure A-2. Surcharging Along Glen Oak Road – Alternative A

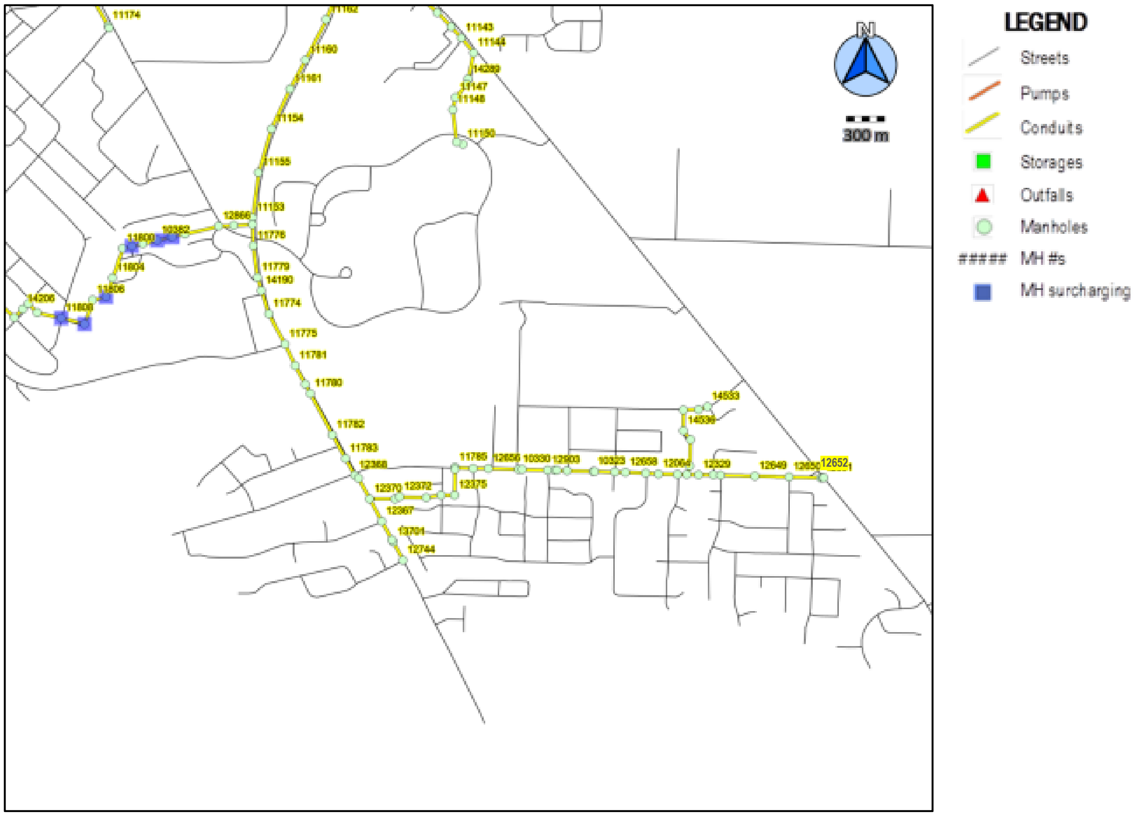


Figure A-3. Surcharging (within 5-feet of rim) Along Glen Oak Road – Alternative A

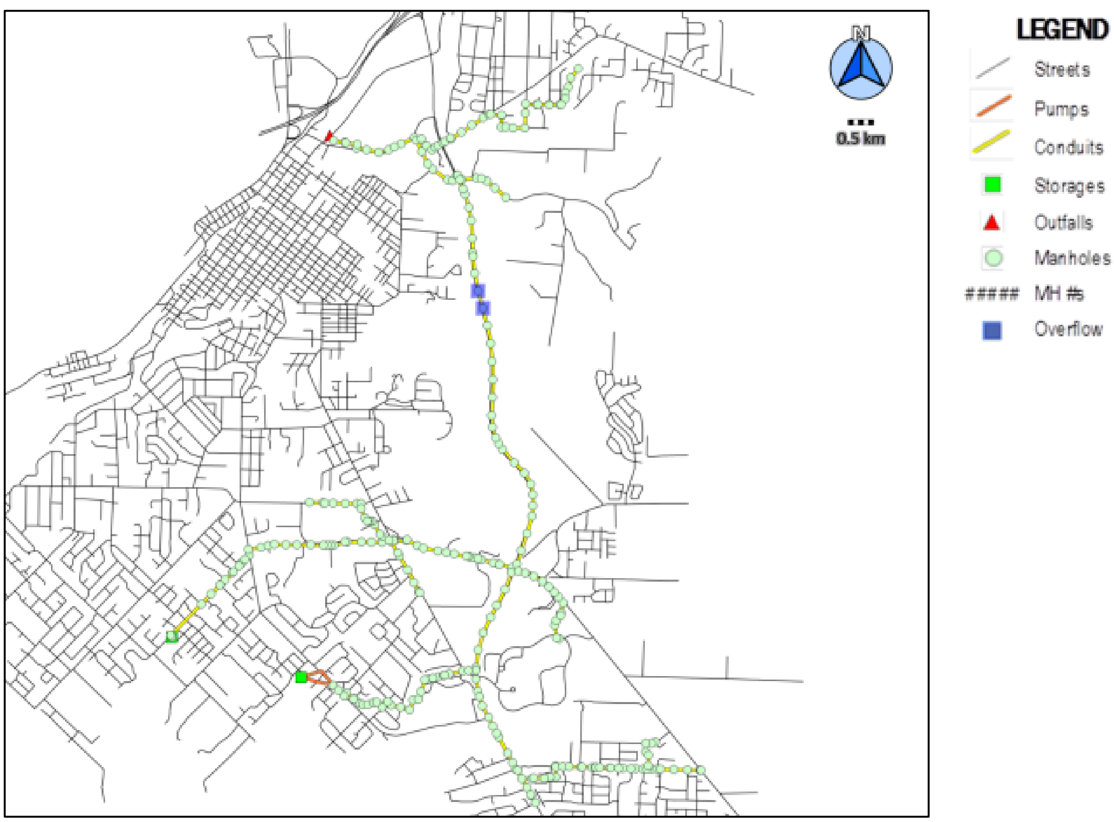


Figure A-4. Overflows – Alternative A

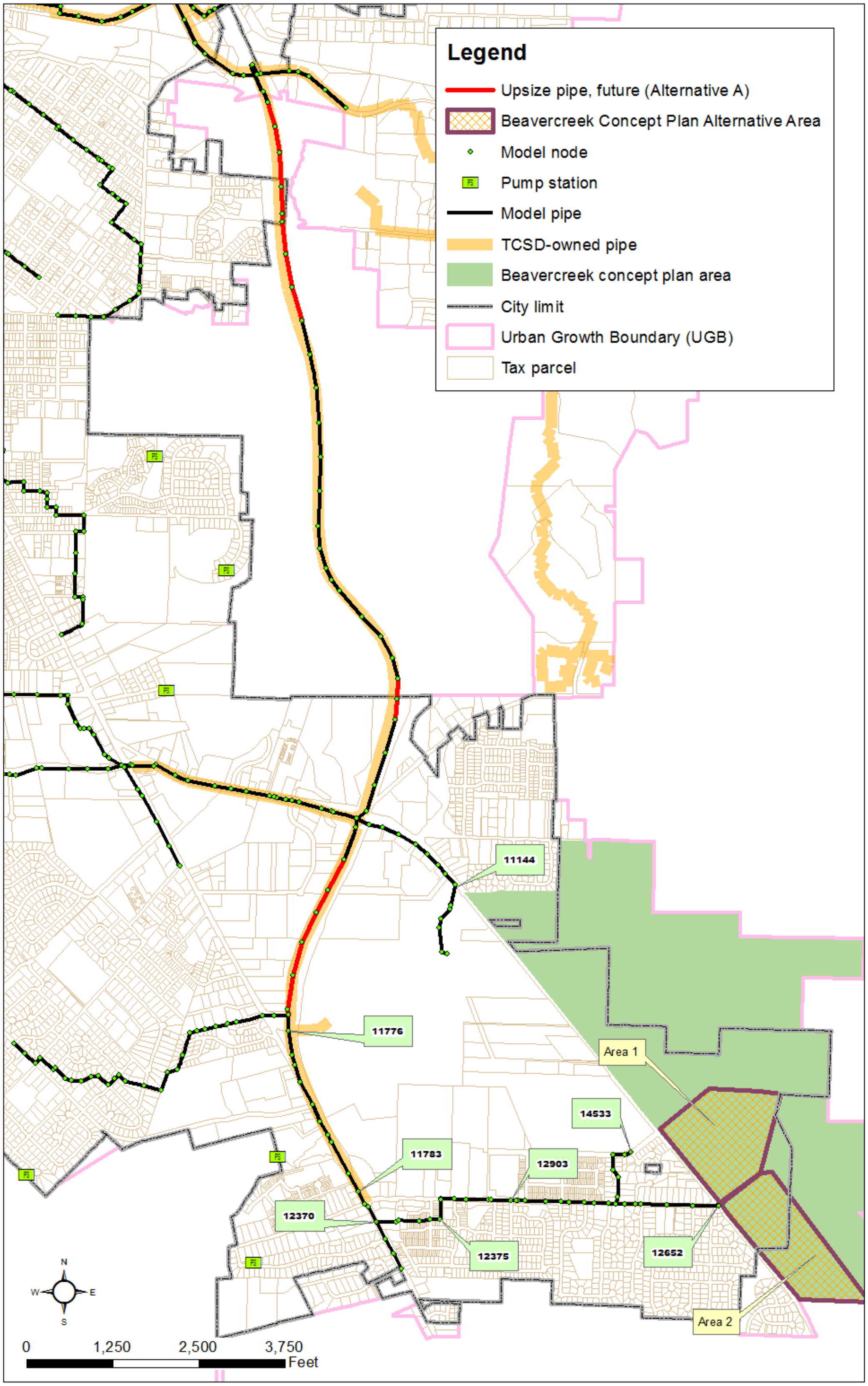


Figure A-5. Required Improvements – Alternative A

# Attachment B: Routing Alternative B

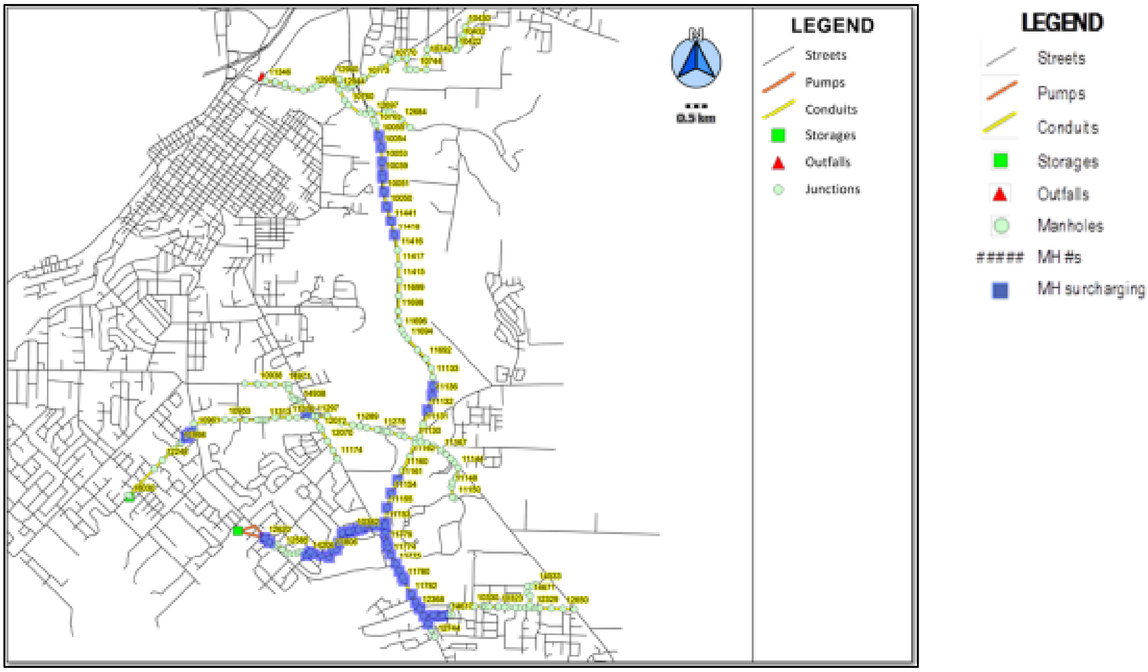


Figure B-1. Surcharging – Routing Alternative B

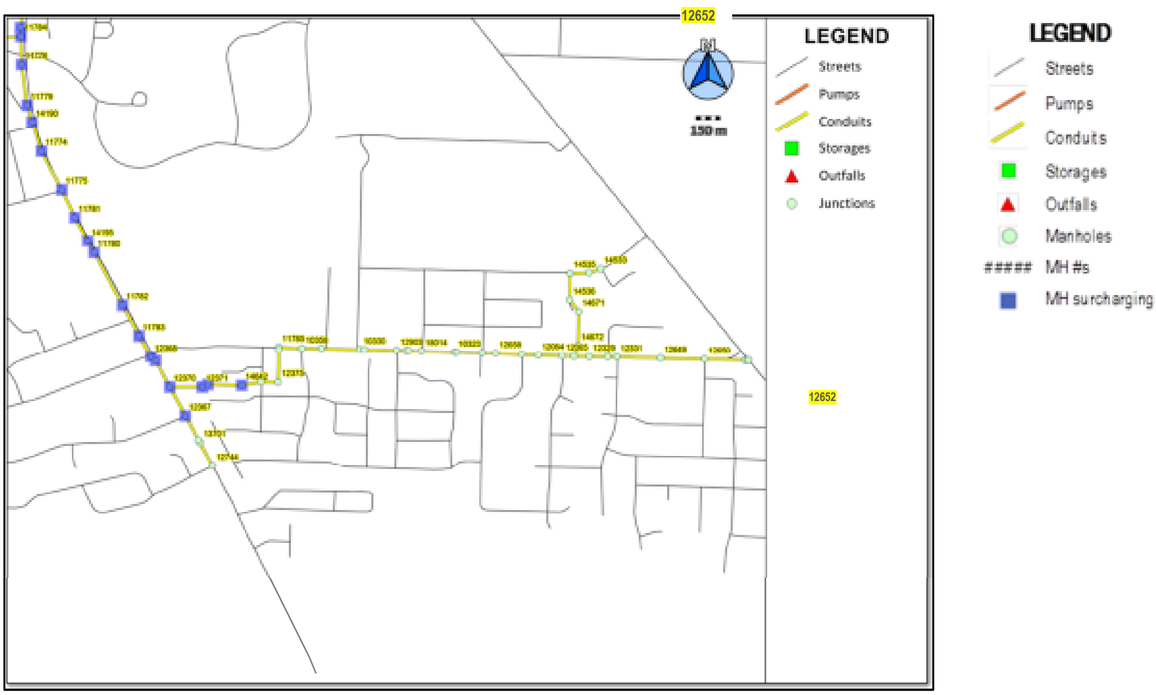


Figure B-2. Surcharging Along Glen Oak Road – Routing Alternative B

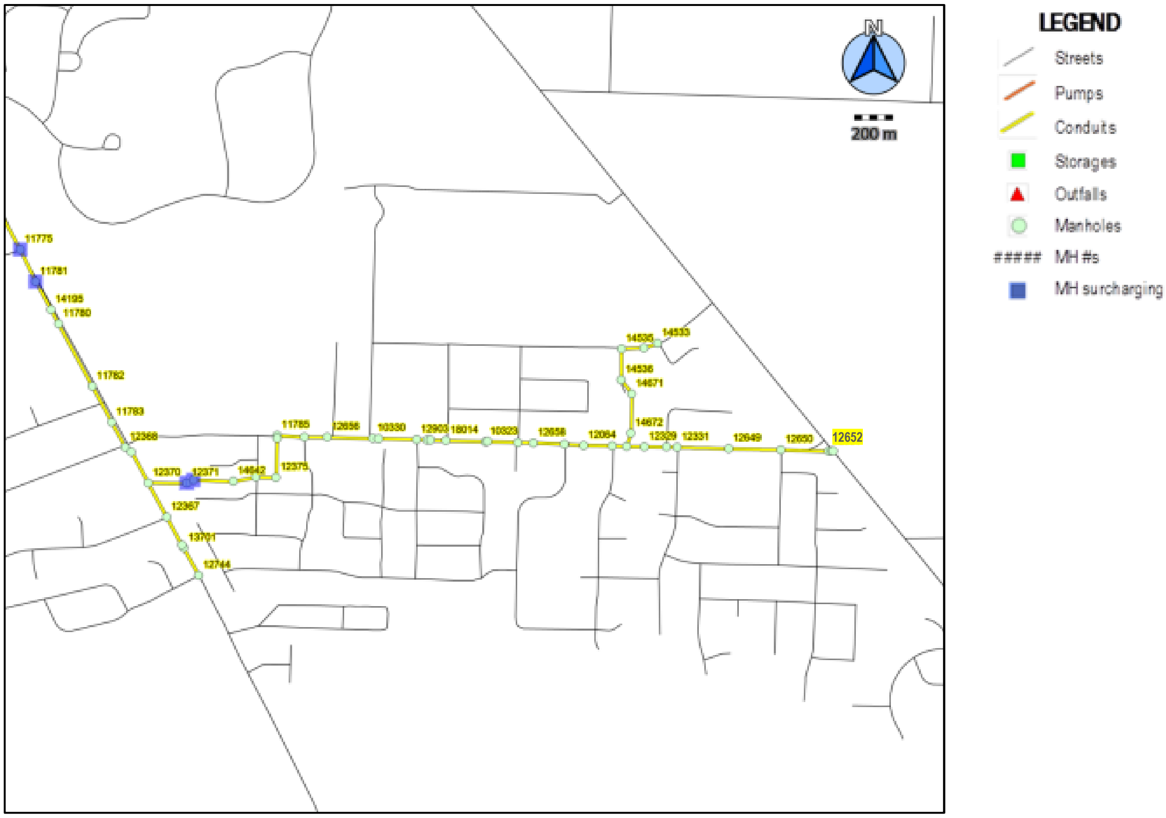


Figure B-3. Surcharging (within 5-feet of rim) Along Glen Oak Road – Routing Alternative B

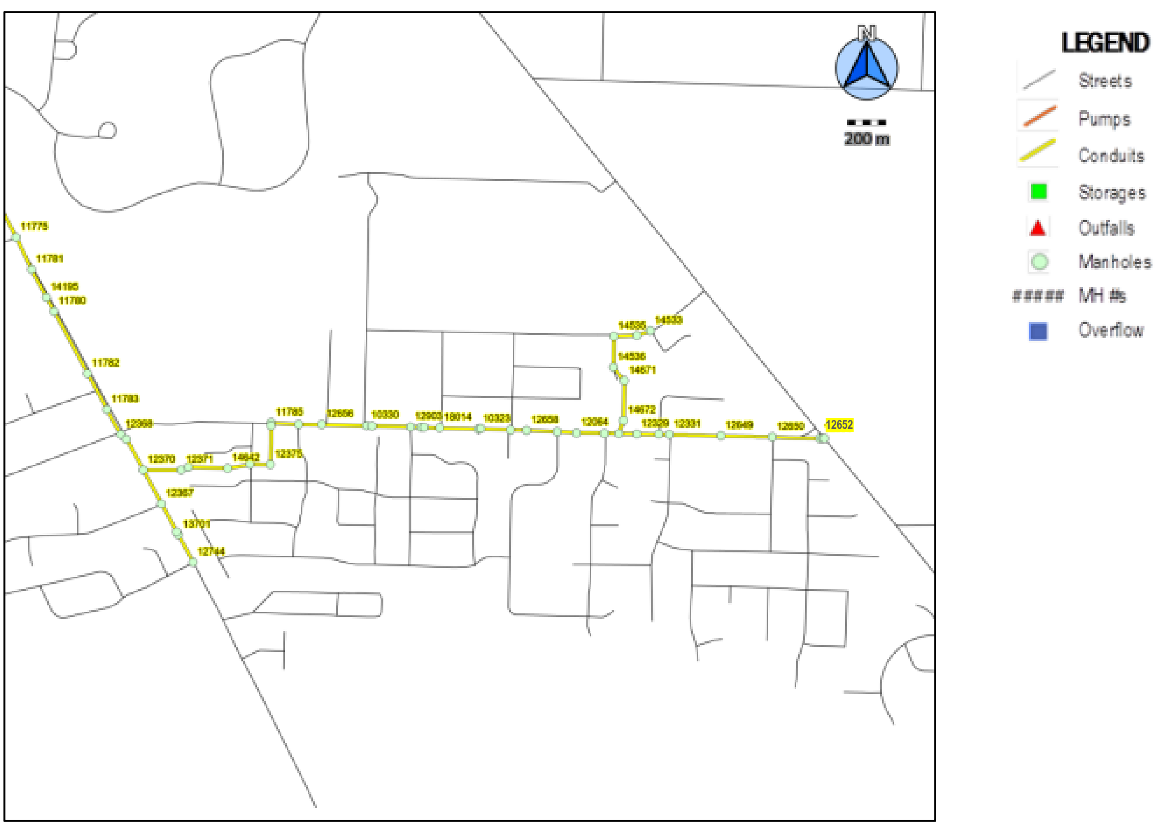


Figure B-4. Overflows – Routing Alternative B

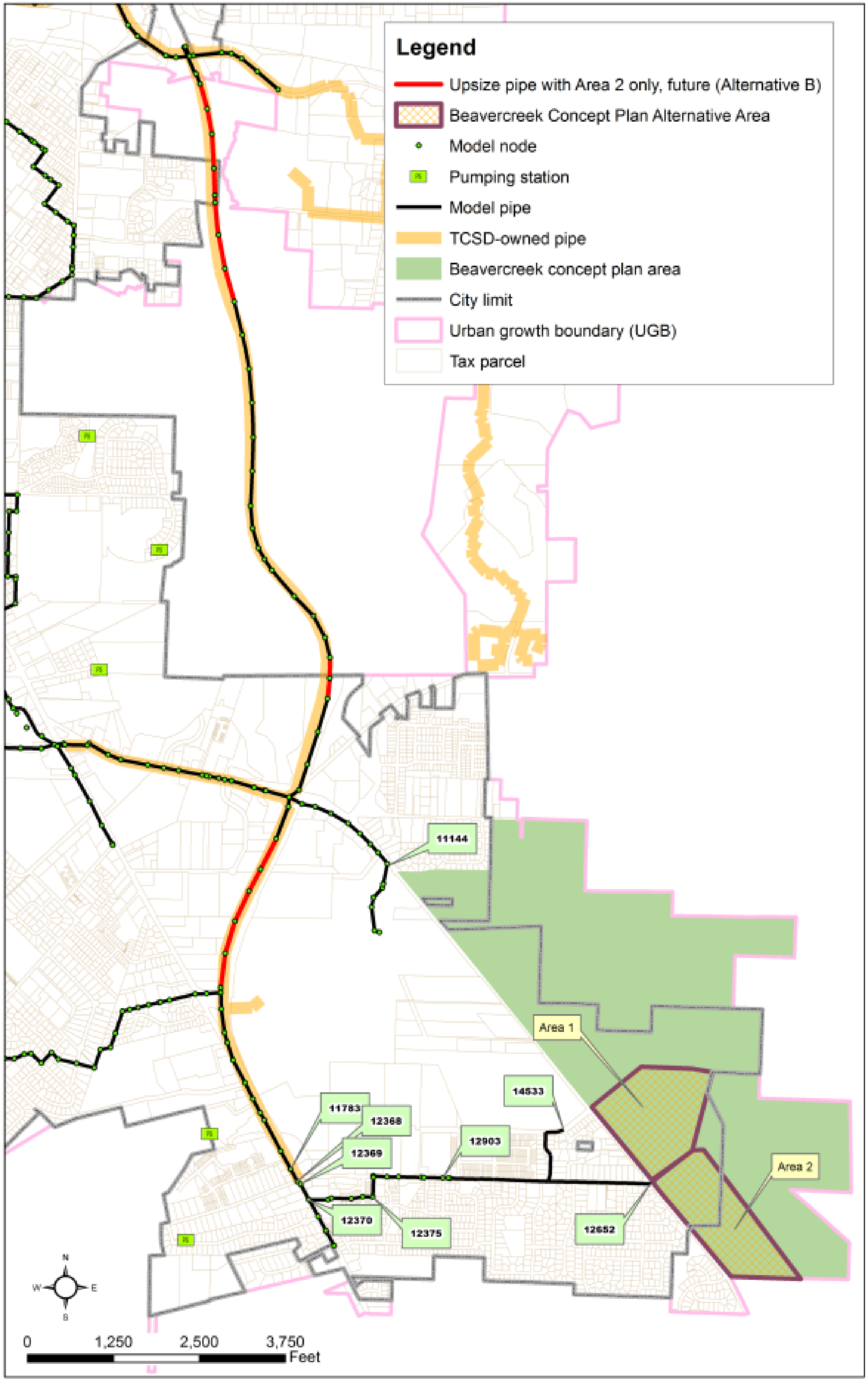


Figure B-5. Required Improvements – Routing Alternative B

# Attachment C: Routing Alternative C

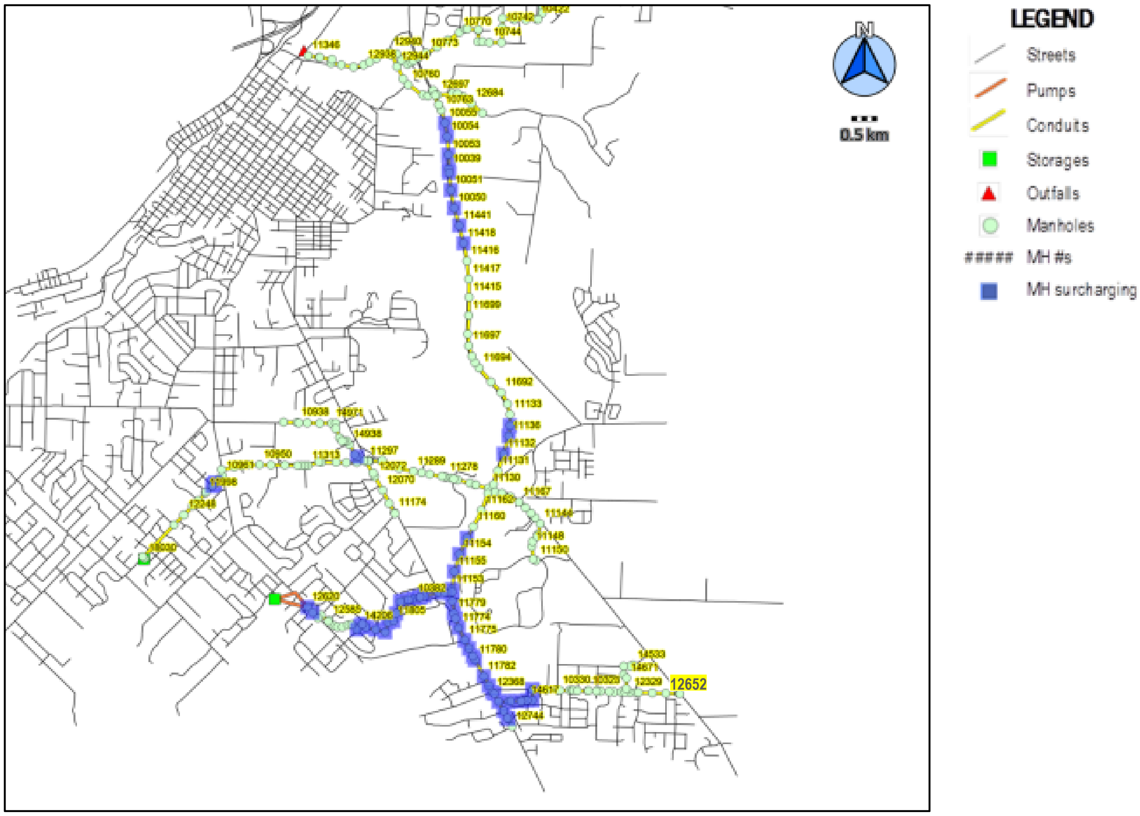


Figure C-1. Surcharging – Routing Alternative C

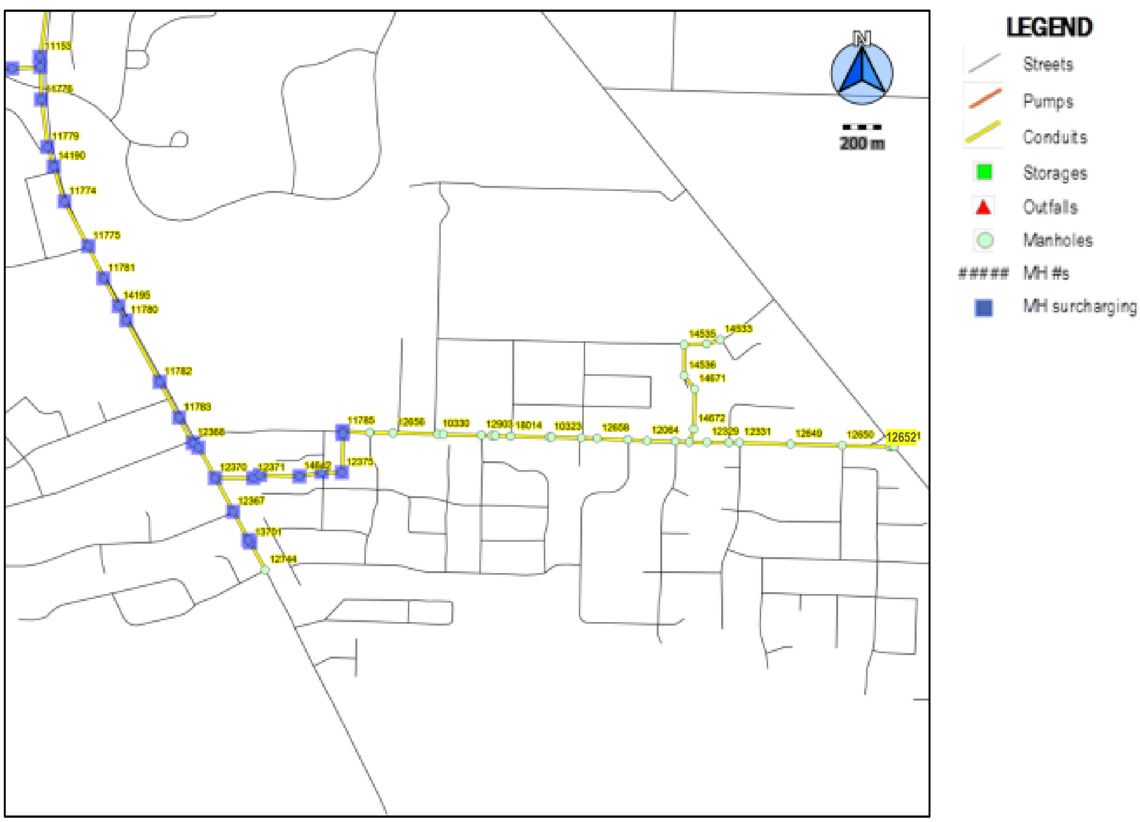


Figure C-2. Surcharging Along Glen Oak Road – Routing Alternative C

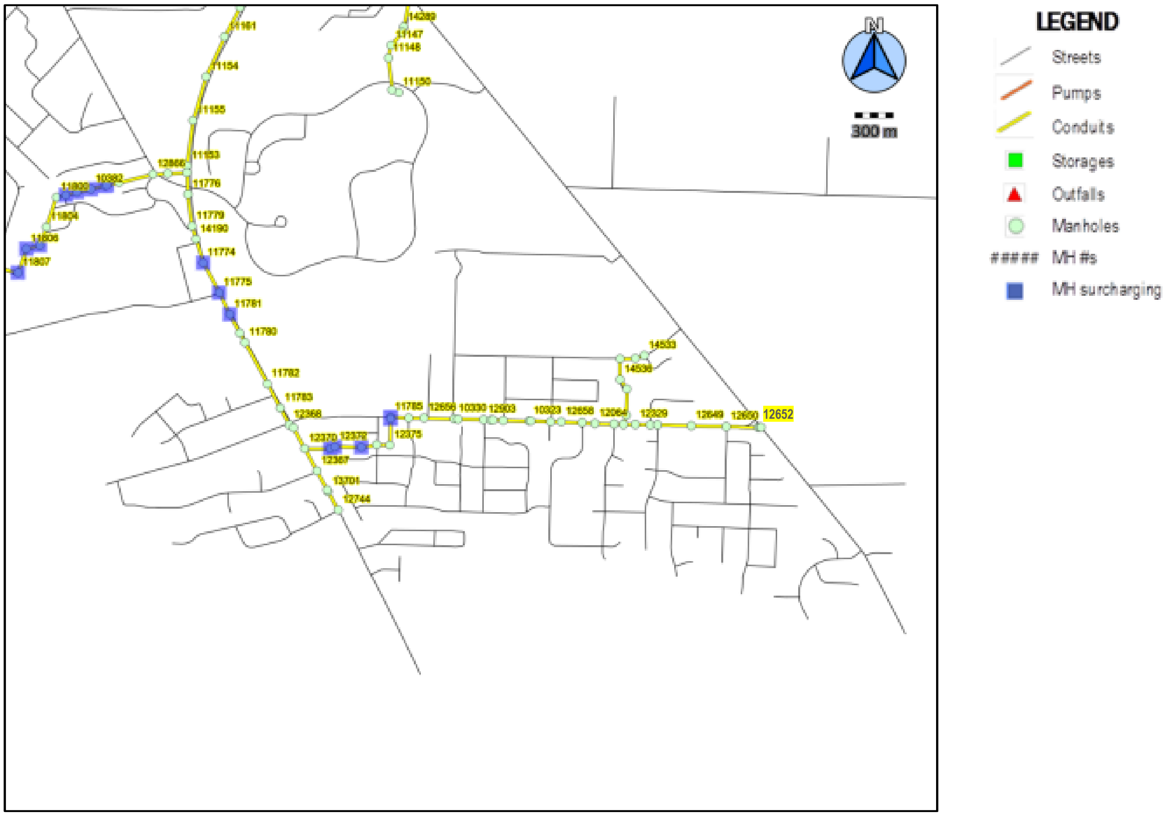


Figure C-3. Surcharging (within 5-feet of rim) Along Glen Oak Road – Routing Alternative C

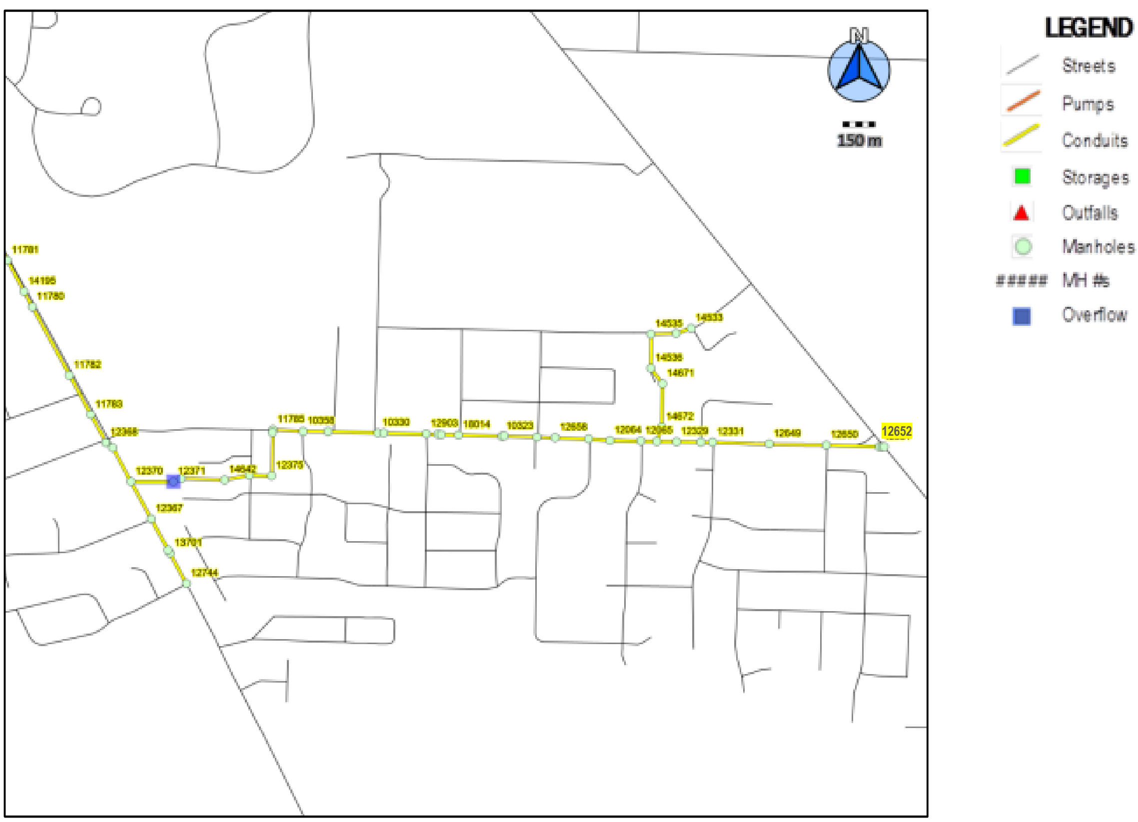


Figure C-4. Overflows – Routing Alternative C

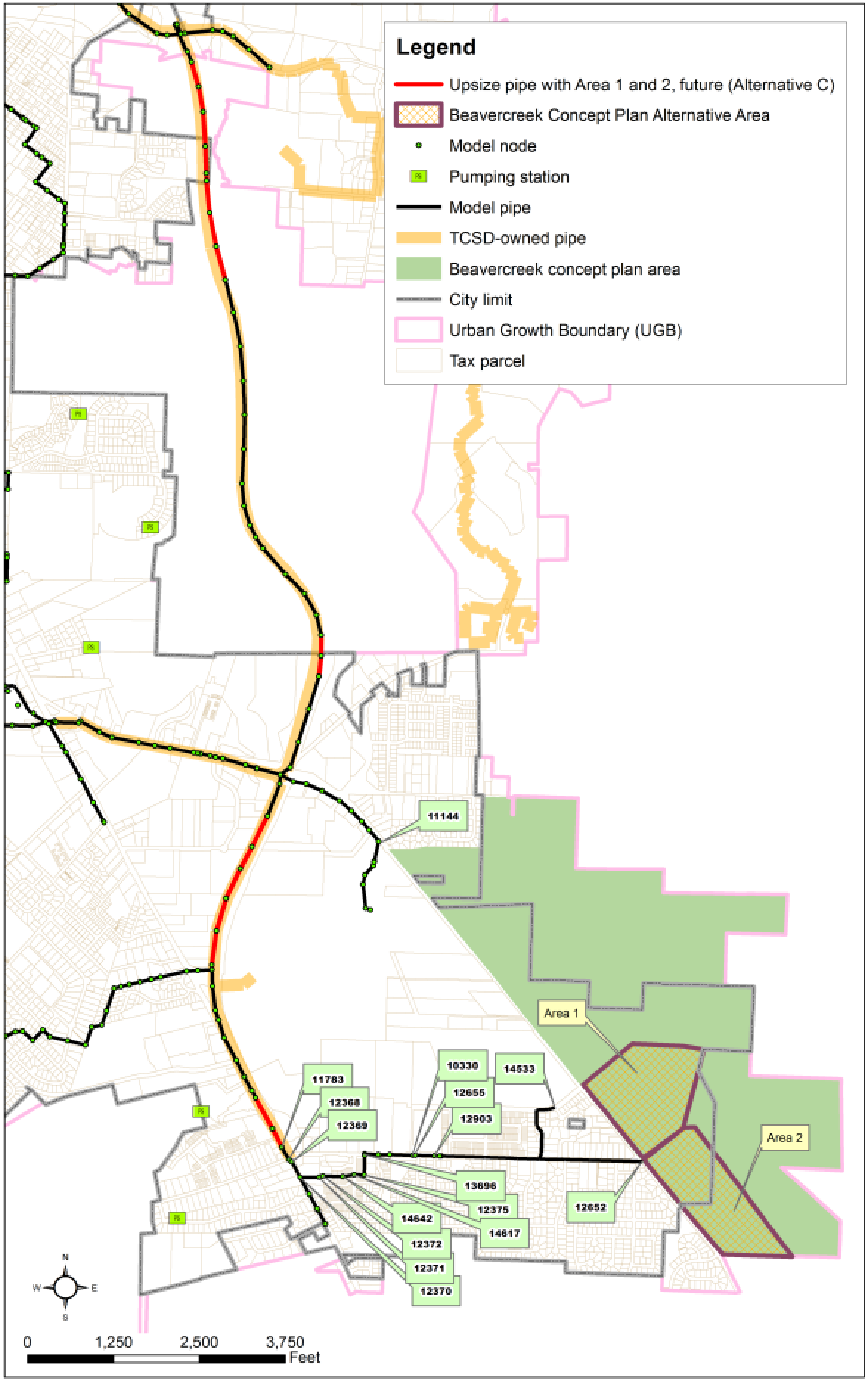


Figure C-5. Required Improvements – Routing Alternative C

# Appendix J: 5-year Storm Event Modeling

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# Technical Memorandum

Prepared for: City of Oregon City, Oregon

Project Title: City of Oregon City Sanitary Sewer Master Plan

Project No.: 142029

**Technical Memorandum**

Subject: 5-Year Storm Event Modeling

Date: April 29, 2014

To: Erik Wahrgren, City of Oregon City

From: James Hansen, BC Portland

Technical Reviewer: Justin Twenter, BC Seattle

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# Section 1: Introduction

In 2012, the City of Oregon City (City) retained Brown and Caldwell to assist with the development of a new sanitary sewer master plan (SSMP). The new SSMP will identify capital improvements that are required for improving existing and future sanitary sewer service and for providing services to new areas as they are developed and annexed by the City.

The SSMP defines the 1-in 10-year, 24-hour storm event as the design storm. A hydrologic/hydraulic model is used to identify where excessive surcharging and flooding [i.e., sanitary sewer overflows (SSOs)] may occur as a result of the design storm. These hydraulically constrained areas are the focus of pipe replacement activities as required to alleviate surcharging and flooding.

This technical memorandum (TM) presents the results of modeling the sanitary sewer collection system based on a 1-in 5-year, 24-hour storm event for the existing condition scenario. The modeling results for the 1- in 5-year storm are used to identify where surcharging and flooding are more likely and more frequently to occur. The results of this modeling effort provide the basis for prioritizing future sewer upgrades and/or inflow and infiltration reduction measures. All upgrades should be sized to convey the 1- in 10-year storm event.

# Section 2: Analysis Methodology

Hydraulic analyses were conducted using Storm Water Management Model (SWMM) urban hydrology and conveyance system hydraulics software. A detailed explanation of how base flows and wet weather flows were developed is included in Section 3 and Appendix A of the SSMP. The SSMP uses the 1- in 10-year storm event (recurrence interval) as the basis of planning. This technical memorandum investigates the results of modeling the 1- in 5-year storm event.

## 2.1 Base Flows

Base flows include wastewater contributions from residential, commercial, and industrial sources and long-term groundwater infiltration that finds its way into sewers and manholes through cracks, joint separations, and other defects. Rainfall-derived infiltration/inflow (I/I) is not included in the base flow, whereas long-term groundwater is included. Contributions may include perched water sources that contribute groundwater infiltration during the wet season only. The flow monitoring record includes the groundwater sources so that with the addition of the wet weather I/I, the modeling represents the entire wet weather flow regime. Base flows are the same for the 1- in 5-year and 1- in 10-year storm events.

## 2.2 Wet Weather Flows

Wet weather flows are based on the results of flow monitoring during the wet season and pump station run time data. Wet weather data were used to calibrate the model such that modeled flow matched observations and measurements of actual flow in the collection system. Once calibrated, the model was used to simulate the 1- in 5-year storm event and determine capacity deficiencies in the system. The rainfall depths associated with the two storm events are listed in Table 1.

**Table 1. Storm Flow Volumes**

| Storm event | Flow volume, inches |
|---|---|
| 5-year, 24-hour | 3.0 |
| 10-year, 24-hour | 3.5 |

## 2.3 Assessment Criteria

Two criteria are used to evaluate whether pipes are too small to convey the design flow. The percent of capacity used is a ratio of maximum predicted flow (Q) to pipe capacity (Qm) expressed as a percentage. The maximum predicted flow, Q, is the calculated peak flow in each pipe from the model. The pipe capacity (Qm) is the theoretical pipe capacity according to Manning's equation, which assumes unpressurized flow (no surcharging). A percentage of greater than 100 indicates that the pipe is carrying more flow than is theoretically possible for unpressurized flow for a given pipe slope, diameter, and internal roughness. A percent capacity of greater than 100 is an indication of a surcharged pipe.

Unfortunately, the percent capacity alone cannot be used for determining pipe capacity due to the way that SWMM-based models report their data. In some situations, peak flows reported by the model exist for extremely short periods of time, sometimes only for seconds. Consequently, some of these peak flow values should not be used as the basis for pipe replacement. The second criterion, the ratio of depth of water to pipe diameter (d/D) is often more reliable. Use of the d/D ratio is described in more detail below.

In an unpressurized pipe, or a pipe with open-channel flow characteristics, the hydraulic grade line (HGL) is the elevation of the water surface within the pipe, or the d value. In a pipe that is surcharged (pressurized flow), the HGL is defined by the elevation to which water would rise in an open pipe, or manhole, as shown in Figure 1. In hydraulic terms, the HGL is equal to the pressure head measured above the invert of the pipe.

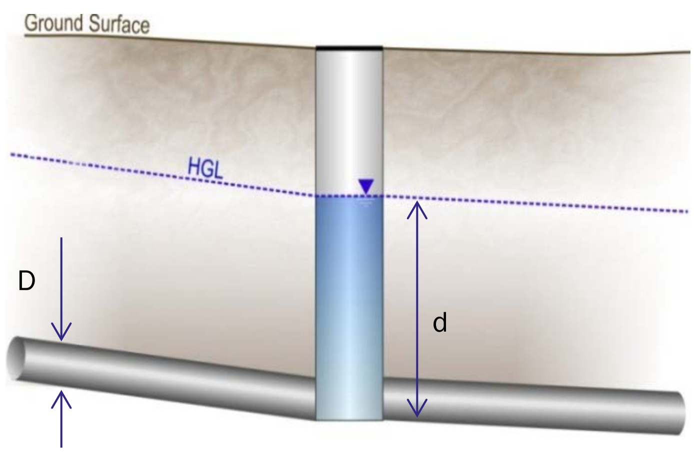


**Figure 1. HGL for surcharged condition**

The recommended approach for determining which pipes need to be upsized is to consider the amount and frequency of surcharging. For example, if minor surcharging (less than 1 to 2 feet) were to occur during large storm events only (i.e., the 1- in 10-year storm) and the surcharging did not impact property or create a sanitary sewer overflow (SSO), City staff should not consider upsizing this pipe. However, if the frequency or amount of surcharging were to increase and endanger property or overflow, then the pipe should be upsized. Modeling of the 1- in 5-year storm event is used to help identify where surcharging occurs more frequently.

Pipes that surcharge frequently should be upsized since frequent surcharging has the potential to reduce their structural stability due to loss of pipe support from fine-grained soils washing into the sewer. Similarly, if the amount of surcharging is more than 1 or 2 feet, City staff should consider the amount of remaining freeboard (i.e., distance between water surface in manhole and ground surface, or to the elevation of basements in the area) with regard to the risk of SSOs or basement backups. This approach will help to ensure that the City has adequate capacity for conveying the design flows without spending more capital dollars than necessary.

In general, most sewers with d/D ratios of between 1 and 3 are not identified for replacement. City staff should monitor these sewers during large storm events to quantify the amount of surcharging that actually occurs. If the observed surcharging increases to the point of risking property or becoming an SSO, then the pipe or pipes should be upsized. Some pipes with minor surcharging are identified for replacement even though their d/D ratio is less than 1. Upsizing of these pipes will help to reduce more significant surcharging in the upstream system.

## 2.4 Surcharged Sewer Modeling

A flooded condition (i.e., HGL exceeds the ground surface) in most hydraulic modeling allows flow to leave the model, thereby acting like a relief valve on the system. This would effectively reduce the HGL at the overflow point just like it would under actual flow conditions. In situations where manhole covers are bolted down, flow cannot leave the piped system, resulting in a higher HGL than would have been experienced if flow were allowed to escape. The modeling for the Highway 99E interceptor assumed that the manholes are bolted down.

# Section 3: Results

This section presents the results of the 1-in 5-year modeling, including a description of surcharged pipes, locations for potential SSOs (flooding), undersized pipes and costs to upsize pipes.

## 3.1 Existing Condition – Modeling Results

The 1-in 5-year storm event modeling was performed with the existing conditions scenario (i.e., 2014 conditions). The 1- in 5-year storm was not modeled for the future conditions scenario since the 1- in 10-year storm event is used for identifying excessive surcharging associated with future conditions and the sewer sizes required to reduce surcharging and flooding.

Predicted surcharging and flooding for the 1- in 5-year, existing conditions scenario are shown in Figure 2. As shown, surcharging is limited to just a few areas of the city, including 12th Street, 13th Street, Division Street, Linn Avenue, and the Hazelwood area. Flooding was predicted in two locations: in the Hazelwood area along Warner-Parrott Road and along Division Street. City maintenance staff concur with the modeling results except for those on Division Street. Staff have not observed flooding in the predicted location along Division Street.

In addition, surcharging was observed in the Highway 99E interceptor along the Willamette River. Since there was no flooding predicted under the 1- in 5-year storm modeling, the HGL was not affected by the bolted-down manhole cover assumption used in the model. The HGL was affected by the bolted-down manhole assumption for the 1- in 10-year modeling that was performed for the SSMP since the original modeling showed flow leaving the system as a SSO or flooding. The bolt-down manhole cover modeling results in increases in the HGL since flow cannot leave the pipeline as a SSO. The Highway 99E interceptor is owned and operated by the Tri-City Service District (TCSD).

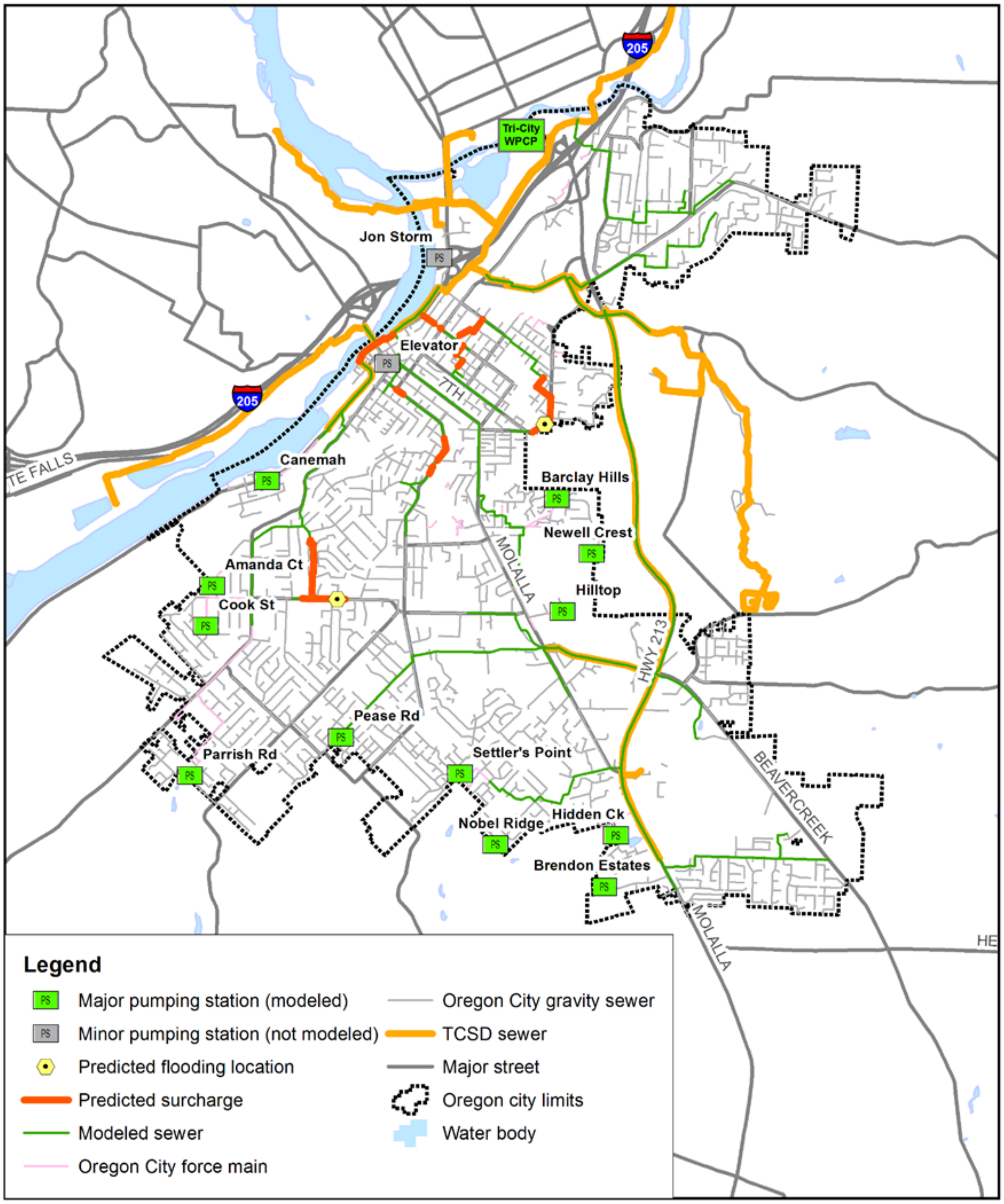


**Figure 2. Surcharging and flooding 1- in 5-year storm event**

## 3.2 Existing Condition – Pipe Upsizing

Sewers that would have to be replaced to relieve the predicted surcharging and/or flooding are shown in Figure 3. Please note that not all pipes identified as surcharging need to be replaced since not all surcharging is excessive and the replacement of downstream constraints often reduces the surcharging in upstream sewers.

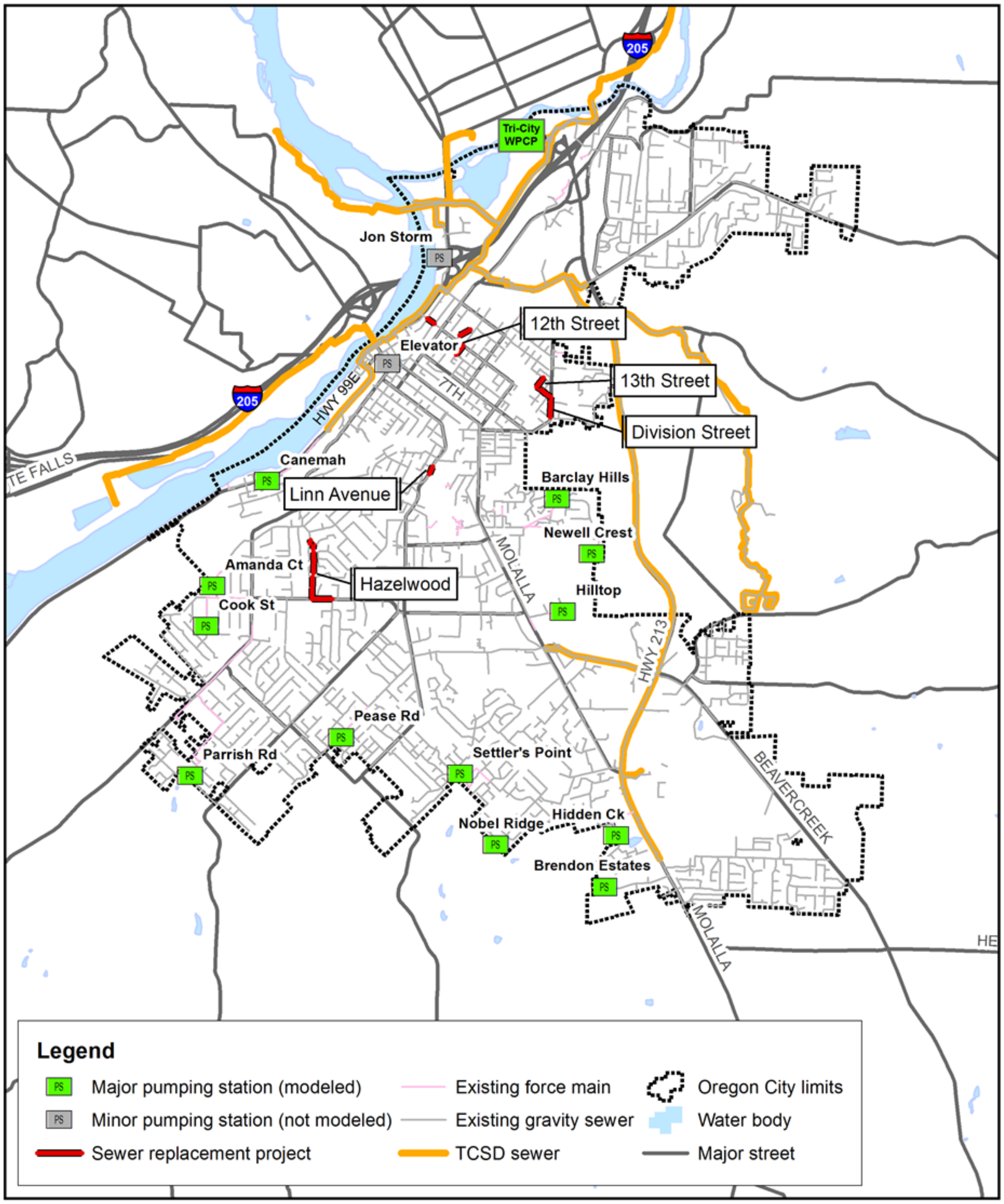


**Figure 3. 1- in 5-year storm event projects**

Costs to upsize the sewers identified in Figure 3 are listed in Table 2. The costs are based on sizing replacement sewers to convey the 1- in 5-year storm event under existing conditions. Actual replacement of any of these pipes will be based on the 10-year storm event modeling and pipe sizing. Table 2 does not include the benefits of potential I/I reduction measures. [Note: the cost analysis was prepared for use with a future financial analysis that needs to consider costs of improvements to bring the collection system up to current standards. The cost shown should not be used for future capital improvement budgeting.

The TCSD Highway 99E interceptor is not identified for replacement. The existing sewer has bolt-down manhole covers so that it can act as a pressure pipe without flow escaping from the manhole covers.

| Table 2. Sewer Upsizing Requirements. 5-year Storm event, Existing Conditions Scenario | | | | | | |
|---|---|---|---|---|---|---|
| Pipe ID | Owner | Length, feet | Existing pipe diameter, inches | Upsize diameter, inches | Current total cost, $ | SSMP project name |
| 11402_11396 | OC | 250 | 12 | 15 | 110,616 | 12th Street |
| 10259_10157 | OC | 346 | 8 | 10 | 128,789 | 12th Street |
| 12402_12401 | OC | 367 | 12 | 15 | 86,858 | 12th Street |
| 10171_10057 | OC | 339 | 8 | 10 | 126,350 | 13th Street |
| 10170_10171 | OC | 203 | 8 | 10 | 75,618 | 13th Street |
| 10060_10170 | OC | 216 | 8 | 10 | 111,222 | 13th Street |
| 10064_10060 | OC | 110 | 8 | 10 | 74,337 | 13th Street |
| 10063_10064 | OC | 144 | 8 | 10 | 97,388 | Division Street |
| 10071_10063 | OC | 167 | 8 | 10 | 112,880 | Division Street |
| 10056_10071 | OC | 287 | 8 | 10 | 194,127 | Division Street |
| 11546_11547 | OC | 230 | 12 | 15 | 101,788 | Linn Avenue |
| 10930_10928 | OC | 89 | 10 | 12 | 35,100 | Hazelwood |
| 11858_11857 | OC | 132 | 10 | 12 | 83,522 | Hazelwood |
| 10312_11859 | OC | 260 | 10 | 12 | 127,524 | Hazelwood |
| 11862_10312 | OC | 355 | 10 | 12 | 173,929 | Hazelwood |
| 13051_10918 | OC | 331 | 10 | 12 | 162,156 | Hazelwood |
| 10991_13051 | OC | 218 | 10 | 12 | 106,766 | Hazelwood |
| 10992_10991 | OC | 109 | 10 | 12 | 53,202 | Hazelwood |
| 11044_10992 | OC | 179 | 8 | 10 | 92,088 | Hazelwood |
| 11046_11044 | OC | 431 | 8 | 10 | 221,253 | Hazelwood |
| Total all pipe replacements | | | | | 2,275,514 | |

## 3.3 Selected Profiles

The modeling software can present profiles of selected sewers that show the HGL, locations of flooding, and the distance between the HGL and the ground surface. The portrayal of the modeling results helps provide a visual understanding of how the sewer performs under various flow events. For this TM, the following three profiles are provided: Highway 99E, Hazelwood area, and Highway 213.

### 3.3.1 Highway 99E

Profiles for the 1- in 5-year storm event modeling of the Highway 99E sewer are shown in Figures 4 and 5. As shown in the two figures, the flow is conveyed as gravity flow (unpressurized) from approximately Manhole (MH)-10669 to the downstream extents of the modeled section of sewer at MH-11389. Above MH-10669 the sewer is surcharging (pressurized) with the HGL above the crown up to approximately MH-13881. Above MH-13881 normal gravity flow is shown (no surcharging). The surcharging is a result of too much flow for the existing pipe diameter and grade. As stated previously, as-built drawings for this section of sewer show that the manhole covers are bolted down such that flooding should not occur at these manholes even if the HGL were to exceed the elevation of the ground surface.

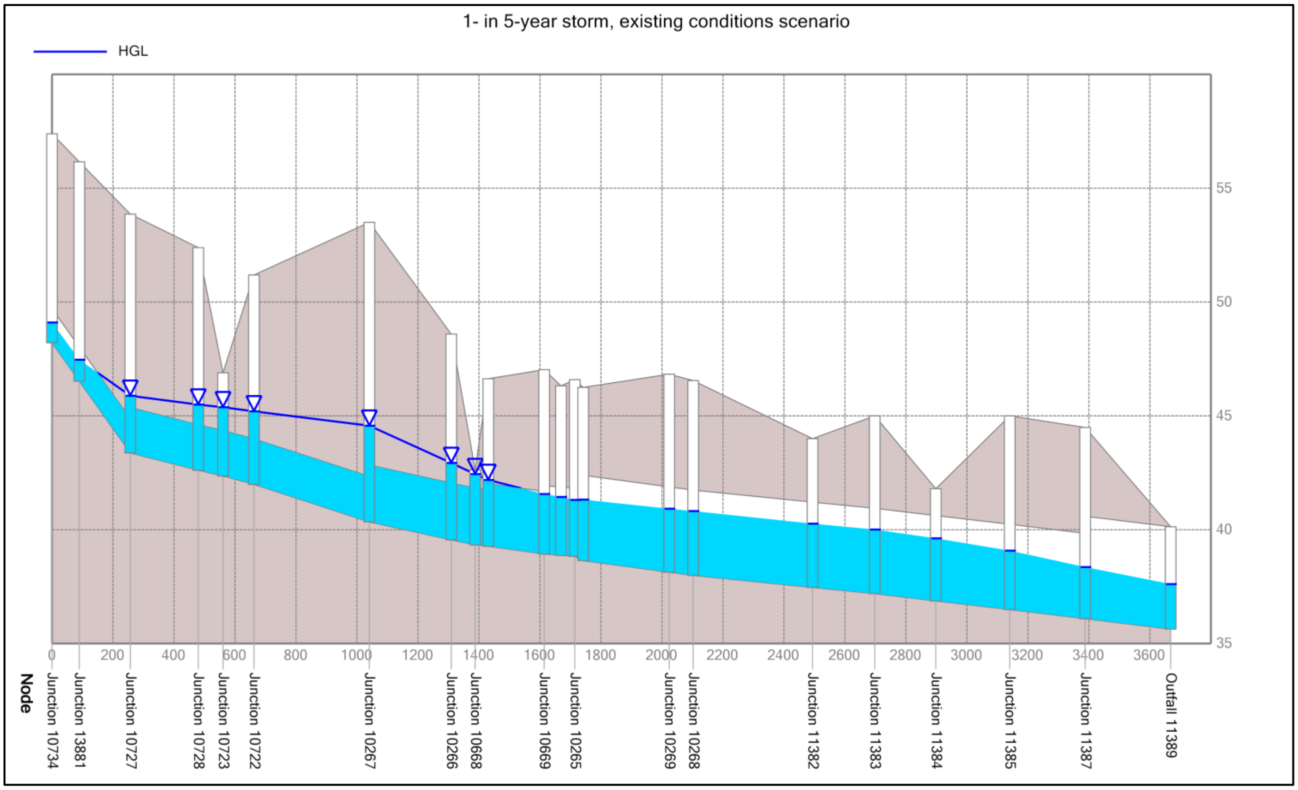


**Figure 4. Highway 99E sewer profile – Main Street to 15th Street**

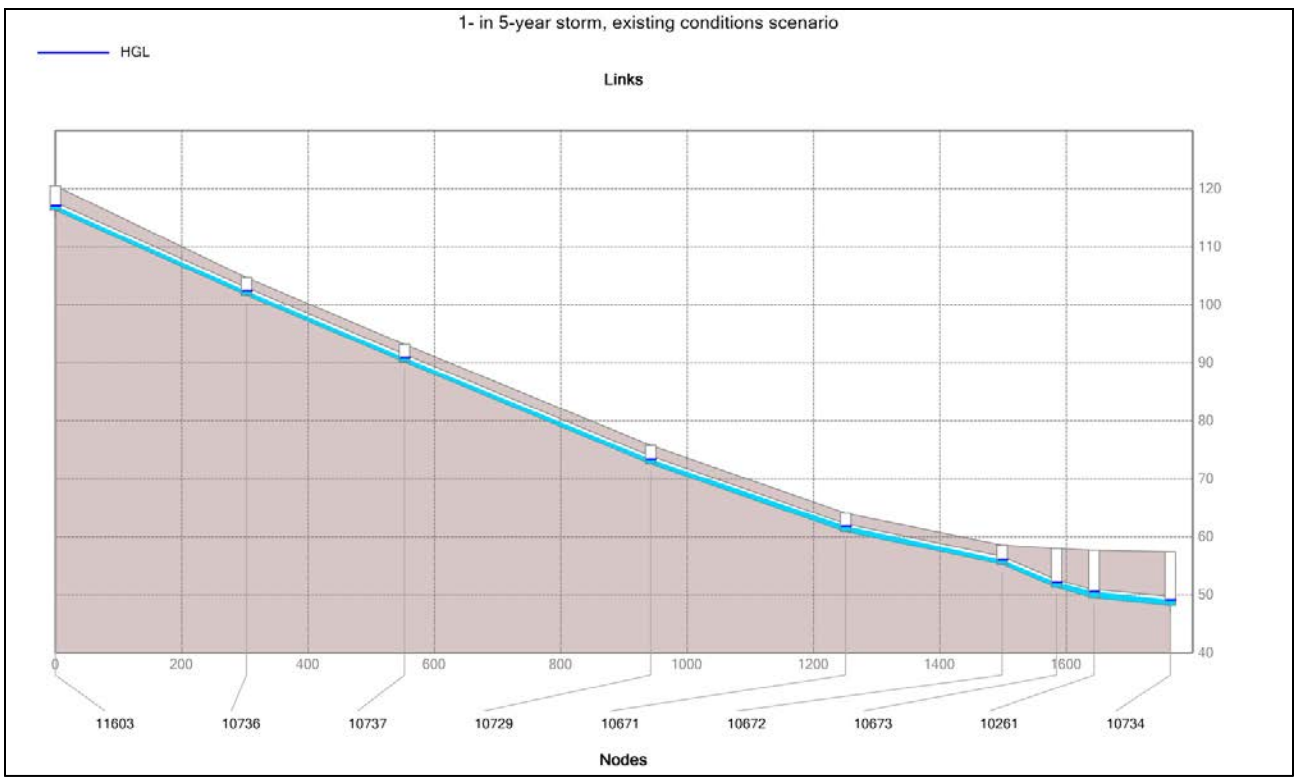


**Figure 5. Highway 99E sewer profile – Tumwater Drive to Main Street**

A review of City sewers in the area of the Highway 99E that experience surcharging indicates that the HGL is approximately 5 to 7 feet below the elevation of the manhole rim, as shown in Figure 6. City staff should monitor water surface elevations in the adjacent City manholes during large storm events to determine actual water surface elevations. In addition, the City needs to determine if there are basements in the vicinity that could be impacted by high-water surface elevations. Recommended City manholes to observe during storm events are shown in Figure 6.

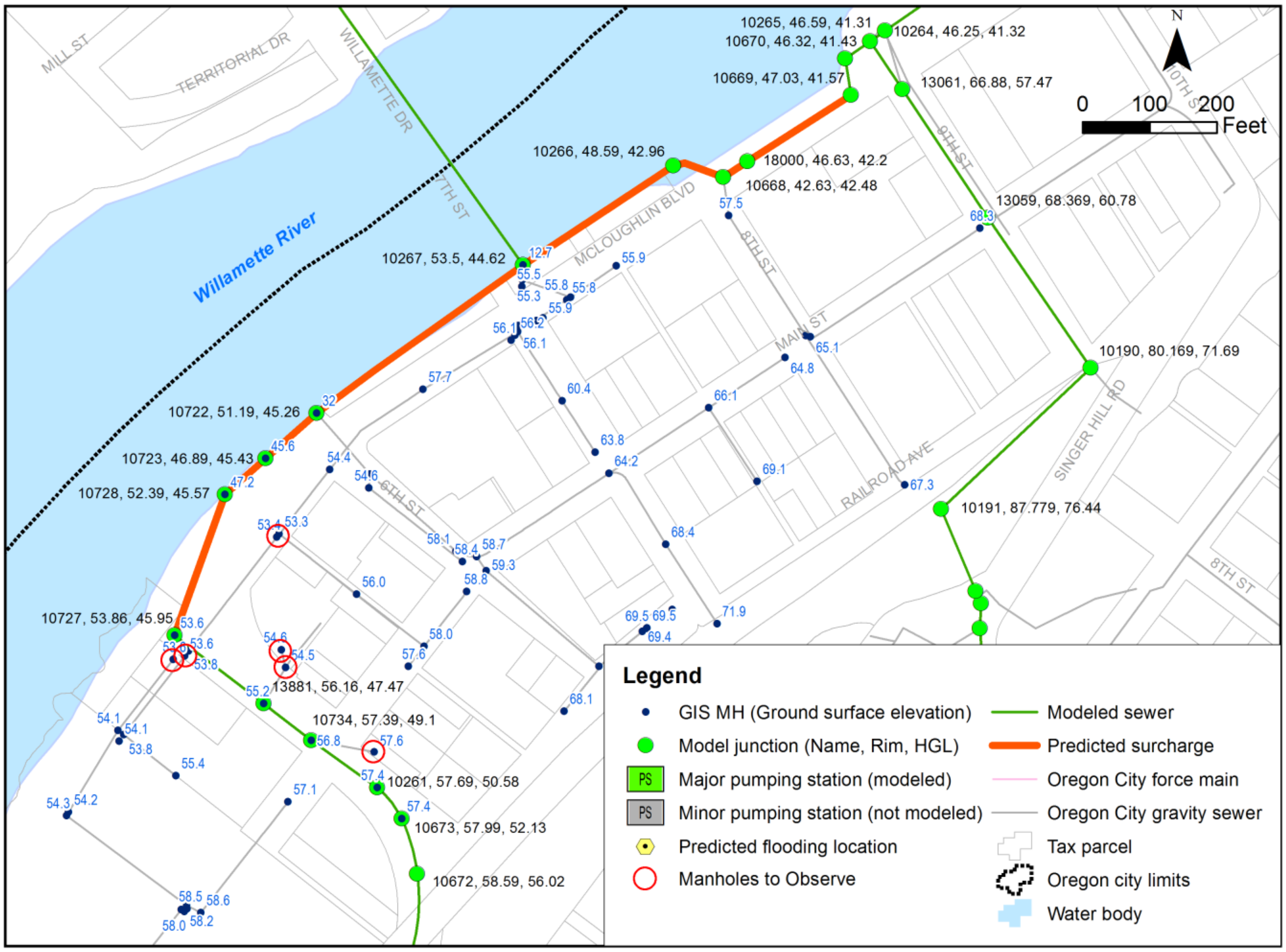


**Figure 6. Downtown city sewer elevations**

## 3.3.2 Hazelwood Area

A profile for the 1- in 5-year storm event modeling of the Hazelwood area is shown in Figure 7. As shown, the flow is conveyed as gravity flow (unpressurized) downstream of MH-10928. Above this manhole the surcharging increases at a steady rate up to MH-18025 at which point the HGL exceeds the elevation of the ground surface and flooding is predicted. It appears that flooding nearly occurs at MH-11046. City staff report that flooding has been observed in this general area in the past.

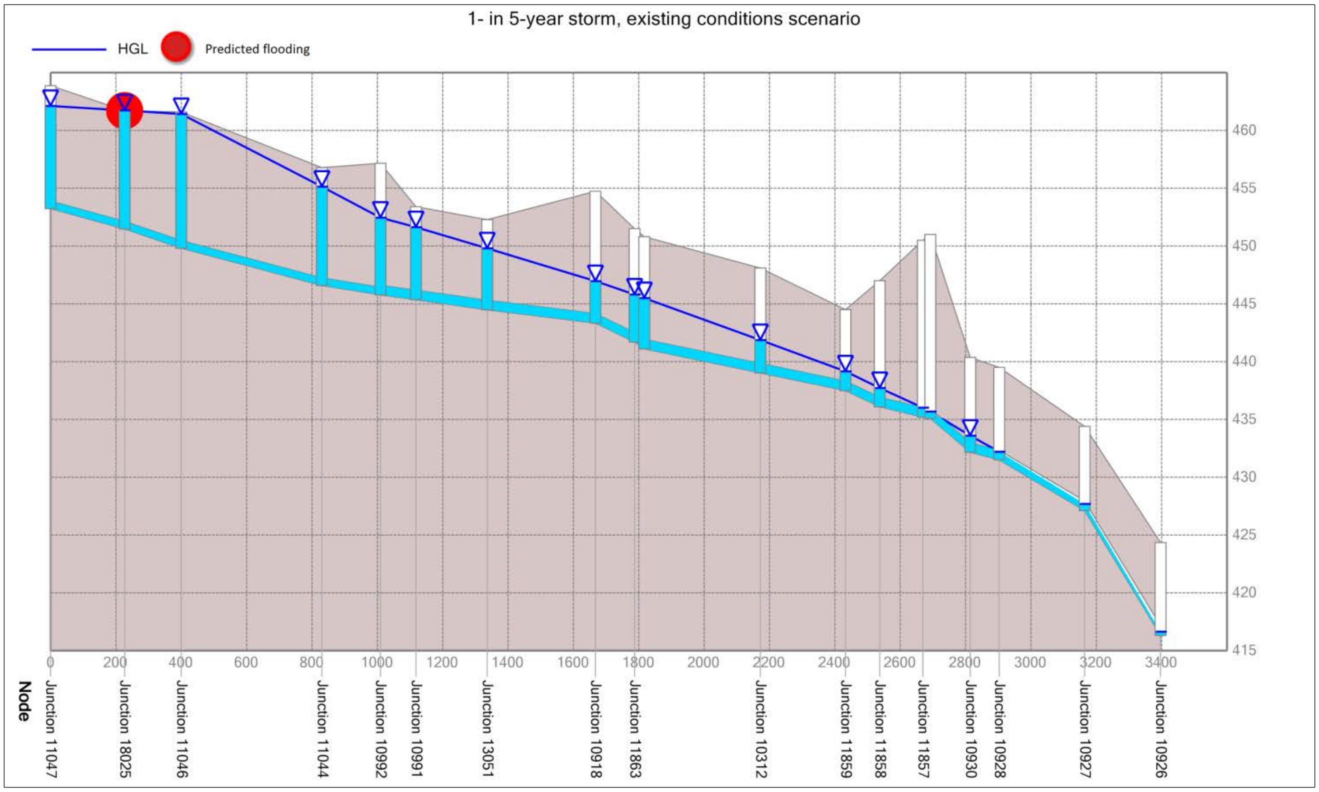


**Figure 7. Hazelwood sewer profile**

### 3.3.3 Highway 213

Profiles for the 1- in 5-year storm event modeling of the Highway 213 interceptor are shown in Figures 8 through 10. As shown, the flow is conveyed as gravity flow (unpressurized) within the entire section of sewer (i.e., no surcharging). TCSD owns and operates the interceptor above MH-12368 (according to the City's geographic information system).

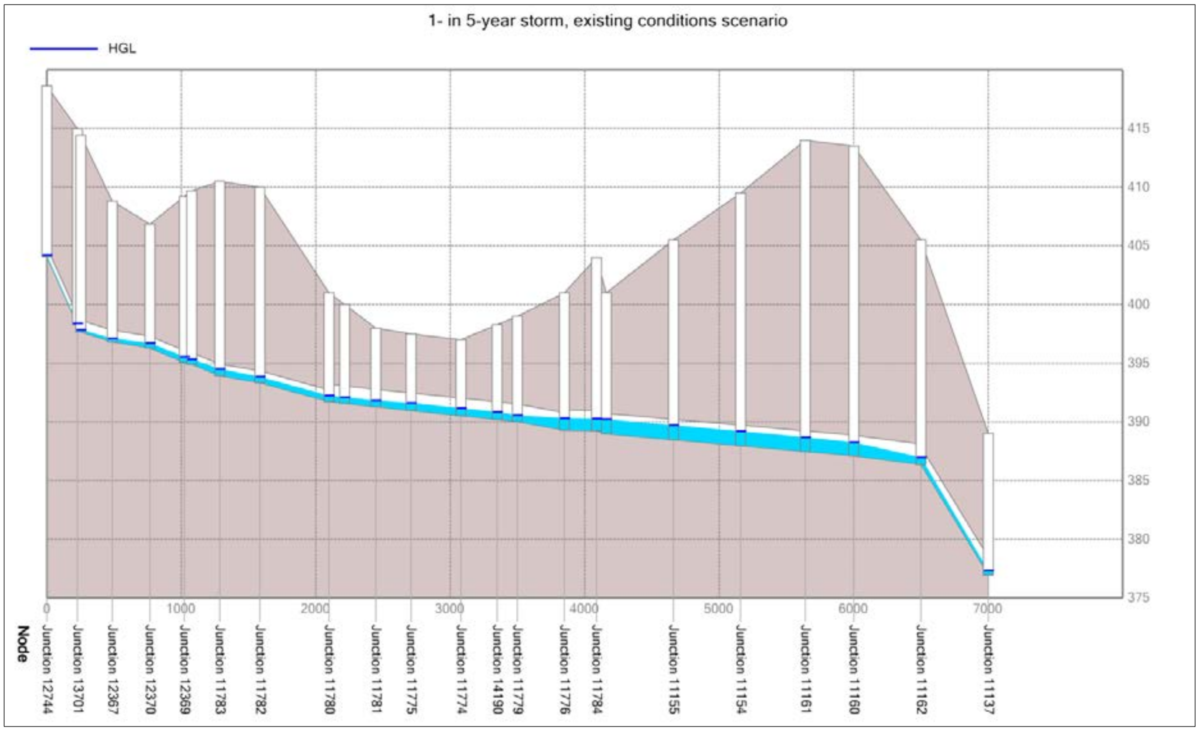


Figure 8. Highway 213 Sewer Profile – City Limits to Beavercreek Road

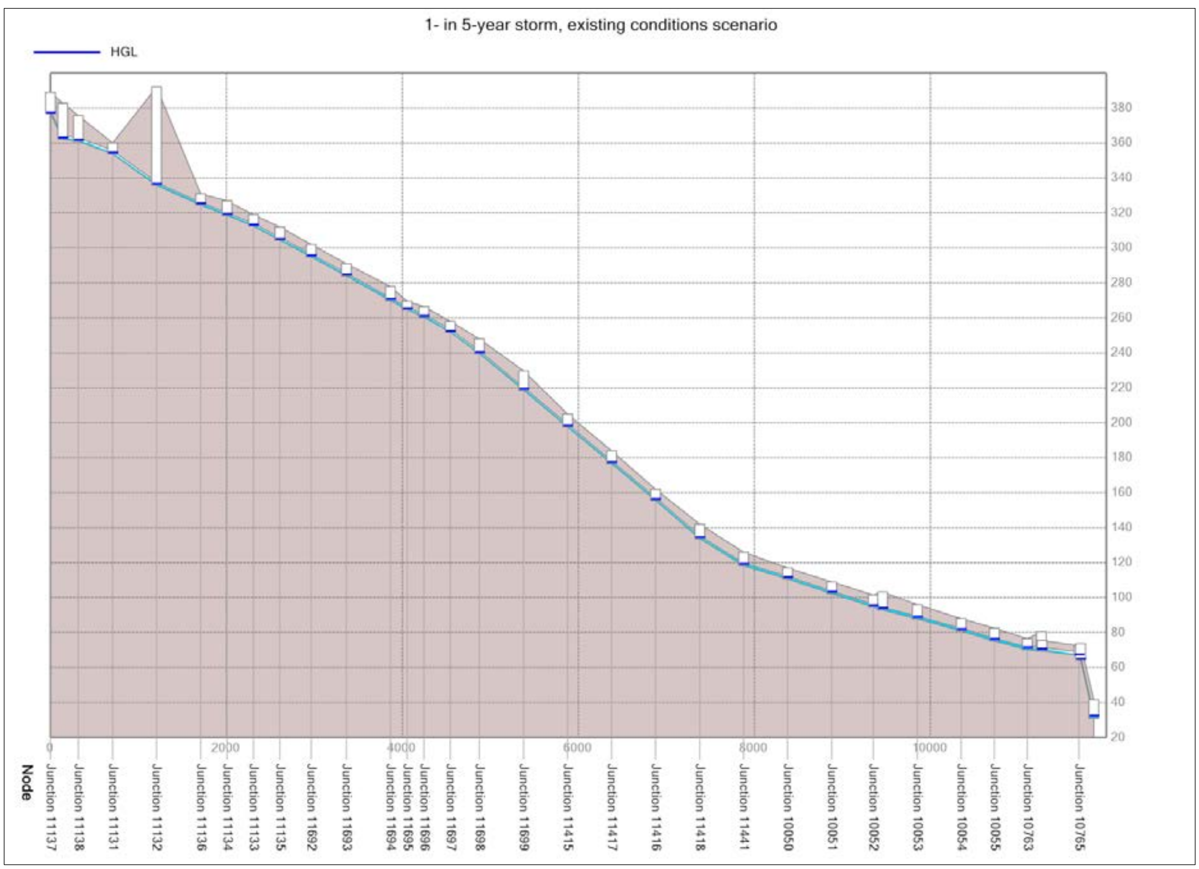


Figure 9. Highway 213 Sewer Profile – Beavercreek Road to Redland Road

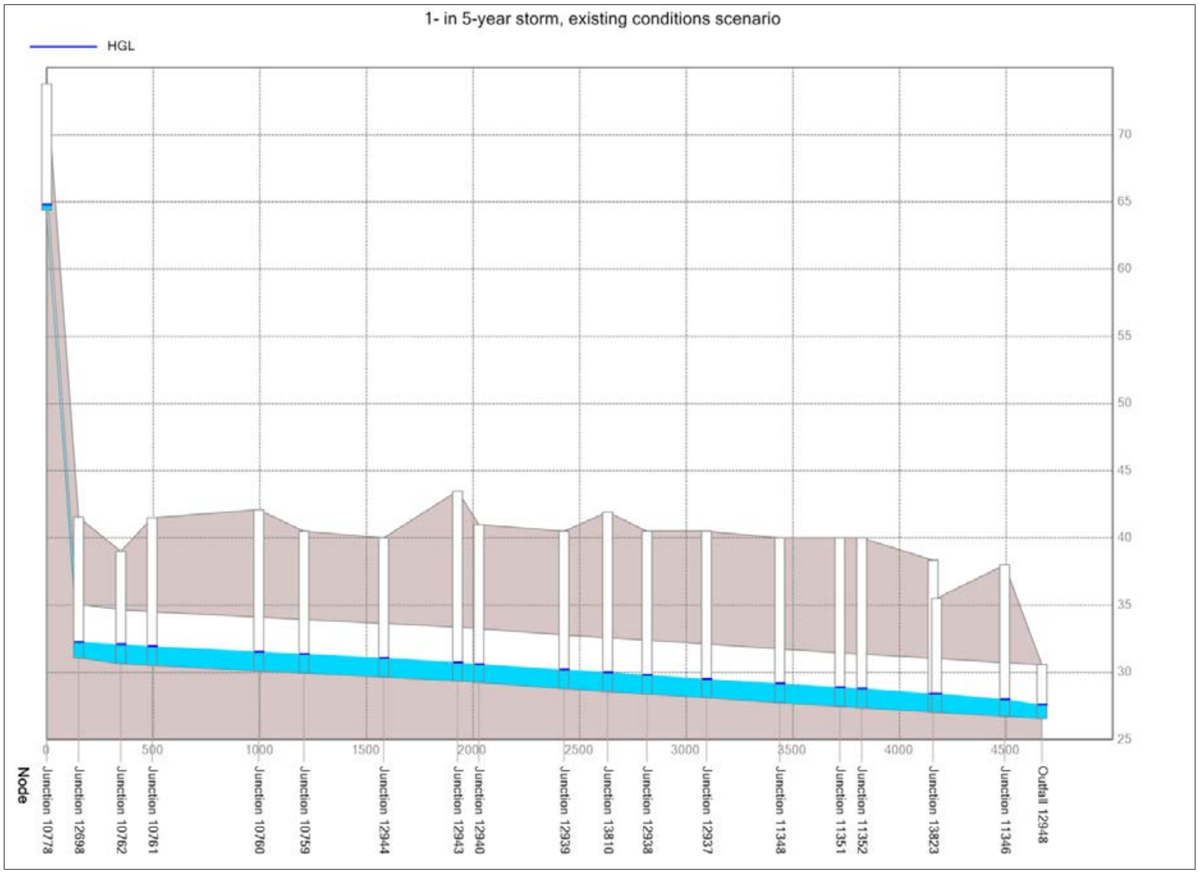


**Figure 10. Sewer Profile – Highway 213 and Redland Road to Highway 99E**

# Section 4: Recommendations

The areas shown in Figure 2 surcharge during the modeled 1- in 5-year storm event. Consequently, some of the sewers in these areas should be a high priority for sewer replacement, and/or an I/I abatement program that would reduce the flows to an acceptable level. Figure 3 and Table 2 identify the sewers that would need to be replaced to alleviate the surcharging and flooding. Any additional flows introduced into sewers under-sized for the 1- in 5-year storm event prior to implementation of the capital improvement recommendations will increase surcharging and increase the potential for flooding and/or basement backups in the area. Sizing of replacement sewers should be based on the recommendations of the SSMP as determined to convey the 1- in 10-year storm event.

# Appendix K: Constrained Area Evaluation

Brown AND Caldwell

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# Technical Memorandum

Prepared for: City of Oregon City, Oregon

Project Title: City of Oregon City Sanitary Sewer Master Plan

Project No.: 142029

**Technical Memorandum**

Subject: Constrained Area Evaluation

Date: May 15, 2014

To: Erik Wahrgren, City of Oregon City

From: James Hansen, BC-Portland

Prepared By: Janice Keeley, BC-Portland

Technical Reviewer: James Hansen, BC-Portland

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# Section 1: Introduction

In 2012, the City of Oregon City (City) retained Brown and Caldwell to assist with the development of a new sanitary sewer master plan (SSMP). The new SSMP identifies capital improvements that are required for improving existing and future sanitary sewer service and for providing services to new areas as they are developed and annexed by the City. Initial modeling results for the SSMP found that the sewers in some areas of the city experienced surcharging within 5 feet of the manhole rim elevation and sewers in three areas of the city experienced flooding; i.e., sanitary sewer overflows (SSOs) under the existing conditions scenario. The Settler's Point Pumping Station is also undersized and unable to convey flows under the existing conditions scenario. Additional surcharging and flooding is predicted under the future conditions planning scenario. Results of the future conditions planning scenario were the focus of the SSMP document; however, potential and proposed redevelopment in areas contributing to the above noted constrained sewers required that the City take a closer look at the existing flow conditions in these areas. The results of the existing condition scenario modeling provide insight into the severity of the capacity constraints, which can be used as a basis for prioritizing improvements.

This technical memorandum (TM) presents the results of modeling the sanitary sewer collection system in nine flow-constrained areas for the existing conditions 1- in 5-year and 1- in 10-year, 24-hour storm events. The results of this modeling effort and TM will be used by the City to assess potential development in the areas contributing to constrained sewers, shown in Figure 1.

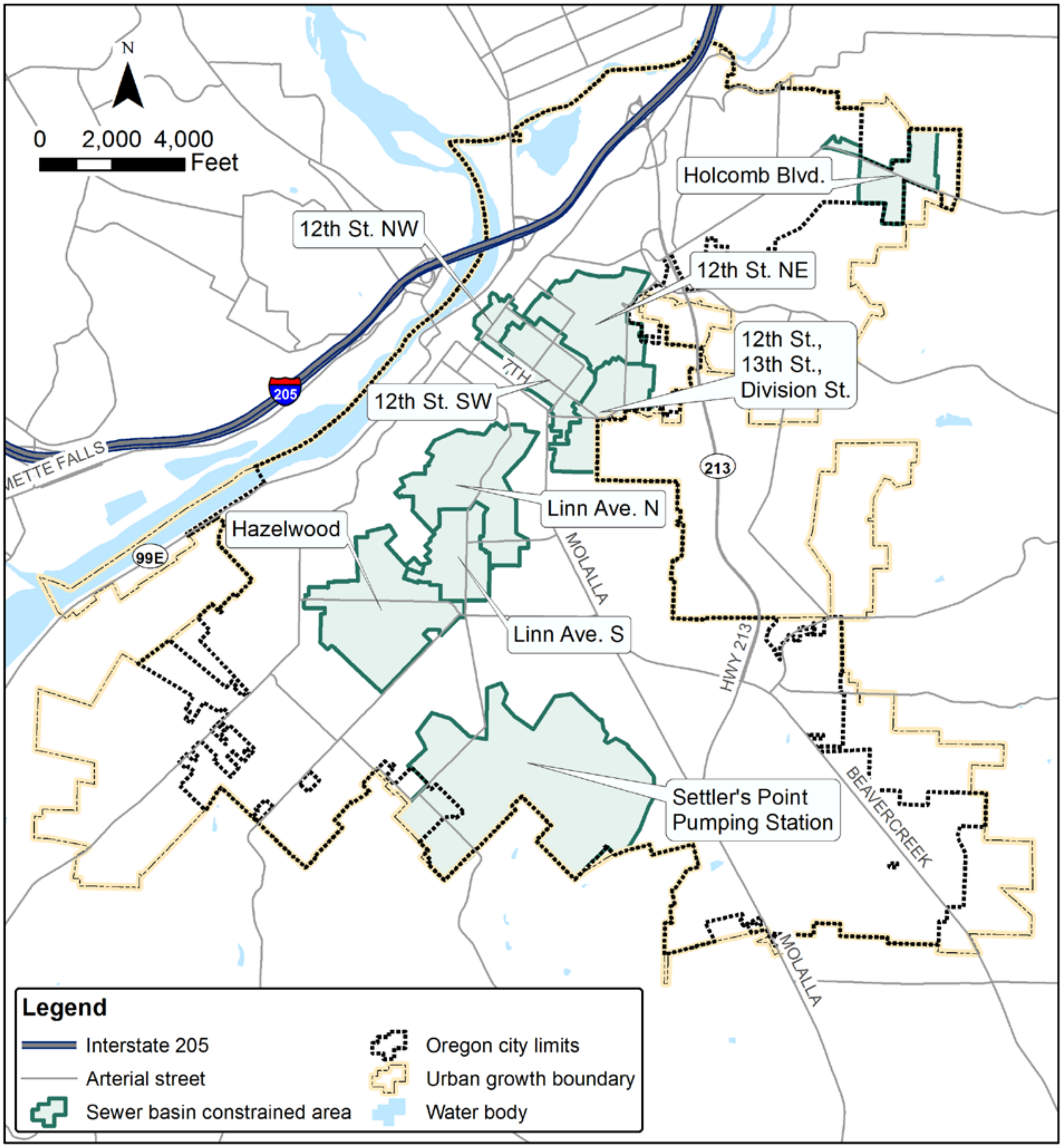



**Figure 1. Constrained sewer contributing areas**

## Section 2: Analysis Methodology

Hydraulic analyses were conducted using Storm Water Management Model (SWMM) urban hydrology and conveyance system hydraulics software. A detailed explanation of how base flows and wet weather flows were developed is included in Section 3 and Appendix A of the SSMP. The SSMP uses the 1- in 10-year storm event (recurrence interval) as the basis of planning. This TM investigates the results of modeling both the 1- in 5-year and 1- in 10-year storm events.

## 2.1 Base Flows

Base flows include wastewater contributions from residential, commercial, and industrial sources and long-term groundwater infiltration that finds its way into sewers and manholes through cracks, joint separations, and other defects. Rainfall-derived infiltration/inflow (I/I) is not included in the base flow, whereas long-term groundwater is included. The groundwater contributions may include perched water sources that contribute groundwater infiltration during the wet season only. The flow monitoring record includes the groundwater sources so that with the addition of the wet weather I/I, the modeling represents the entire wet weather flow regime. Base flows are the same for the 1- in 5-year and 1- in 10-year storm events.

## 2.2 Wet Weather Flows

Wet weather flows are based on the results of flow monitoring during the wet season and pump station run time data. The wet weather data were used to calibrate the model such that modeled flow matched observations and measurements of actual flow in the collection system. Flow meter locations and model calibration are documented in Appendix A of the SSMP. Once calibrated, the model was used to simulate the two storm events and determine capacity deficiencies in the system. The rainfall depths associated with the two storm events are listed in Table 1.

**Table 1. Storm Flow Volumes**

| Storm event | Flow volume, inches |
|---|---|
| 5-year, 24-hour | 3.0 |
| 10-year, 24-hour | 3.5 |

## 2.3 Assessment Criteria

Two criteria are used to evaluate whether pipes are too small to convey the design flow. The percent of capacity used is a ratio of maximum predicted flow (Q) to pipe capacity (Qm) expressed as a percentage. The maximum predicted flow, Q, is the calculated peak flow in each pipe from the model. The pipe capacity (Qm) is the theoretical pipe capacity according to Manning's equation, which assumes unpressurized flow (no surcharging). A percentage of greater than 100 indicates that the pipe is carrying more flow than is theoretically possible for unpressurized flow for a given pipe slope, diameter, and internal roughness. A percent capacity of greater than 100 is an indication of a surcharged pipe.

Unfortunately, the percent capacity alone cannot be used for determining pipe capacity due to the way that SWMM-based models report their data. In some situations, peak flows reported by the model exist for extremely short periods of time, sometimes only for seconds. Consequently, some of these peak flow values should not be used as the basis for pipe replacement. The second criterion, the ratio of depth of water to pipe diameter (d/D) is often more reliable. Use of the d/D ratio is described in more detail below.

In an unpressurized pipe, or a pipe with open-channel flow characteristics, the hydraulic grade line (HGL) is the elevation of the water surface within the pipe, or the d value. In a pipe that is surcharged (pressurized flow), the HGL is defined by the elevation to which water would rise in an open pipe, or manhole, as shown in Figure 2. In hydraulic terms, the HGL is equal to the pressure head measured above the invert of the pipe.

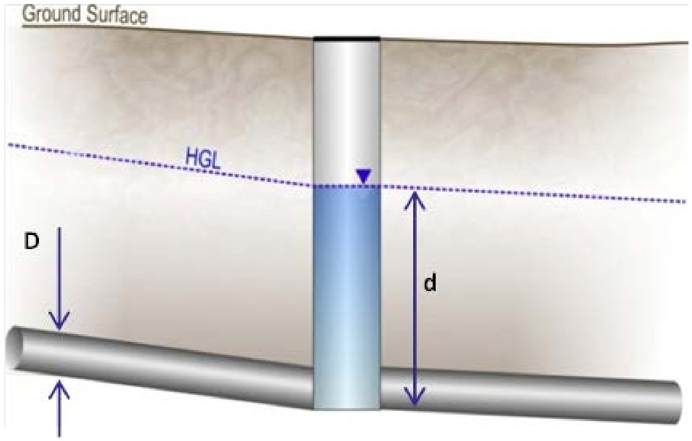



Figure 2. HGL for surcharged condition

The recommended approach for determining which pipes need to be upsized is to consider the amount and frequency of surcharging. For example, if minor surcharging (less than 1 to 2 feet) were to occur during large storm events only (i.e., the 1- in 10-year storm) and the surcharging did not impact property or create an SSO, City staff should not consider upsizing this pipe. However, if the frequency or amount of surcharging were to increase and endanger property or overflow, then the pipe should be upsized. Modeling of the 1- in 5-year storm event is used to help identify where surcharging occurs more frequently.

Pipes that surcharge frequently should be upsized since frequent surcharging has the potential to reduce their structural stability due to loss of pipe support from fine-grained soils washing into the sewer. Similarly, if the amount of surcharging is more than 1 or 2 feet, City staff should consider the amount of remaining freeboard (i.e., distance between water surface in manhole and ground surface, or to the elevation of basements in the area) with regard to the risk of SSOs or basement backups. This approach will help to ensure that the City has adequate capacity for conveying the design flows without spending more capital dollars than necessary.

In general, most sewers with d/D ratios of between 1 and 3 are not identified for replacement. City staff should monitor these sewers during large storm events to quantify the amount of surcharging that actually occurs. If the observed surcharging increases to the point of risking property or becoming an SSO, then the pipe or pipes should be upsized. Some pipes with minor surcharging are identified for replacement even though their d/D ratio is less than 1. Upsizing of these pipes will help to reduce more significant surcharging in the upstream system.

# Section 3: Results

This section presents the results of the existing condition scenario 1- in 10-year and 1- in 5-year modeling for the constrained areas. Each sub-section describes a constrained area and includes a description of surcharged pipes, locations for potential SSOs (flooding), undersized pipes, and costs to upsize pipes.

## 3.1 Linn Avenue

Linn Avenue is located south of downtown Oregon City and parallels Singer Creek. The existing 12-inch gravity sewer within the Linn Avenue roadway alignment from Summit Street to 4th Street is discussed in this section.

### 3.1.1 Existing Condition: 1- in 10-year Modeling Results

The 1- in 10-year storm event modeling was performed with the existing conditions scenario (i.e., 2014 conditions). This storm event was modeled first since the 1- in 10-year storm is consistent with the modeling performed for the SSMP.

The model-predicted surcharging and flooding for the 1- in 10-year, existing conditions scenario, is shown in Figure 3. Surcharging starts at manhole (MH) 11564 and increases upstream to MH 11570. Surcharging is reduced in the steeper segment from MH 11570 to MH 11547, but occurs again in the segment from MH 11547 to MH 11546. In the profile view, Figure 4, the HGL is less than 5 feet from the rim elevations of MHs 11569, 13748, 11570, and 11546.

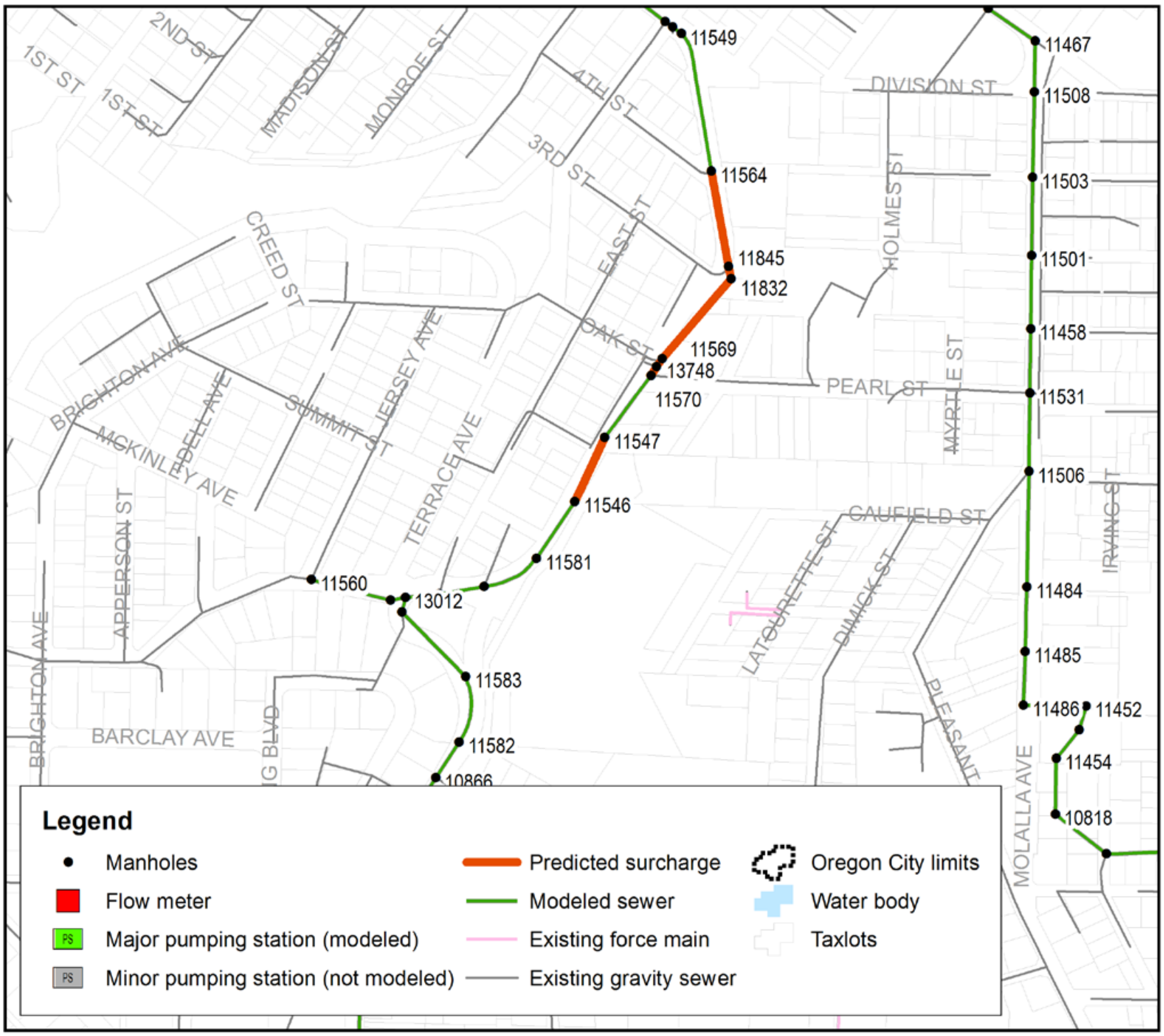



Figure 3. Surcharging and flooding along Linn Avenue sewer, 1- in 10-year storm event

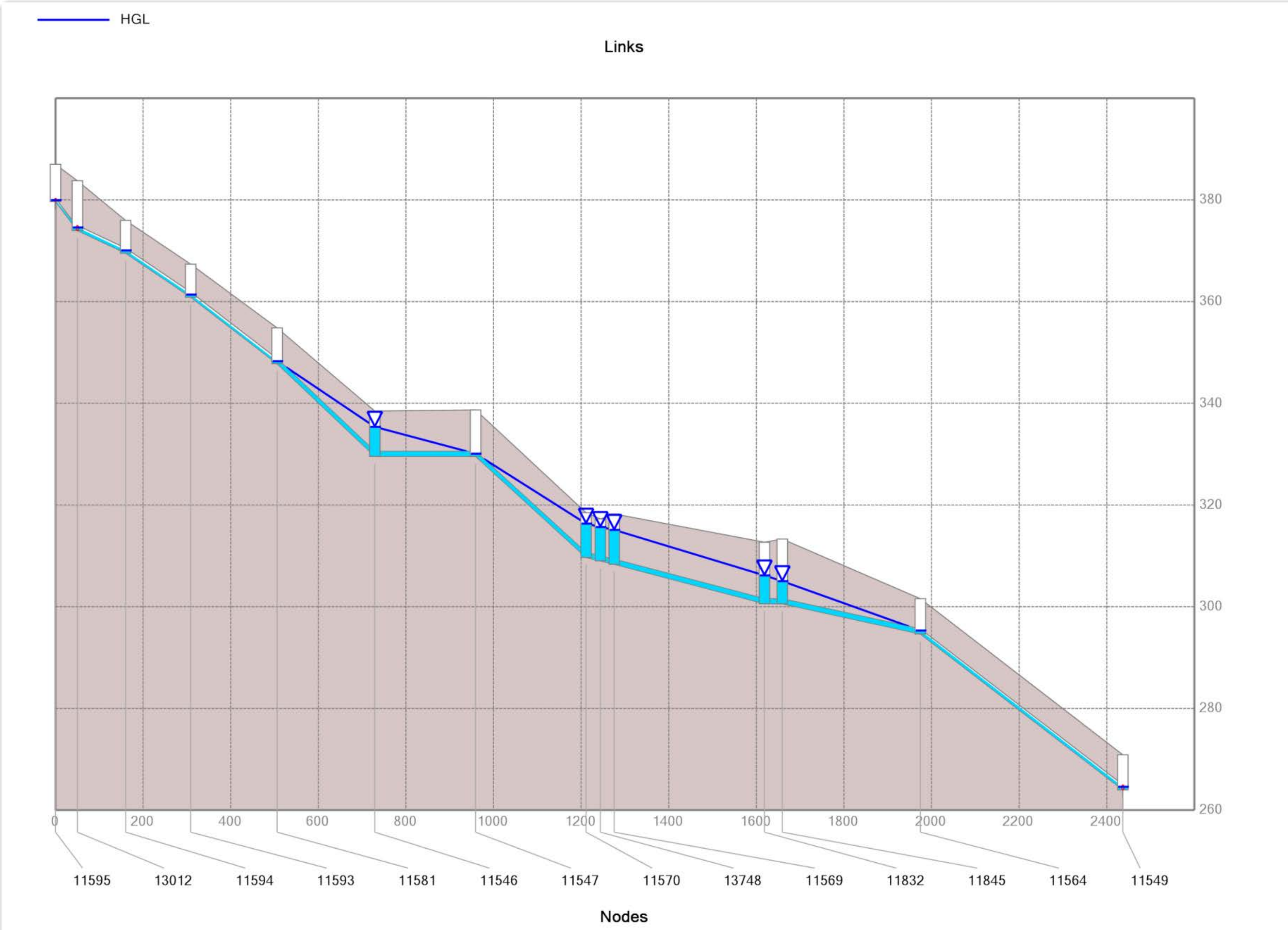



Figure 4. Linn Avenue sewer profile, 1- in 10-year storm event

### 3.1.2 Existing Condition: 1- in 5-year Modeling Results

The 1- in 5-year storm event modeling was performed with the existing conditions scenario (i.e., 2014 conditions). This modeling helps to identify the sewers that will surcharge more frequently than the 1- in 10-year design storm used in the SSMP. As shown in Figure 5, the surcharging extends over the same range of pipes as with the 1- in 10 year storm event modeling, but the surcharging depths are reduced. However, the HGL is less than 5 feet from the rim elevation of MH 11546.

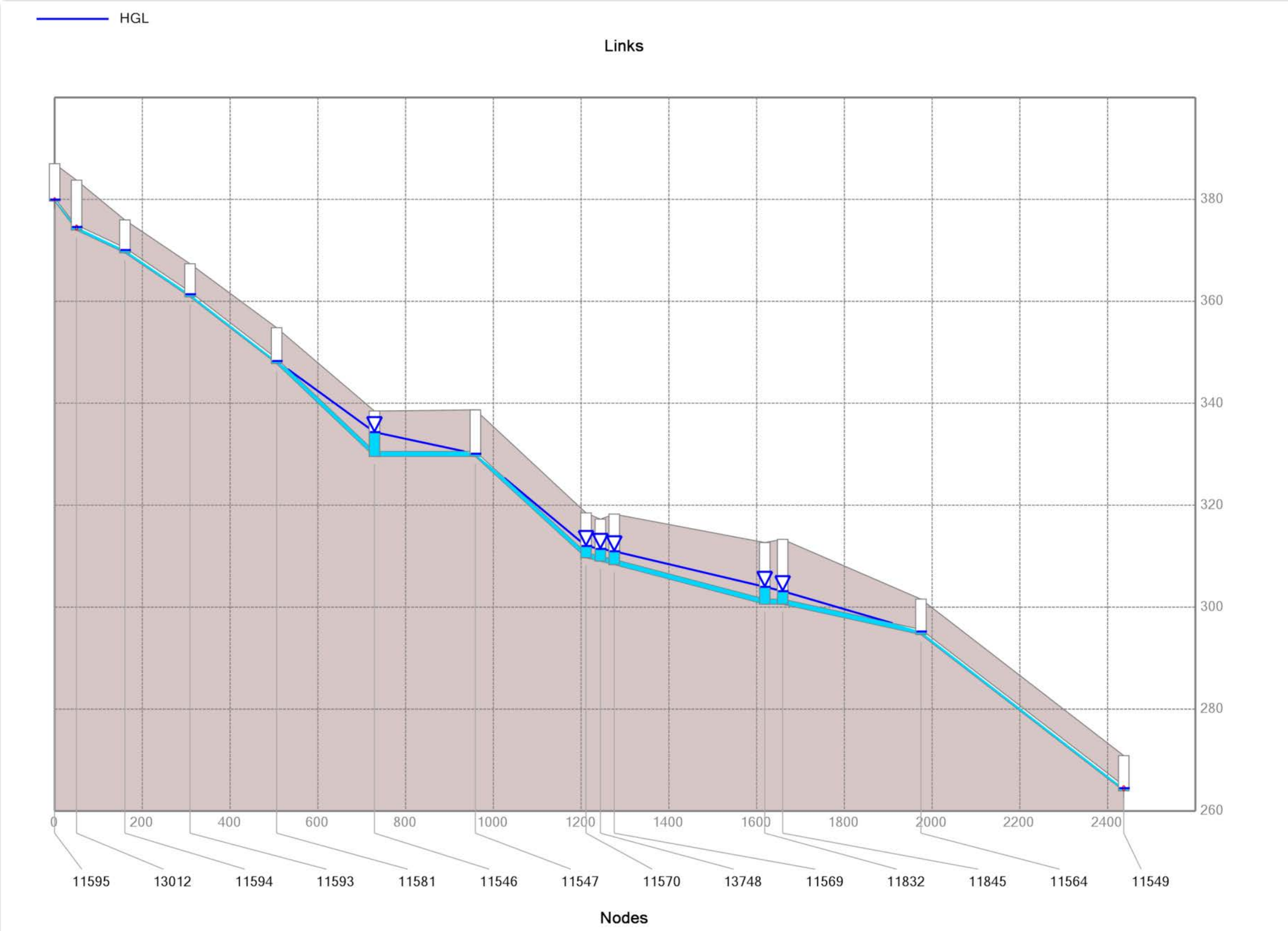



Figure 5. Linn Avenue sewer profile, 1- in 5-year storm event

### 3.1.3 Required Improvements: Existing Condition

There is one sewer segment that would need to be replaced to relieve the predicted surcharging and flooding for the existing condition, 1- in 5-year storm event, which is shown in Figure 6. Please note that not all pipes identified as surcharging need to be replaced since not all surcharging is excessive and the replacement of downstream constraints often reduces the surcharging in upstream sewers.

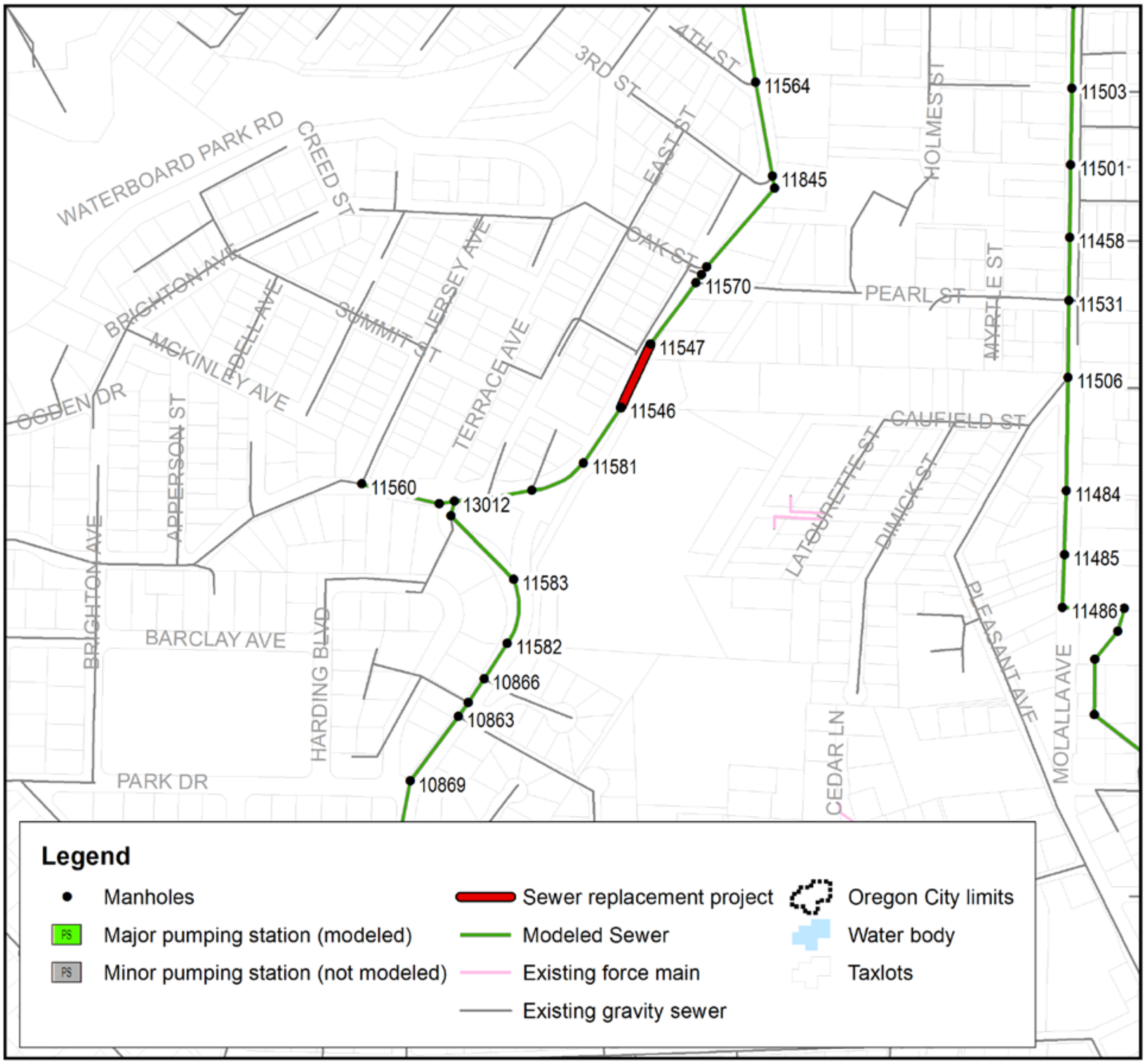



**Figure 6. Required Linn Avenue sewer upgrades, 1- in 5-year storm event**

Costs to upsize the sewers identified in Figure 6 are listed in Table 2. The costs are based on sizing replacement sewers to convey the 1- in 5-year storm event under existing conditions. Actual replacement of any of these pipes will be based on the 10-year storm event modeling for the future condition which is listed in Table 3. Table 2 does not include the benefits of potential I/I reduction measures.

| Table 2. Sewer Upsizing Requirements – 5-year Storm Event, Existing Conditions Scenario | | | | | | |
|---|---|---|---|---|---|---|
| Pipe ID | Owner | Length, feet | Existing pipe diameter, inches | Upsize diameter, inches | Current total cost, $ | SSMP project name |
| 11546_11547 | OC | 230 | 12 | 15 | 101,788 | (4) Linn Avenue |
| Total all pipe replacements | | | | | 101,788 | |

The costs listed in Table 3 are based on sizing of replacement sewers to convey the 1- in 10-year storm event under the existing conditions scenario. The required pipe size does not change from what is required for the 1- in 5-year storm modeling, but the number of sewers that require replacement increases. Upsizing the pipes listed in Table 3 will convey the 1- in 10-year storm under existing conditions with little surcharging and no flooding, as shown in Figure 7.

| Table 3. Sewer Upsizing Requirements – 10-year Storm Event, Existing Conditions Scenario | | | | | | |
|---|---|---|---|---|---|---|
| Pipe ID | Owner | Length, feet | Existing pipe diameter, inches | Upsize diameter, inches | Current total cost, $ | SSMP project name |
| 11546_11547 | OC | 230 | 12 | 15 | 101,788 | (4) Linn Avenue |
| 11832_11845 | OC | 41 | 12 | 15 | 24,341 | (4) Linn Avenue |
| 11845_11564 | OC | 315 | 12 | 15 | 139,464 | (4) Linn Avenue |
| Total all pipe replacements | | | | | 265,590 | |


Figure 7. Linn Avenue sewer profile, 1- in 10-year storm event, pipes upsized

### 3.1.4 Linn Avenue Recommendations

Portions of the Linn Avenue sewer are undersized and currently operating beyond existing capacity, including the 1- in 5-year and 1- in 10-year storm events. The sewers in this area need to be increased in diameter and/or the flows need to be reduced via an I/I abatement program. **Any additional flows introduced into this sewer prior to implementation of the capital improvement recommendations will increase surcharging and increase the potential for flooding and/or basement backups in the area.** The sizing of replacement sewers should be based on the recommendations of the SSMP as determined to convey the future conditions scenario, 1- in 10-year storm event.

## 3.2 Hazelwood Drive

Hazelwood Drive is located south of downtown Oregon City, north of Warner-Parrott Road. The results in this section are also described in the Hazelwood Area (Warner-Parrott Road) Modeling TM, (Brown and Caldwell, April 28, 2014.

### 3.2.1 Existing Condition: 1- in 10-year Modeling Results

The 1- in 10-year storm event modeling was performed with the existing conditions scenario (i.e., 2014 conditions). This storm event was modeled first since the 1- in 10-year storm is consistent with the modeling performed for the SSMP.

The model predicted surcharging and flooding for the 1- in 10-year, existing conditions scenario, as shown in Figure 8. Surcharging starts at approximately MH 10928 and increases in the upstream direction until the HGL breaks the ground surface at MH 18025. At MH 18025, flooding is predicted and nearly occurs at MH 11046, as shown in the profile view in Figure 9. As shown, the HGL is high throughout the study area and flooding is predicted at MH 18025. City staff have observed significant surcharging along Warner-Parrett Road and in the sewer that runs up Shenandoah Drive and into Joyce Court. The five properties highlighted in Figure 10 experienced basement flooding during the storm event on January 2, 2009, and two of these same properties again had flooding during the storm event on January 19 to 20, 2012.

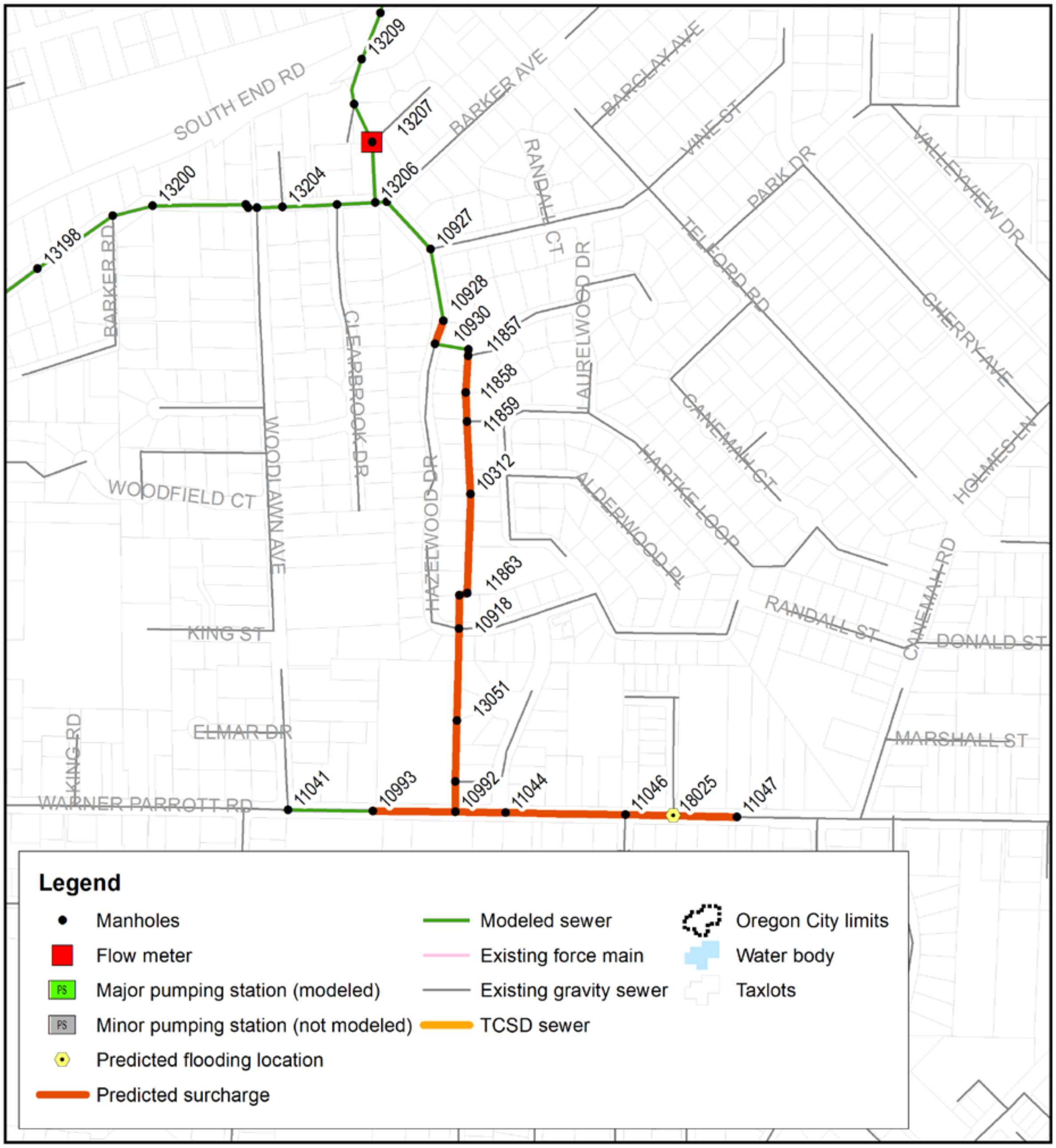



**Figure 8. Surcharging and flooding along Hazelwood sewer, 1- in 10-year storm event**

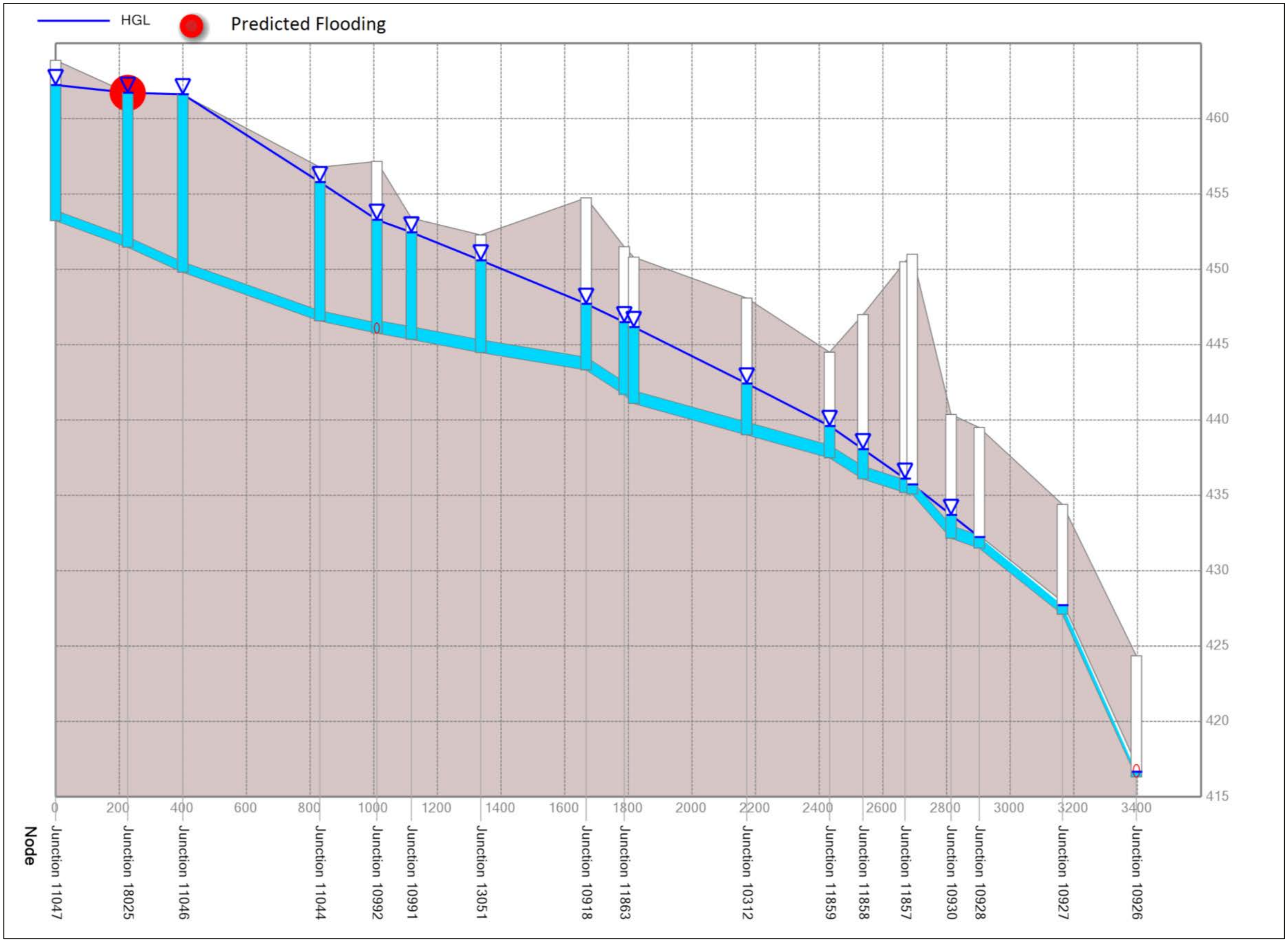



Figure 9. Hazelwood sewer profile, 1- in 10-year storm event

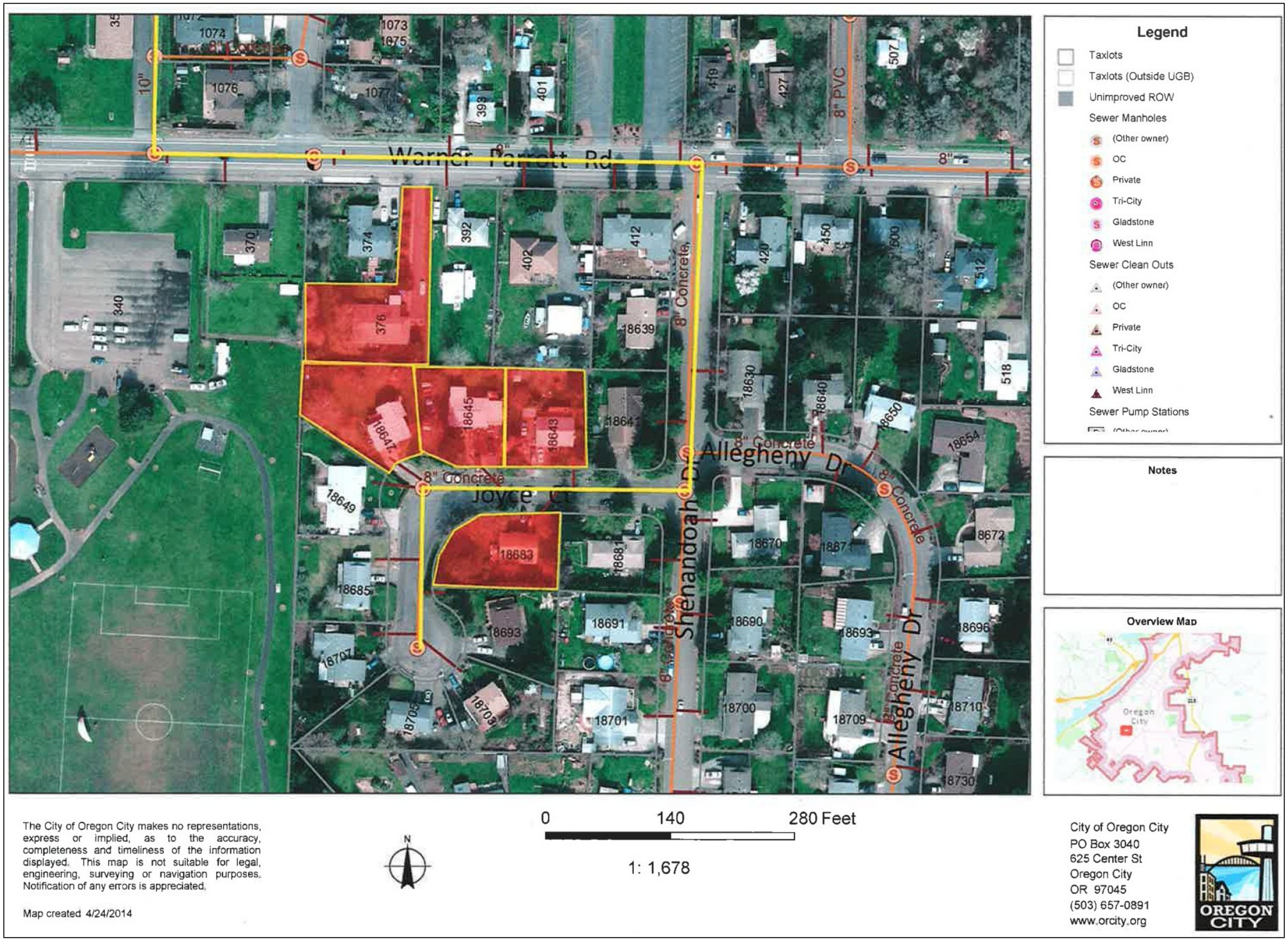



**Figure 10. Recorded basement flooding**

### 3.2.2 Existing Condition: 1- in 5-year Modeling Results

The 1- in 5-year storm event modeling was performed with the existing conditions scenario (i.e., 2014 conditions). This modeling helps to identify the sewers that will surcharge more frequently than the 1- in 10-year design storm used in the SSMP. As shown in Figure 11, the profile is nearly the same as the 1- in 10-year storm event modeling. The HGL is only slightly lower for the 5-year event than the larger 10-year storm. Surcharging extends over the same range of pipes and flooding occurs at the same location as with the 1- in 10-year storm event modeling.

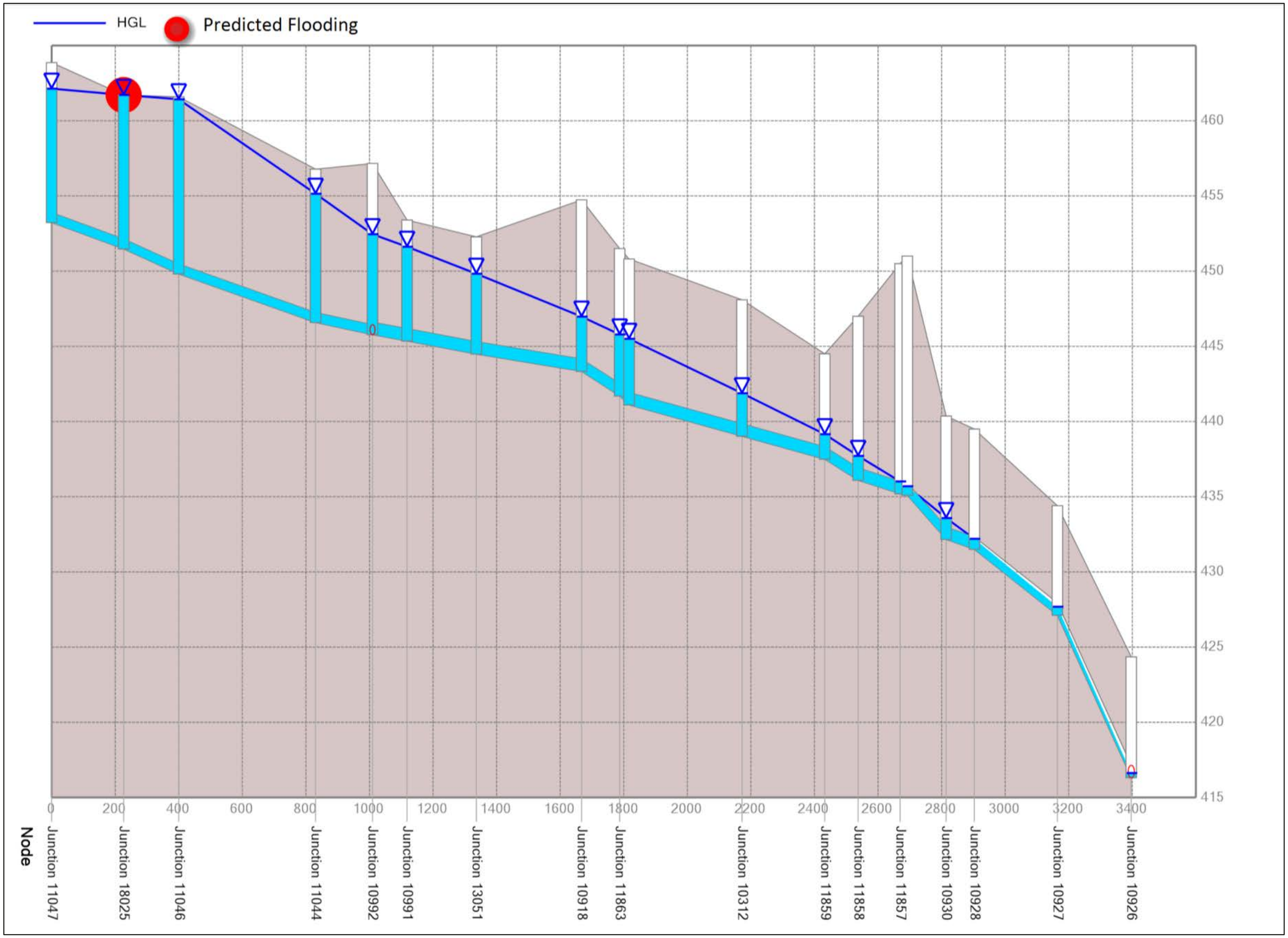



**Figure 11. Hazelwood sewer profile, 1- in 5-year storm event**

### 3.2.3 Required Improvements: Existing Conditions

Sewers that would need to be replaced to relieve the predicted surcharging and flooding for the existing condition, 1- in 5-year storm event are shown in Figure 12. Please note that not all pipes identified as surcharging need to be replaced since not all surcharging is excessive and the replacement of downstream constraints often reduces the surcharging in upstream sewers.

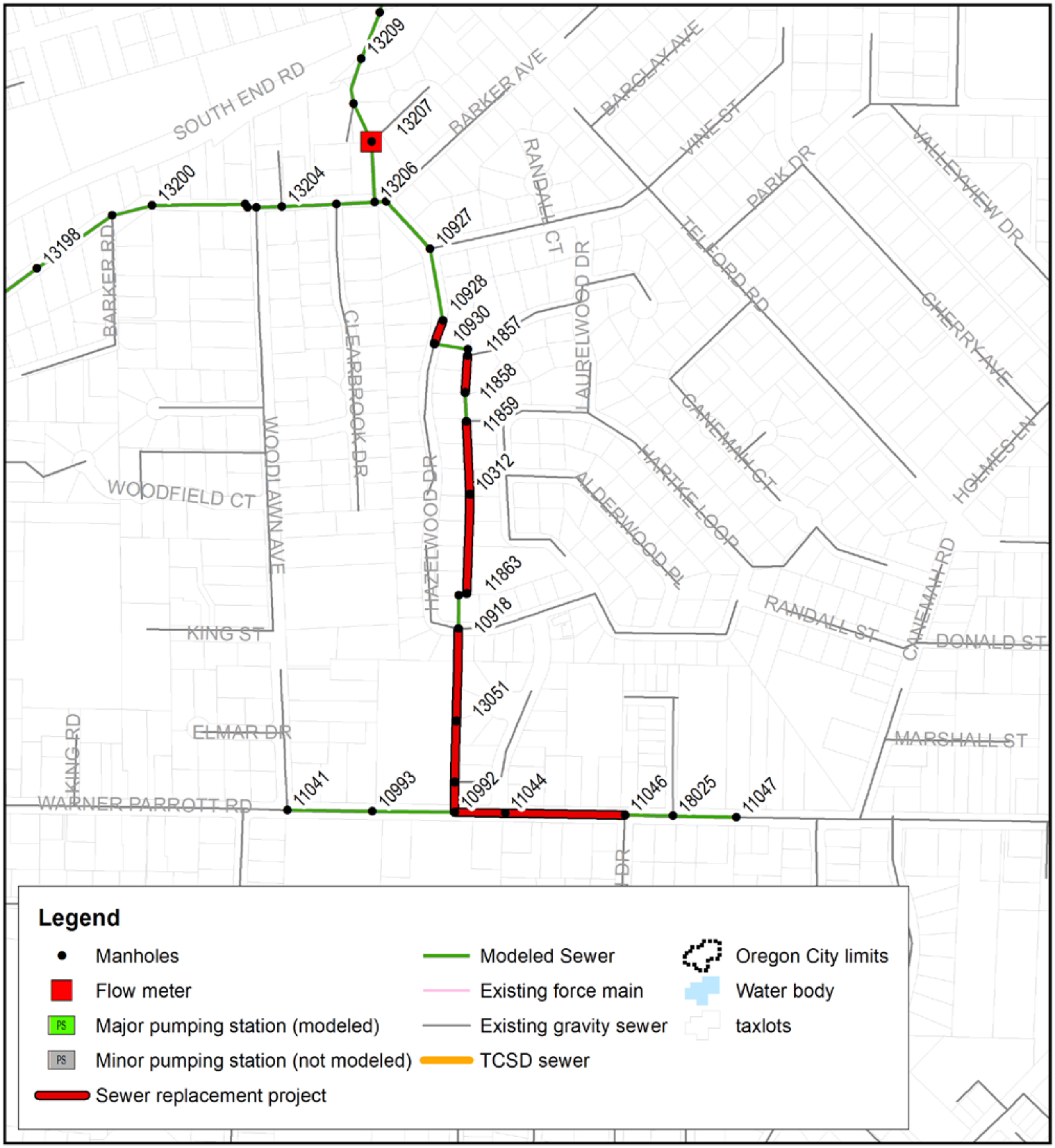



Figure 12. Required Hazelwood sewer upgrades, 1- in 5-year storm event

Costs to upsize the sewers identified in Figure 12 are listed in Table 4. The costs are based on sizing replacement sewers to convey the 1- in 5-year storm event under existing conditions. Actual replacement of any of these pipes will be based on the 10-year storm event modeling for the future condition. Table 4 does not include the benefits of potential I/I reduction measures.

**Table 4. Sewer Upsizing Requirements – 5-year Storm Event, Existing Conditions Scenario**

| Pipe ID | Owner | Length, feet | Existing pipe diameter, inches | Upsize diameter, inches | Current total cost, $ | SSMP project name |
|---|---|---|---|---|---|---|
| 10930_10928 | OC | 89 | 10 | 12 | 35,100 | Hazelwood |
| 11858_11857 | OC | 132 | 10 | 12 | 83,522 | Hazelwood |
| 10312_11859 | OC | 260 | 10 | 12 | 127,524 | Hazelwood |
| 11862_10312 | OC | 355 | 10 | 12 | 173,929 | Hazelwood |
| 13051_10918 | OC | 331 | 10 | 12 | 162,156 | Hazelwood |
| 10991_13051 | OC | 218 | 10 | 12 | 106,766 | Hazelwood |
| 10992_10991 | OC | 109 | 10 | 12 | 53,202 | Hazelwood |
| 11044_10992 | OC | 179 | 8 | 10 | 92,088 | Hazelwood |
| 11046_11044 | OC | 431 | 8 | 10 | 221,253 | Hazelwood |
| Total all pipe replacements | | | | | 1,055, 539 | |

The costs listed in Table 5 are based on sizing of replacement sewers to convey the 1- in 10-year storm event under the existing conditions scenario. The required pipe sizes do not change from what is required for the 1- in 5-year storm modeling, but the number of sewers that require replacement increases. Upsizing the pipes listed in Table 5 will convey the existing condition 1- in 10-year storm with little surcharging and no flooding, as shown in Figure 13.

**Table 5. Sewer Upsizing Requirements – 10-year Storm Event, Existing Conditions Scenario**

| Pipe ID | Owner | Length, feet | Existing pipe diameter, inches | Upsize diameter, inches | Current total cost, $ | SSMP project name |
|---|---|---|---|---|---|---|
| 10928_10927 | OC | 261 | 10 | 12 | 103,447 | Hazelwood |
| 10930_10928 | OC | 89 | 10 | 12 | 35,100 | Hazelwood |
| 11857_11856 | OC | 23 | 10 | 12 | 18,052 | Hazelwood |
| 11858_11857 | OC | 132 | 10 | 12 | 83,522 | Hazelwood |
| 11859_11858 | OC | 105 | 10 | 12 | 51,370 | Hazelwood |
| 10312_11859 | OC | 260 | 10 | 12 | 127,524 | Hazelwood |
| 11862_10312 | OC | 355 | 10 | 12 | 173,929 | Hazelwood |
| 11863_11862 | OC | 30 | 10 | 12 | 14,549 | Hazelwood |
| 10918_11863 | OC | 120 | 10 | 12 | 75,758 | Hazelwood |
| 13051_10918 | OC | 331 | 10 | 12 | 162,156 | Hazelwood |
| 10991_13051 | OC | 218 | 10 | 12 | 106,766 | Hazelwood |
| 10992_10991 | OC | 109 | 10 | 12 | 53,202 | Hazelwood |
| 11044_10992 | OC | 179 | 8 | 10 | 92,088 | Hazelwood |
| 11046_11044 | OC | 431 | 8 | 10 | 221,253 | Hazelwood |
| Total all pipe replacements | | | | | 1,318,715 | |

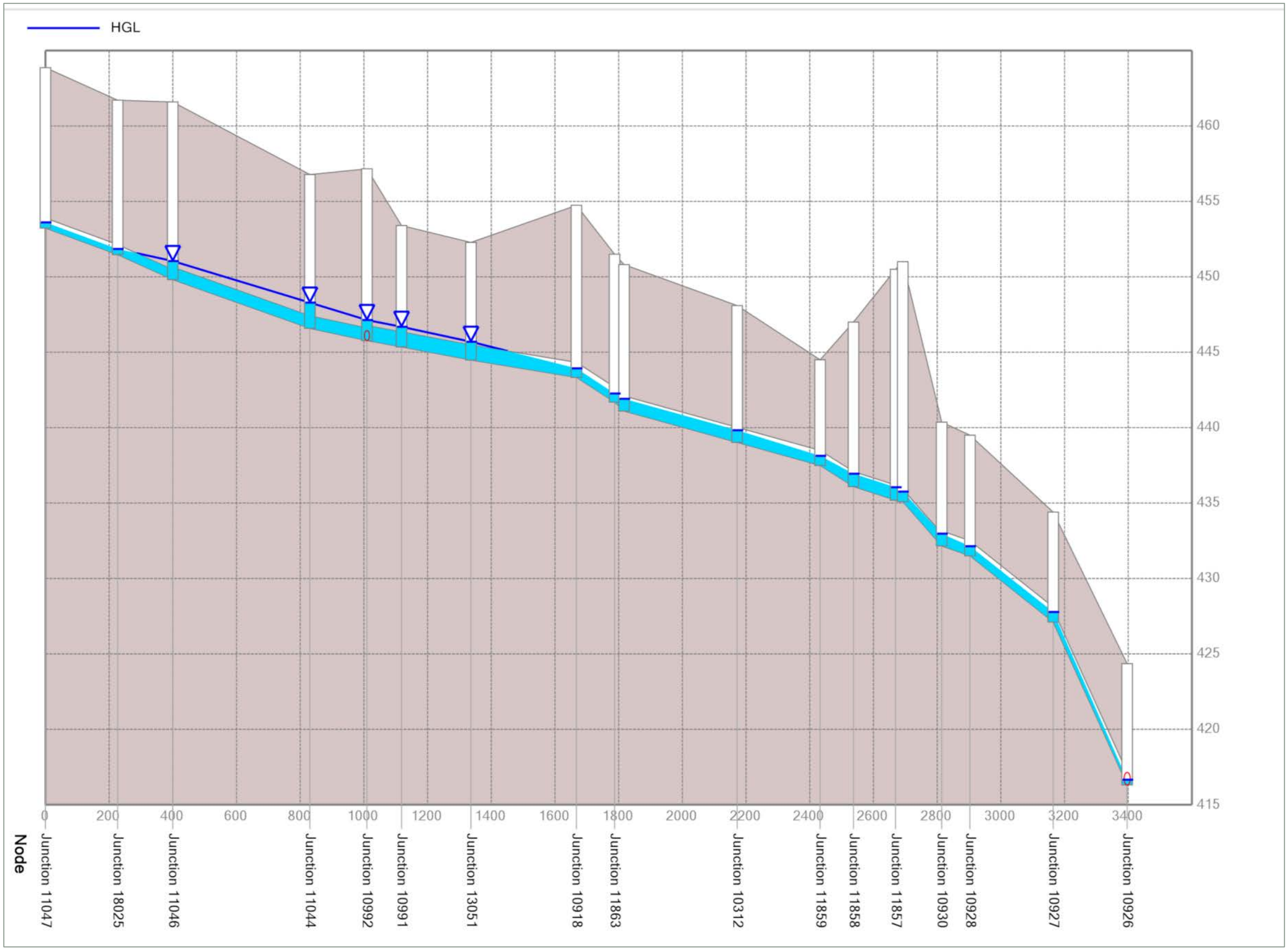



**Figure 13. Hazelwood sewer profile, 1- in 10-year existing conditions storm event, pipes upsized**

Additional analyses were performed to determine if upsizing only a few of the sewers (either upstream or downstream) would reduce the surcharging to an acceptable level and eliminate the potential for flooding. Modeled pipes were upsized between MH 11046 and MH 10918. The pipe upsizing eliminated the flooding at MH 18025 but produced flooding at MH 13051, a manhole farther downstream. This is attributed to the upsizing of the upstream pipes which allows more flow to be moved downstream, thereby increasing the surcharging and flooding downstream of the improvements. Conversely, modeled pipes were upsized for several of the downstream sewers from MH 10928 through MH 10991. No flooding was predicted for this alternative, but excessive surcharging still was found at MH 11046 and MH 18025. In summary, all sewers identified in Table 5 need to be upsized to reduce surcharging effectively and eliminate the potential for flooding under existing conditions.

### 3.2.4 Hazelwood Recommendations

Portions of the Hazelwood Drive sewer are undersized and currently operating beyond existing capacity, including the 1- in 5-year and 1- in 10-year storm events. The sewers in this area need to be increased in diameter and/or the flows need to be reduced via an I/I abatement program. **Any additional flows introduced into this sewer prior to implementation of the capital improvement recommendations will increase surcharging and increase the potential for flooding and/or basement backups in the area.** The sizing of replacement sewers should be based on the recommendations of the SSMP as determined to convey the future conditions scenario, 1- in 10-year storm event.

## 3.3 12th Street

The 12th Street sewer refers to the gravity sewers located in downtown Oregon City on 12th Street from Jefferson Street to Highway (Hwy) 99E and also the two tributary sewers on Madison and Monroe Streets.

### 3.3.1 Existing Condition: 1- in 10-year Modeling Results

The 1- in 10-year storm event modeling was performed with the existing conditions scenario (i.e., 2014 conditions). This storm event was modeled first since the 1- in 10-year storm is consistent with the modeling performed for the SSMP.

Model-predicted surcharging and flooding for the 1- in 10-year, existing conditions scenario, is shown in Figure 14. A significant decrease in slope from MH 11402 to the Tri-City Service District (TCSD) sewer results in surcharging from MH 11402 to MH 11397 and flooding at MH 11402 on Center Street. In the profile view on Figure 15, the HGL is shown from Madison Street on the northeast side of 12th Street to MH 11387 (Meter 5). In the profile view on Figure 16, the HGL is shown from Monroe Street on the southwest side of 12th Street to MH 11387 (Meter 5).

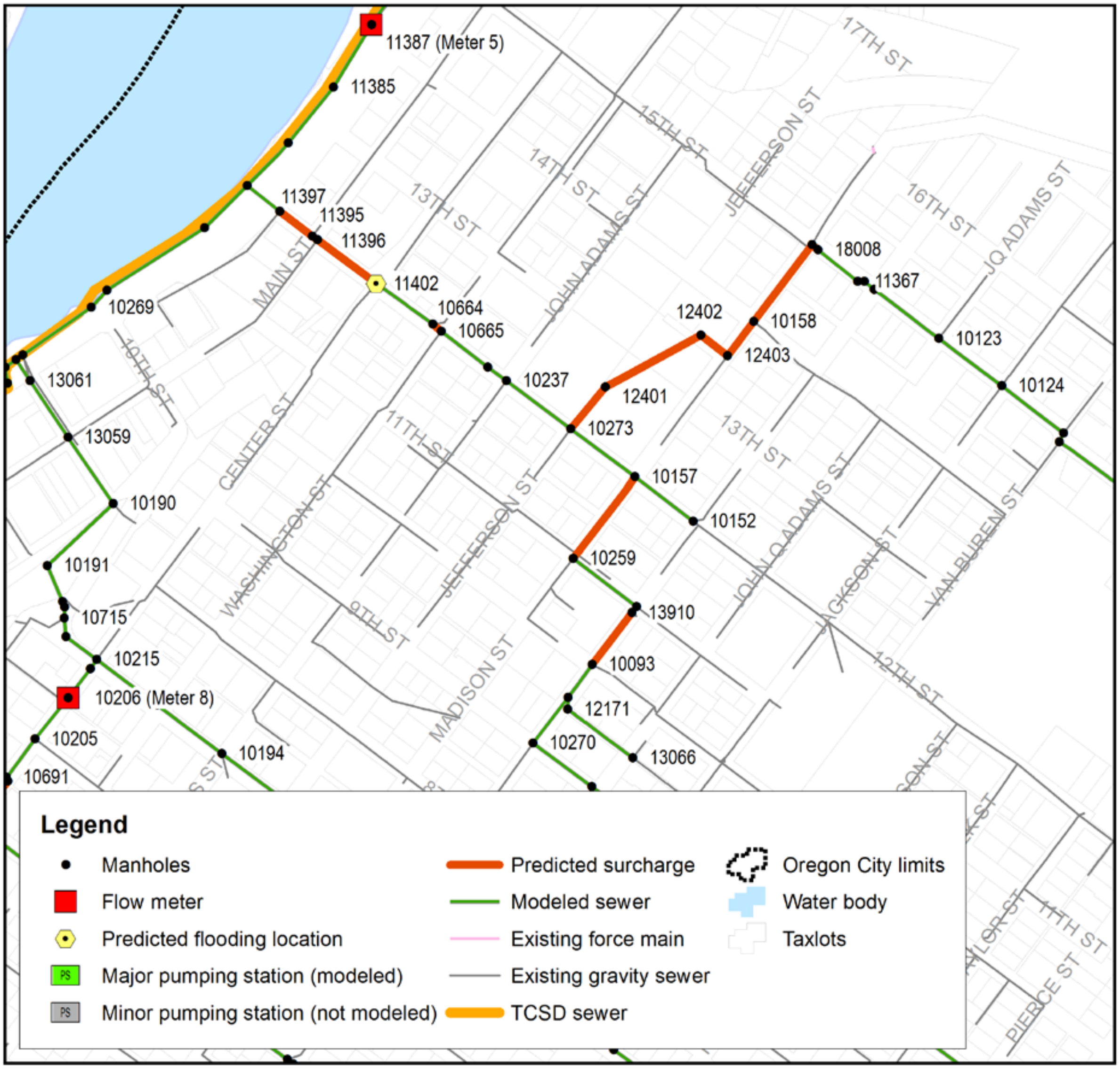



Figure 14. Surcharging and flooding along 12th Street sewer, 1- in 10-year storm event

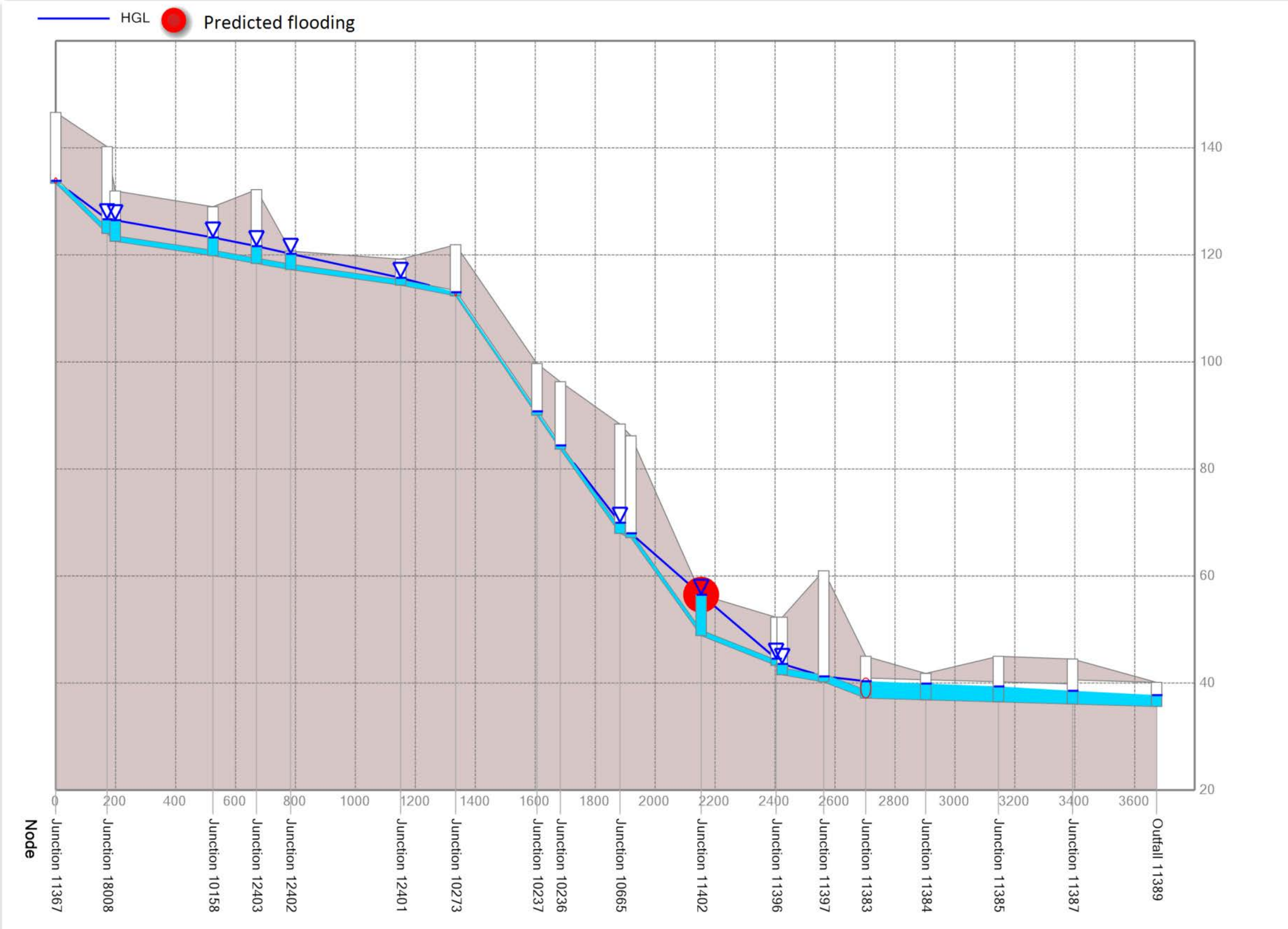



**Figure 15. 12th Street sewer profile (1 of 2), 1- in 10-year storm event**

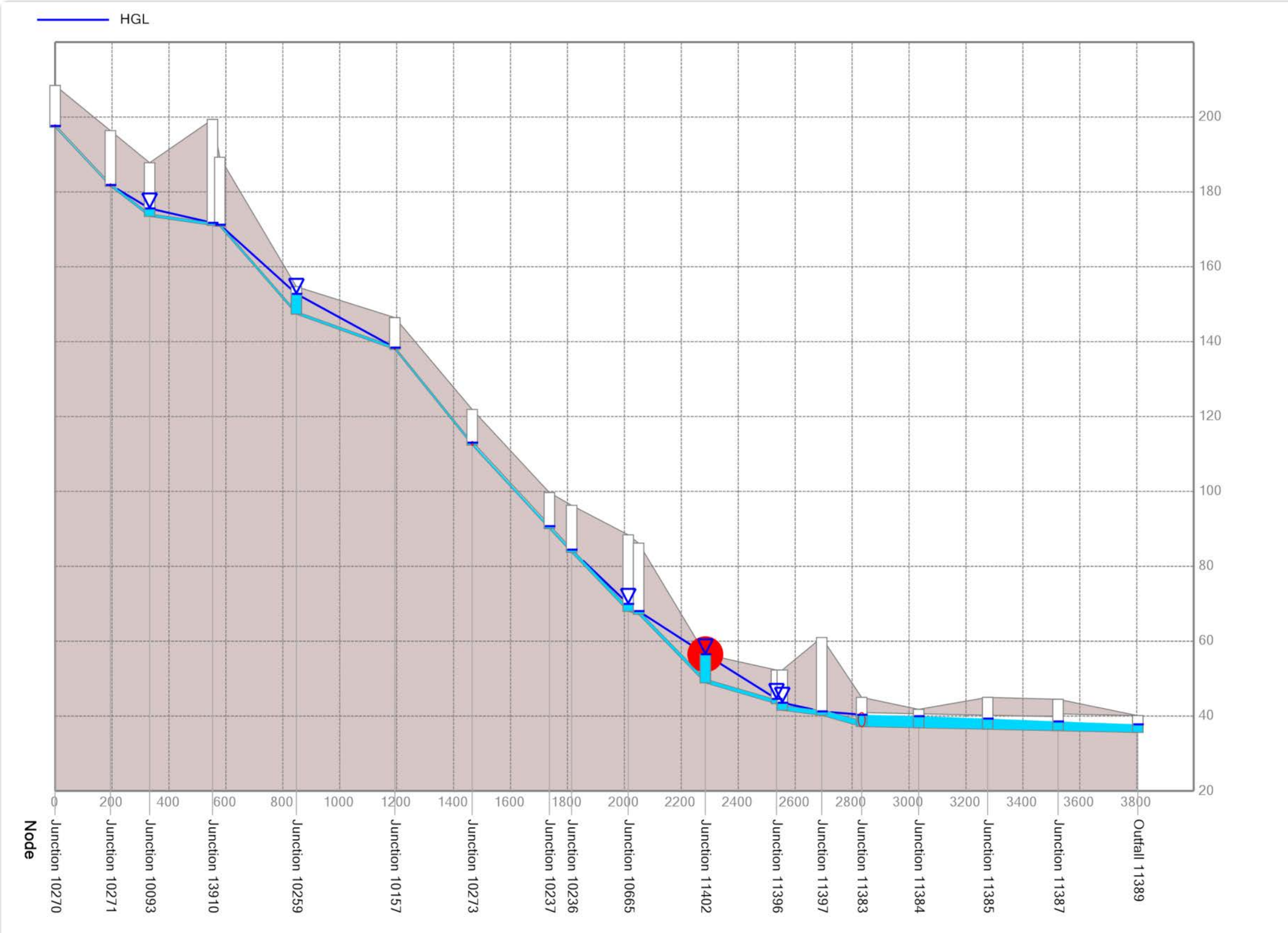



Figure 16. 12th Street sewer profile (2 of 2), 1- in 10-year storm event

### 3.3.2 Existing Condition: 1- in 5-year Modeling Results

The 1- in 5-year storm event modeling was performed with the existing conditions scenario (i.e., 2014 conditions). This modeling helps to identify the sewers that will surcharge more frequently than the 1- in 10-year design storm used in the SSMP. As shown in Figures 17 and 18, the 12th Street profiles are nearly the same as the 1- in 10-year storm event modeling. The HGL is only slightly lower for the 5-year event than for the larger 10-year storm. Surcharging extends over the same range of with the 1- in 10-year storm event modeling, however, flooding is no longer predicted at MH 11402.

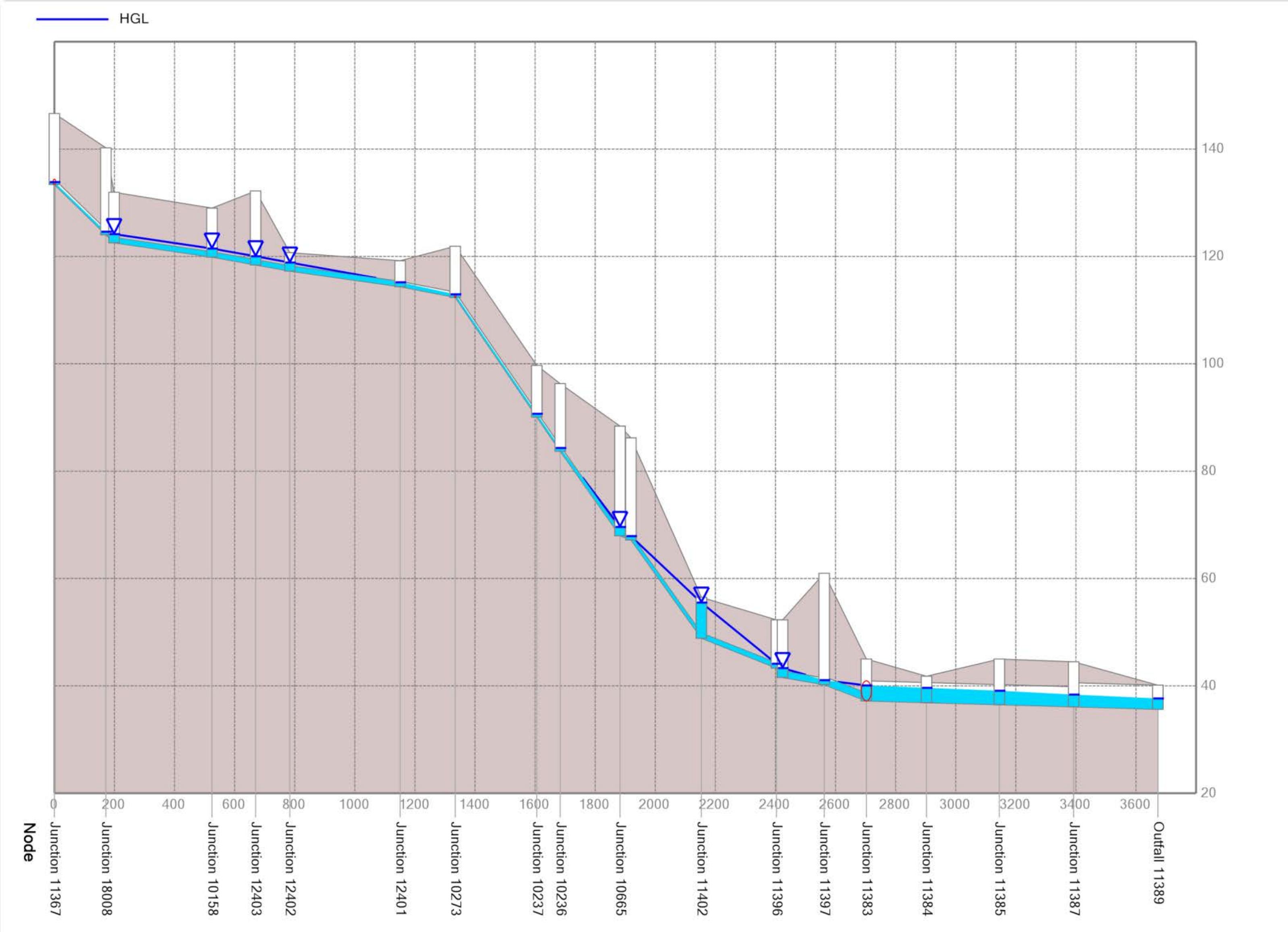



Figure 17. 12th Street sewer profile (1 of 2), 1- in 5-year storm event

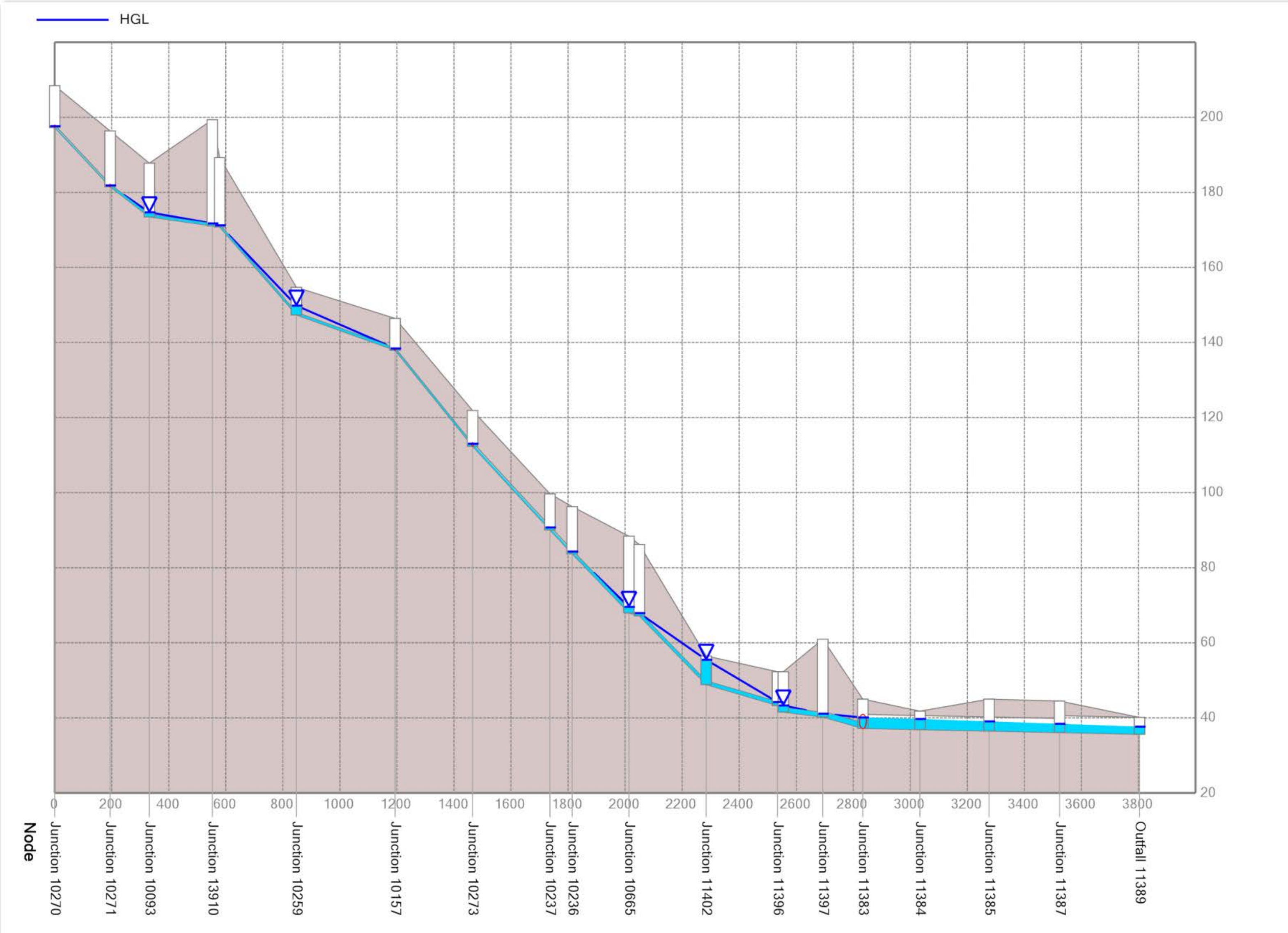



Figure 18. 12th Street sewer profile (1 of 2), 1- in 5-year storm event

### 3.3.3 Required Improvements: Existing Condition

Sewers that would need to be replaced to relieve the predicted surcharging for the existing condition, 1- in 5-year storm event are shown in Figure 19. Please note that not all pipes identified as surcharging need to be replaced since not all surcharging is excessive and the replacement of downstream constraints often reduces the surcharging in upstream sewers.

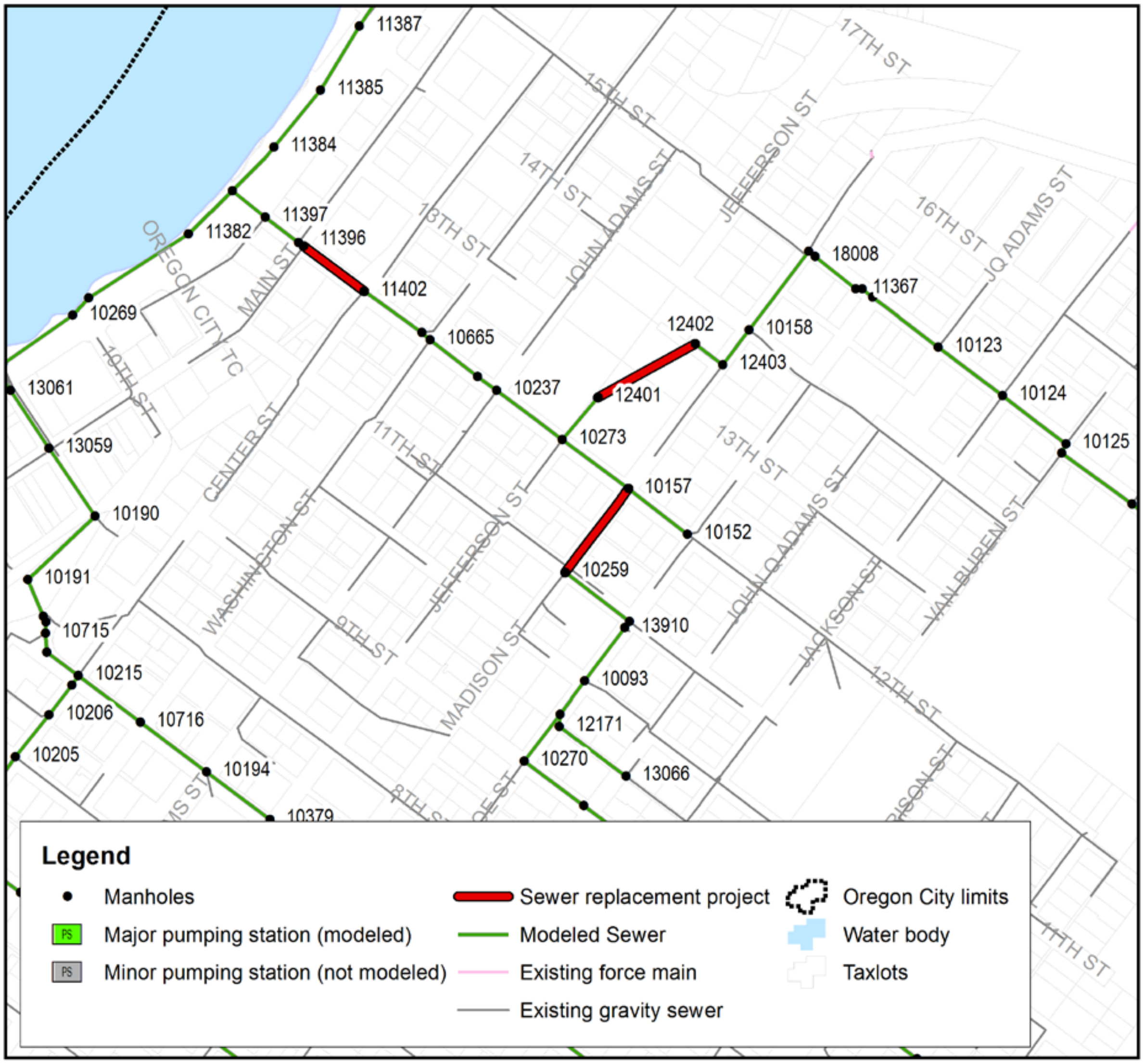



**Figure 19. Required 12th Street sewer upgrades, 1- in 5-year storm event**

Costs to upsize the sewers identified in Figure 19 are listed in Table 6. The costs are based on sizing replacement sewers to convey the 1- in 5-year storm event under existing conditions. Actual replacement of any of these pipes will be based on the 10-year storm event modeling for the future condition. Table 6 does not include the benefits of potential I/I reduction measures.

| Table 6. Sewer Upsizing Requirements – 5-year Storm Event, Existing Conditions Scenario | | | | | | |
|---|---|---|---|---|---|---|
| Pipe ID | Owner | Length, feet | Existing pipe diameter, inches | Upsize diameter, inches | Current total cost, $ | SSMP project name |
| 10259_10157 | OC | 346 | 8 | 10 | 128,789 | (1) 12th Street |
| 12402_12401 | OC | 367 | 12 | 15 | 86,858 | (1) 12th Street |
| 11402_11396 | OC | 250 | 12 | 15 | 110,616 | (1) 12th Street |
| Total all pipe replacements | | | | | 326,260 | |

The costs listed in Table 7 are based on sizing of replacement sewers to convey the 1- in 10-year storm event under the existing conditions scenario. The required pipe sizes do not change from what is required for the 1- in 5-year storm modeling, but the number of sewers that require replacement increases. Upsizing the pipes listed in Table 7 will convey the 1- in 10-year storm under the existing conditions with little surcharging and no flooding, as shown in Figures 20 and 21.

| Table 7. Sewer Upsizing Requirements – 10-year Storm Event, Existing Conditions Scenario | | | | | | |
|---|---|---|---|---|---|---|
| Pipe ID | Owner | Length, feet | Existing pipe diameter, inches | Upsize diameter, inches | Current total cost, $ | SSMP project name |
| 10259_10157 | OC | 346 | 8 | 10 | 128,789 | (1) 12th Street |
| 12402_12401 | OC | 367 | 12 | 15 | 86,858 | (1) 12th Street |
| 12401_10273 | OC | 183 | 12 | 15 | 81,202 | (1) 12th Street |
| 11402_11396 | OC | 250 | 12 | 15 | 110,616 | (1) 12th Street |
| Total all pipe replacements | | | | | 407,470 | |

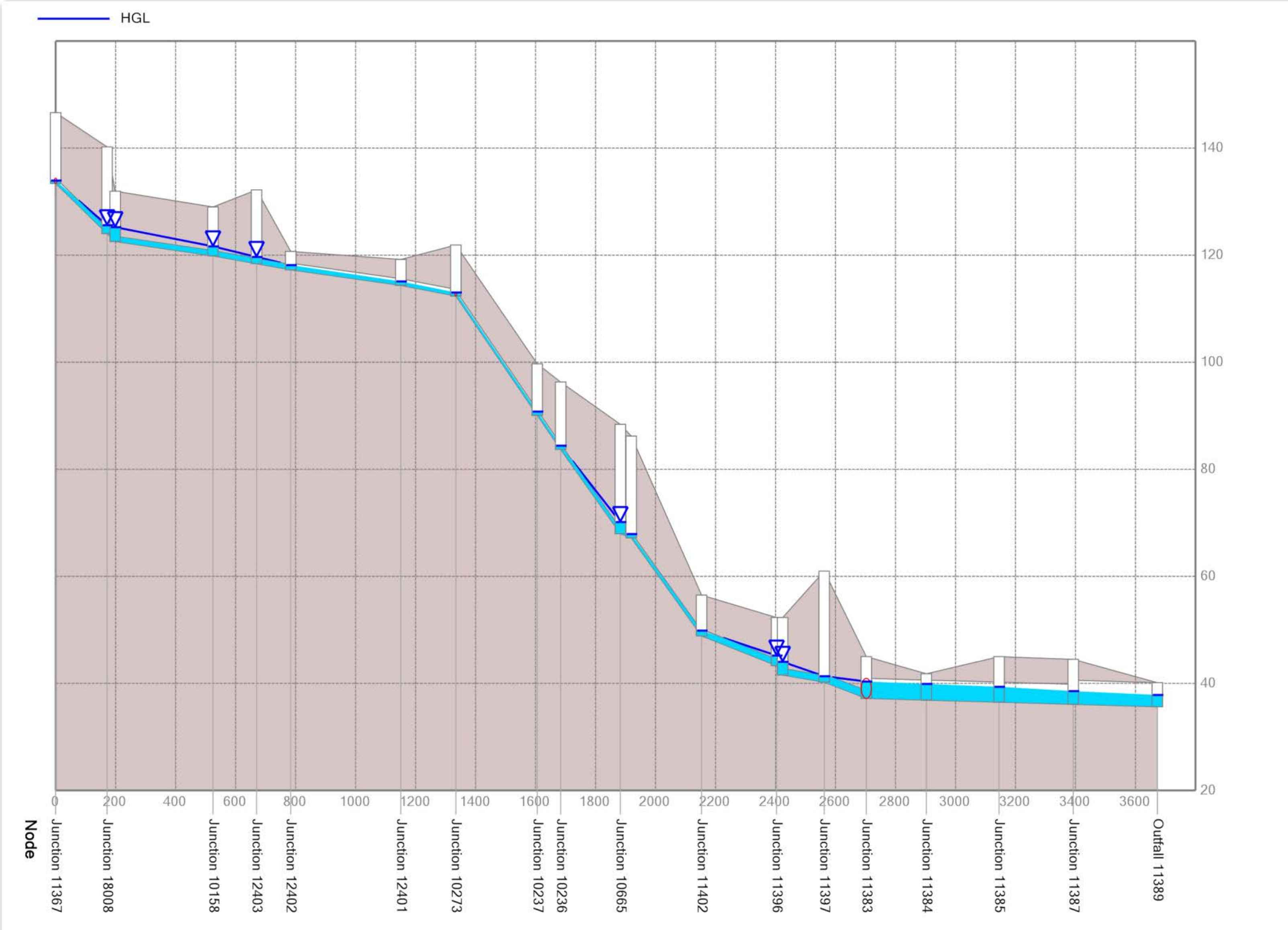



Figure 20. 12th Street sewer profile (1 of 2), 1- in 10-year storm event, pipes upsized

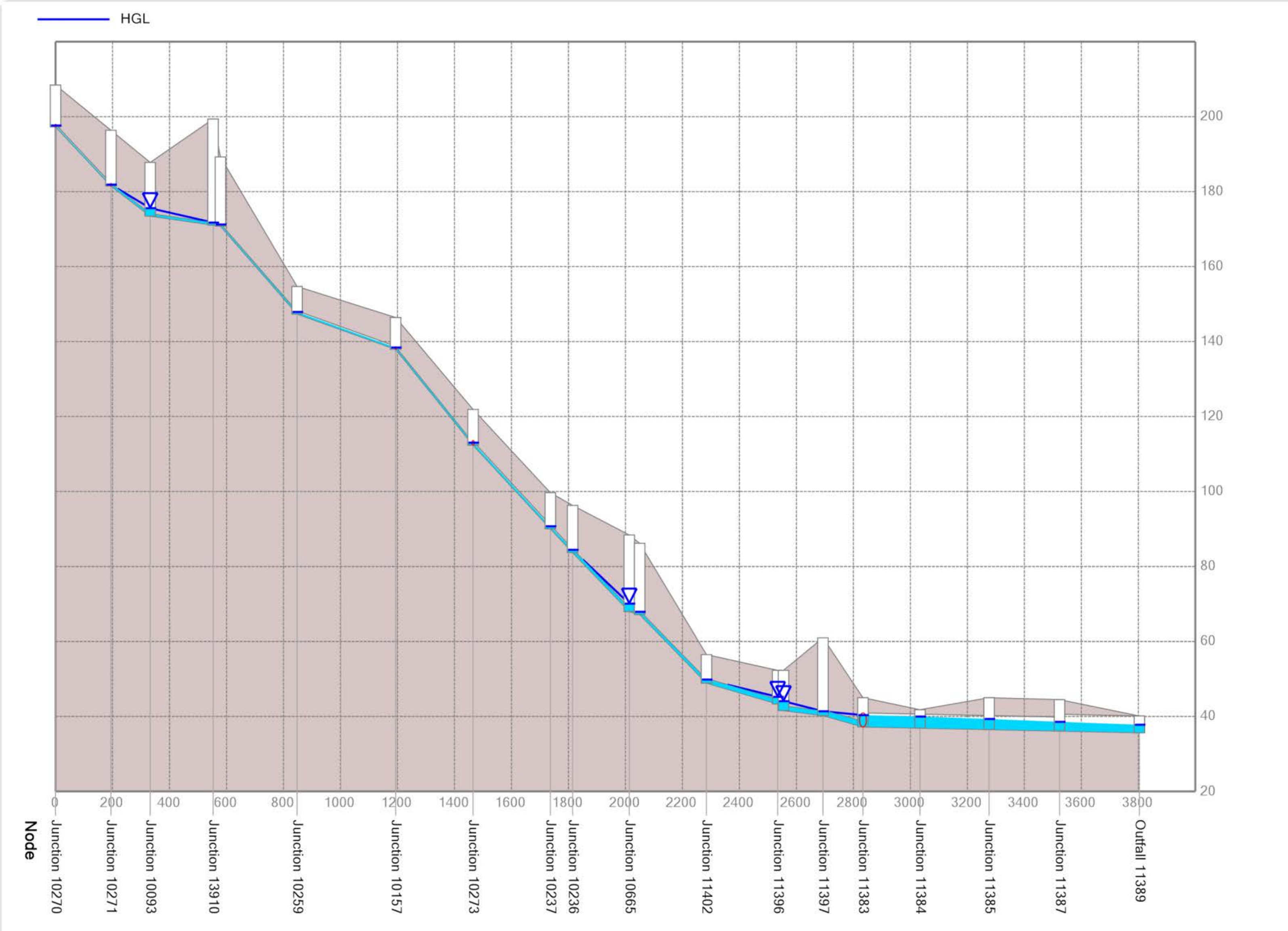



**Figure 21. 12th Street sewer profile (2 of 2), 1- in 10-year storm event, pipes upsized**

### 3.3.4 12th Street Recommendations

Portions of the 12th Street sewer are undersized and currently operating beyond existing capacity, including the 1- in 5-year and 1- in 10-year storm events. The sewers in this area need to be increased in diameter and/or the flows need to be reduced via an I/I abatement program. **Any additional flows introduced into this sewer prior to implementation of the capital improvement recommendations will increase surcharging and increase the potential for flooding and/or basement backups in the area.** The sizing of replacement sewers should be based on the recommendations of the SSMP as determined to convey the future conditions scenario, 1- in 10-year storm event.

## 3.4 13th Street and Division Street

The capacity constraints on 13th Street and Division Street are grouped together in this TM because they are sequential and share some common tributary area. The 13th Street and Division Street projects were identified individually in the SSMP for the purpose of grouping costs into manageable projects.

### 3.4.1 Existing Condition: 1- in 10-year Modeling Results

The 1- in 10-year storm event modeling was performed with the existing conditions scenario (i.e., 2014 conditions). This storm event was modeled first since the 1- in 10-year storm is consistent with the modeling performed for the SSMP.

The model predicted surcharging and flooding for the 1- in 10-year, existing conditions scenario, is shown in Figure 22. Surcharging extends from MH 10173 on 14th Street, upstream to MH 11516 on Division Street. As shown on the profile view on Figure 23, the HGL increases from MH 10172 to MHs 11426 and 11427 where flooding is predicted. The surcharging extends upstream from the flooded manholes to the increase in pipe slope at the pipe segment between MH 11516 and MH 11515.

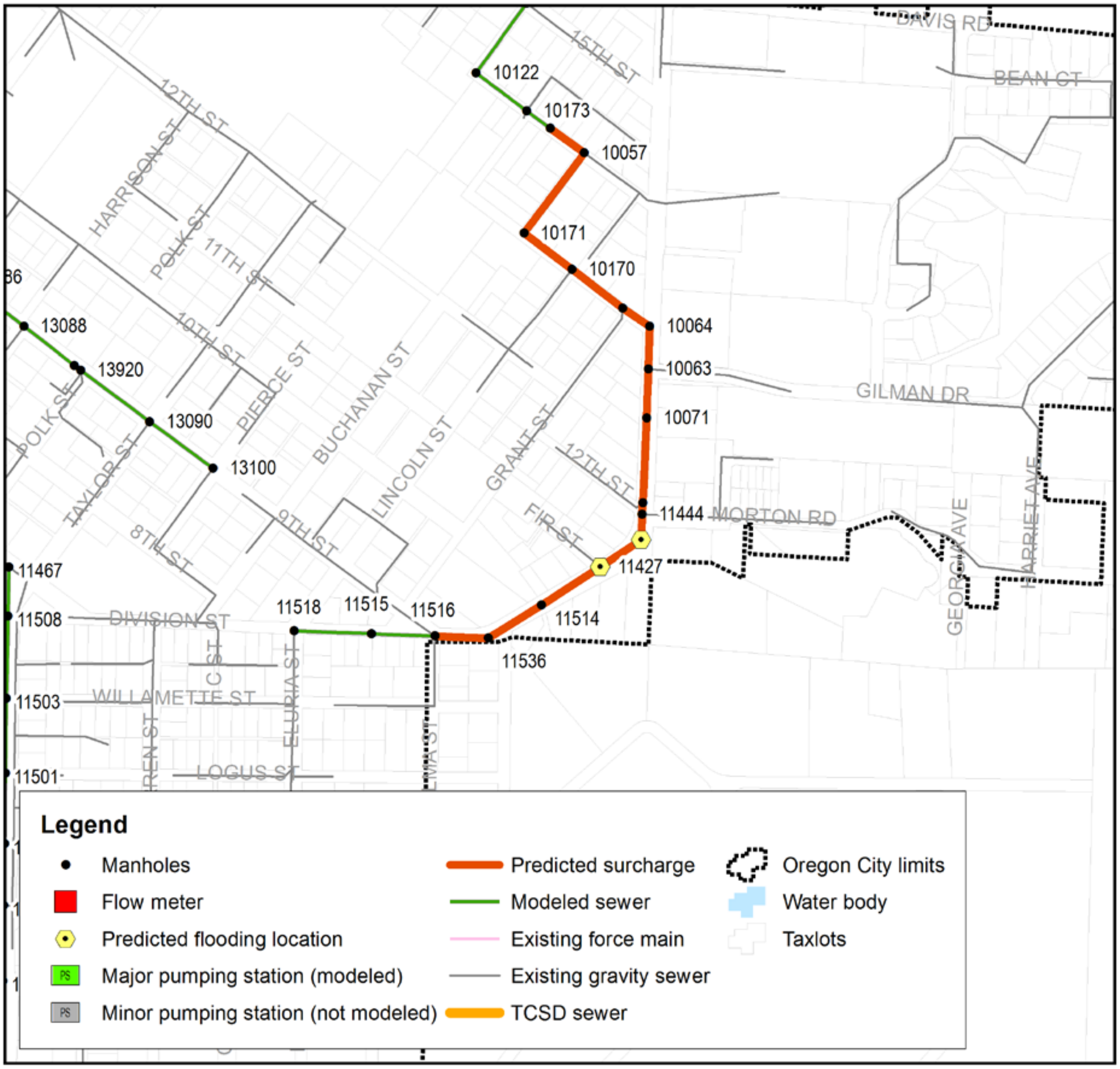



**Figure 22. Surcharging and flooding along 13th Street sewer, 1- in 10-year storm event**

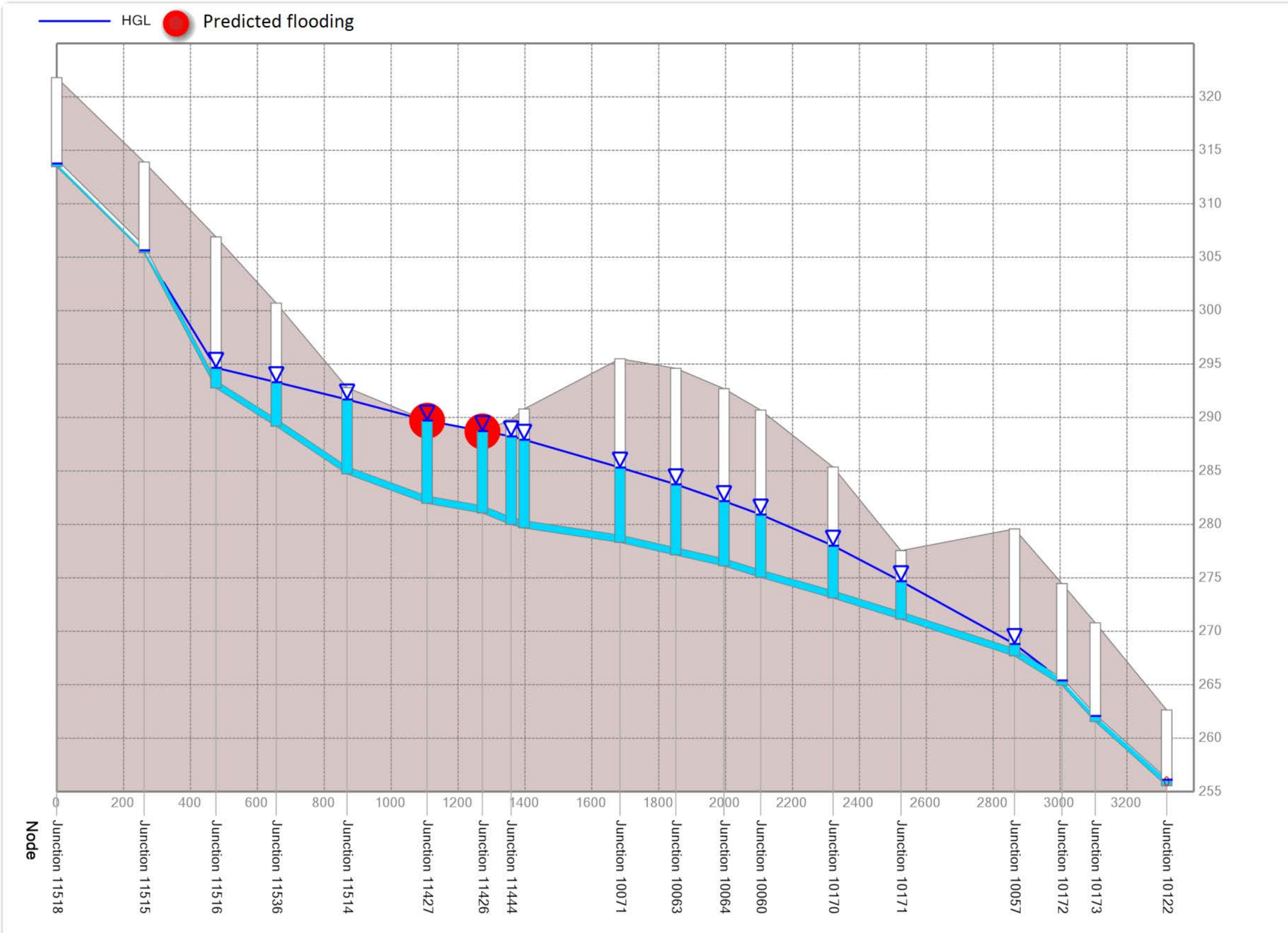



**Figure 23. 13th Street sewer profile, 1- in 10-year storm event**

### 3.4.2 Existing Condition: 1- in 5-year Modeling Results

The 1- in 5-year storm event modeling was performed with the existing conditions scenario (i.e., 2014 conditions). This modeling helps to identify the sewers that will surcharge more frequently than the 1- in 10-year design storm used in the SSMP. As shown in Figure 24, the profile is nearly the same as the 1- in 10-year storm event modeling. The HGL is only slightly lower for the 5-year event than the larger 10-year storm. Surcharging extends over the pipe segments from MH 10057 to MH 11516 and flooding occurs at MH 11427.

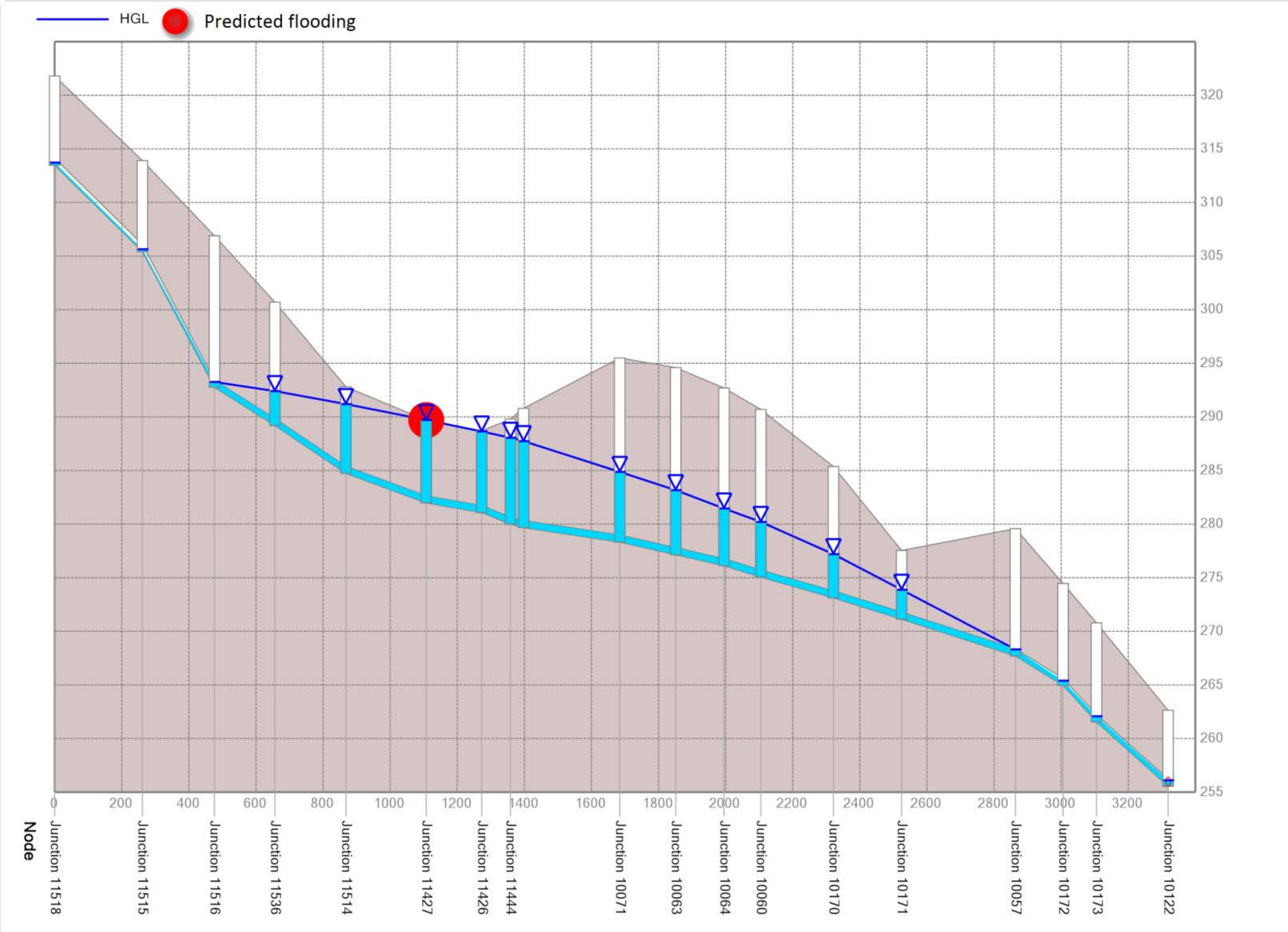



**Figure 24. 13th Street sewer profile, 1- in 5-year storm event**

### 3.4.3 Required Improvements: Existing Condition

Sewers that would need to be replaced to relieve the predicted surcharging and flooding for the existing condition, 1- in 5-year storm event are shown in Figure 25. Please note that not all pipes identified as surcharging need to be replaced since not all surcharging is excessive and the replacement of downstream constraints often reduces the surcharging in upstream sewers.

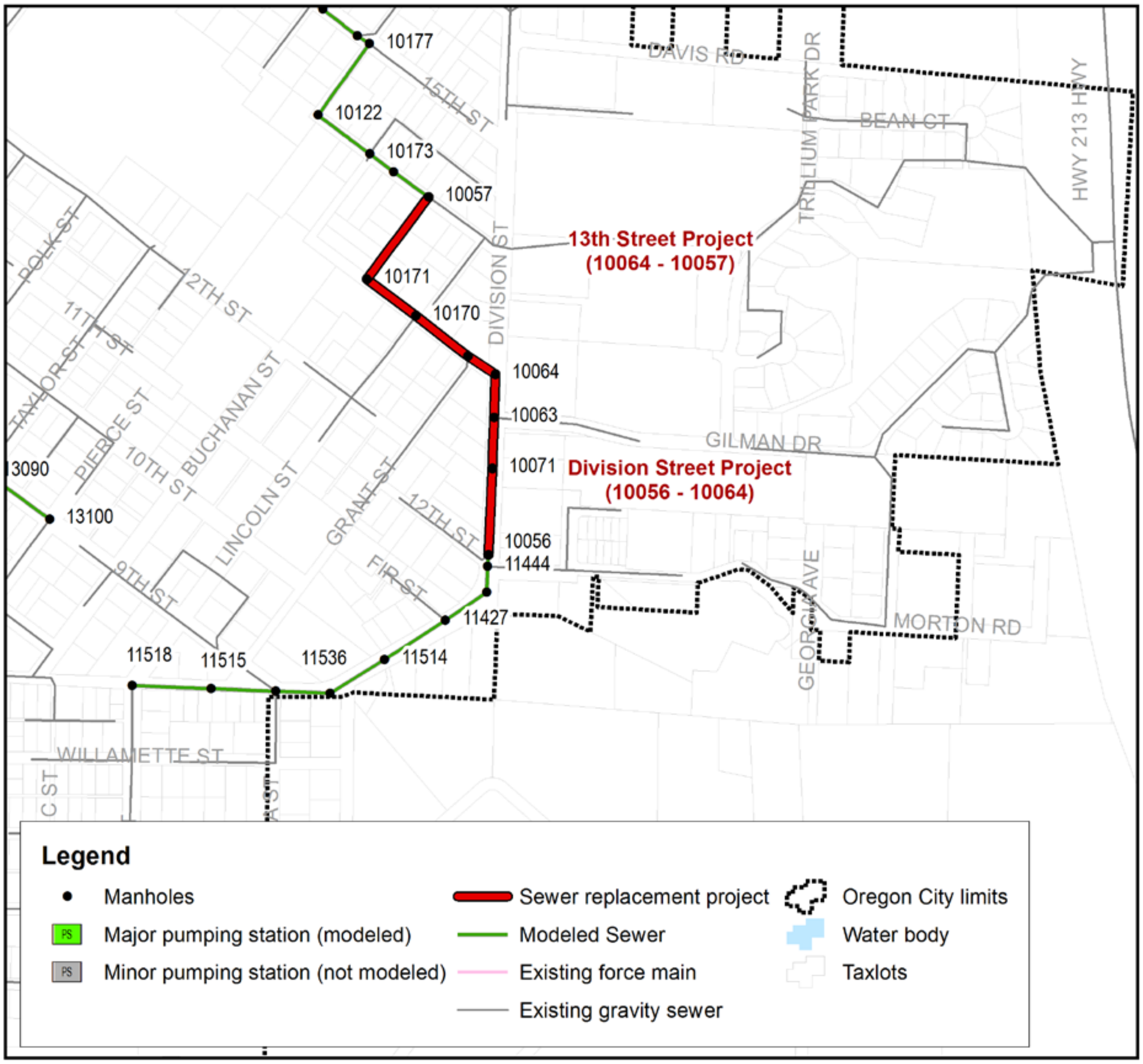



**Figure 25. Required 13th Street and Division Street sewer upgrades, 1- in 5-year storm event**

Costs to upsize the sewers identified in Figure 25 are listed in Table 8. The costs are based on sizing replacement sewers to convey the 1- in 5-year storm event under existing conditions. Actual replacement of any of these pipes will be based on the 10-year storm event modeling for the future condition. Table 8 does not include the benefits of potential I/I reduction measures.

| Table 8. Sewer Upsizing Requirements – 5-year Storm Event, Existing Conditions Scenario | | | | | | |
|---|---|---|---|---|---|---|
| Pipe ID | Owner | Length, feet | Existing pipe diameter, inches | Upsize diameter, inches | Current total cost, $ | SSMP project name |
| 10171_10057 | OC | 339 | 8 | 10 | 126,350 | (2) 13th Street |
| 10170_10171 | OC | 203 | 8 | 10 | 75,618 | (2) 13th Street |
| 10060_10170 | OC | 216 | 8 | 10 | 111,222 | (2) 13th Street |
| 10064_10060 | OC | 110 | 8 | 10 | 74,337 | (2) 13th Street |
| 10063_10064 | OC | 144 | 8 | 10 | 97,388 | (3) Division Street |
| 10071_10063 | OC | 167 | 8 | 10 | 112,880 | (3) Division Street |
| 10056_10071 | OC | 287 | 8 | 10 | 194,127 | (3) Division Street |
| Total all pipe replacements | | | | | 791,920 | |

The costs listed in Table 9 are based on sizing of replacement sewers to convey the 1- in 10-year storm event under the existing conditions scenario. The required pipe sizes do not change from what is required for the 1- in 5-year storm modeling, but the number of sewers that require replacement increases. Upsizing the pipes listed in Table 9 will convey the 1- in 10-year storm with little surcharging and no flooding, as shown in Figure 26.

| Table 9. Sewer Upsizing Requirements – 10-year Storm Event, Existing Conditions Scenario | | | | | | |
|---|---|---|---|---|---|---|
| Pipe ID | Owner | Length, feet | Existing pipe diameter, inches | Upsize diameter, inches | Current total cost, $ | SSMP project name |
| 10057_10172 | OC | 142 | 8 | 10 | 72,918 | (2) 13th Street |
| 10171_10057 | OC | 339 | 8 | 10 | 126,350 | (2) 13th Street |
| 10170_10171 | OC | 203 | 8 | 10 | 75,618 | (2) 13th Street |
| 10060_10170 | OC | 216 | 8 | 10 | 111,222 | (2) 13th Street |
| 10064_10060 | OC | 110 | 8 | 10 | 74,337 | (2) 13th Street |
| 10063_10064 | OC | 144 | 8 | 10 | 97,388 | (3) Division Street |
| 10071_10063 | OC | 167 | 8 | 10 | 112,880 | (3) Division Street |
| 10056_10071 | OC | 287 | 8 | 10 | 194,127 | (3) Division Street |
| 11444_10056 | OC | 38.8 | 8 | 10 | 19,941 | (3) Division Street |
| Total all pipe replacements | | | | | 884,780 | |

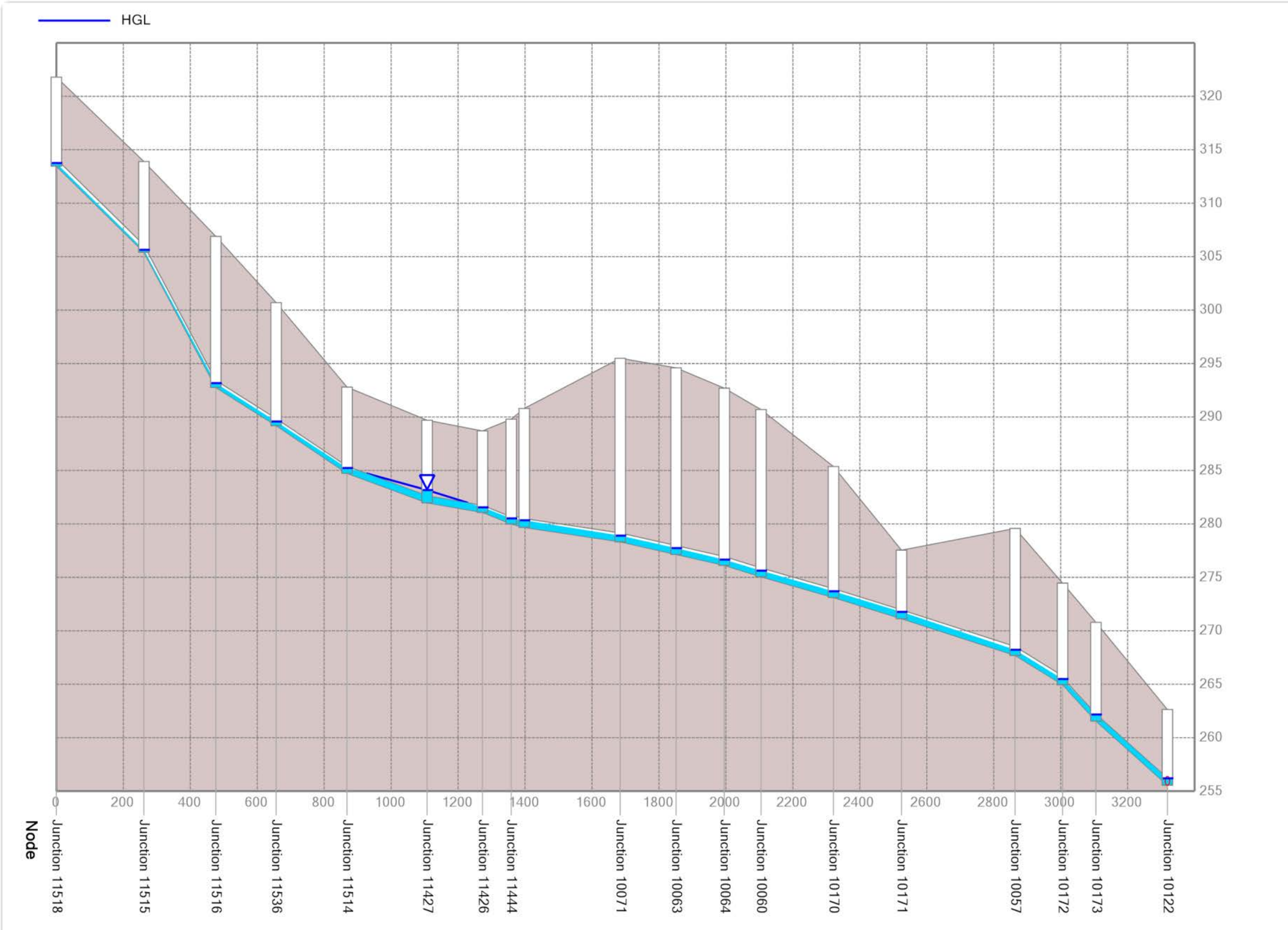



**Figure 26. 13th and Division Street sewer profile, 1- in 10-year storm event, pipes upsized**

### 3.4.4 13th and Division Street Recommendations

Portions of 13$^{th}$ and Division Street sewer are undersized and currently operating beyond existing capacity, including the 1- in 5-year and 1- in 10-year storm events. The sewers in this area need to be increased in diameter and/or the flows need to be reduced via an I/I abatement program. **Any additional flows introduced into this sewer prior to implementation of the capital improvement recommendations will increase surcharging and increase the potential for flooding and/or basement backups in the area.** The sizing of replacement sewers should be based on the recommendations of the SSMP as determined to convey the future conditions scenario, 1- in 10-year storm event.

## 3.5 Holcomb Boulevard

Holcomb Boulevard is located in the northeastern portion of Oregon City, east of Hwy 213 and north of Redland Road. The Holcomb Boulevard sewer evaluated in the SSMP is included in the north zone model and extends from MH 10505 to MH 10458.

The Holcomb Boulevard sewer does not surcharge during the 1-in 10-year storm event, existing conditions scenario. The SSMP provides information on the pipe replacement project required to meet future flow requirements on Holcomb Boulevard. A detailed map of the tributary area to the Holcomb Boulevard sewer is provided in Attachment A.

## 3.6 Settler's Point

The Settler's Point Pumping Station is located at the southern boundary of Oregon City near the intersection of Frontier Parkway and South Meyers Road. The force main extends from the pumping station to the intersection of South Deer Meadows Road and South Meyers Road, where the force main discharges to a gravity sewer conveying flows to the TCSD Hwy 213 interceptor sewer. Capacity constraints at the pumping station and along the force main and gravity sewer are discussed in this section and shown in Figure 27.

### 3.6.1 Settler's Point Pumping Station

The pumping station was originally constructed in 1999 and is challenged with capacity constraints and operations and maintenance issues, as documented in the SSMP. The current pumping capacity is 831 gallons per minute (gpm). Modeled existing flows for the 1-in 5 year storm event are approximately 820 gpm, 1-in 10-year storm event flows are approximately 931 gpm, and projected future flows are predicted to be 1,092 gpm. At a minimum, the pumps should be upgraded at this station to address the frequent maintenance problems and the projected capacity issue.

The existing 8-inch-diameter, 1,210-foot-long force main is slightly undersized to convey the projected future flows and could be upsized to improve energy efficiency at the pumping station. The SSMP did not assume replacement of the force main.

The estimated cost of improvements to the Settler's Point Pumping Station is approximately $300,000 based on information provided by a City consultant, who was engaged to evaluate this pumping station at the time of the writing of the SSMP.

### 3.6.2 Existing Condition: 1- in 10-year Modeling Results

The gravity sewer from MH 12620 at South Deer Meadows Road and South Meyers Road to MH 11784 near the Molalla Avenue and Hwy 213 interchange experiences minimal surcharging in the 1- in 10-year storm event. The surcharging shown between MH 12621 and MH 12620 is the result of model instability where the force main discharges into the gravity sewer and is not presented in the SSMP as a surcharging location. The profile view in Figure 28 shows the HGL along the gravity sewer alignment in the 1-in 10-year storm event.

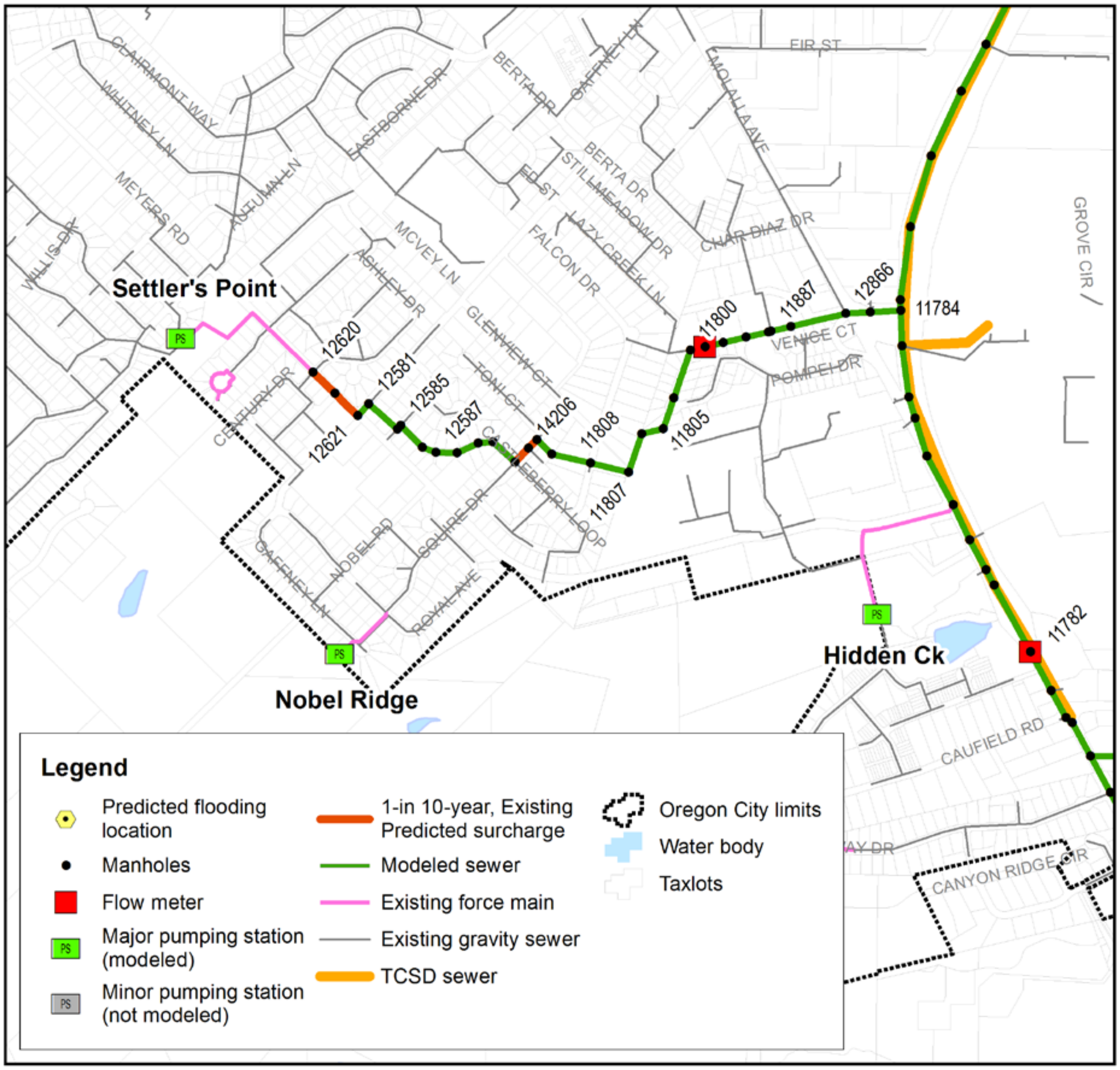



**Figure 27. Surcharging along Settler's Point gravity sewer, 1- in 10-year storm event**

### 3.6.3 Existing Condition: 1- in 5-year Modeling Results

The gravity sewer from MH 12620 at South Deer Meadows Road and South Meyers Road to MH 11784 near the Molalla Avenue and Hwy 213 interchange experiences no surcharging in the 1-in 5-year storm event. The profile view in Figure 29 shows the HGL along the gravity sewer alignment in the 1-in 5-year storm event

### 3.6.4 Settler's Point Recommendations

The Settler's Point Pumping Station meets the demand of the existing conditions 1-in 5-year storm event but is capacity limited in the existing conditions, 1-in 10-year storm event. It is recommended that the City plan for improvements to the pumping station based on recommendations of the SSMP as determined to convey the future conditions scenario, 1-in 10-year storm event, while continuing to monitor the pumping station's capacity in the interim. Surcharging in the manholes upstream of the station should be observed during large storm events to determine the extent of surcharging caused by limitations in the pumping capacity during these events. **Any additional flows introduced to this pumping station prior to implementation of the capital improvement recommendations will increase surcharging in the upstream sewer once the capacity of the pumping station is exceeded and increase the potential for flooding and/or basement backups in the area.**

The gravity sewer downstream of the pumping station has sufficient capacity to convey flows for the existing conditions 1-in 10-year storm event and no immediate recommendations are made for this sewer. However, upsize of the TCSD sewer in Hwy 213 documented in the SSMP does significantly reduce surcharging in this sewer for the future conditions scenario.

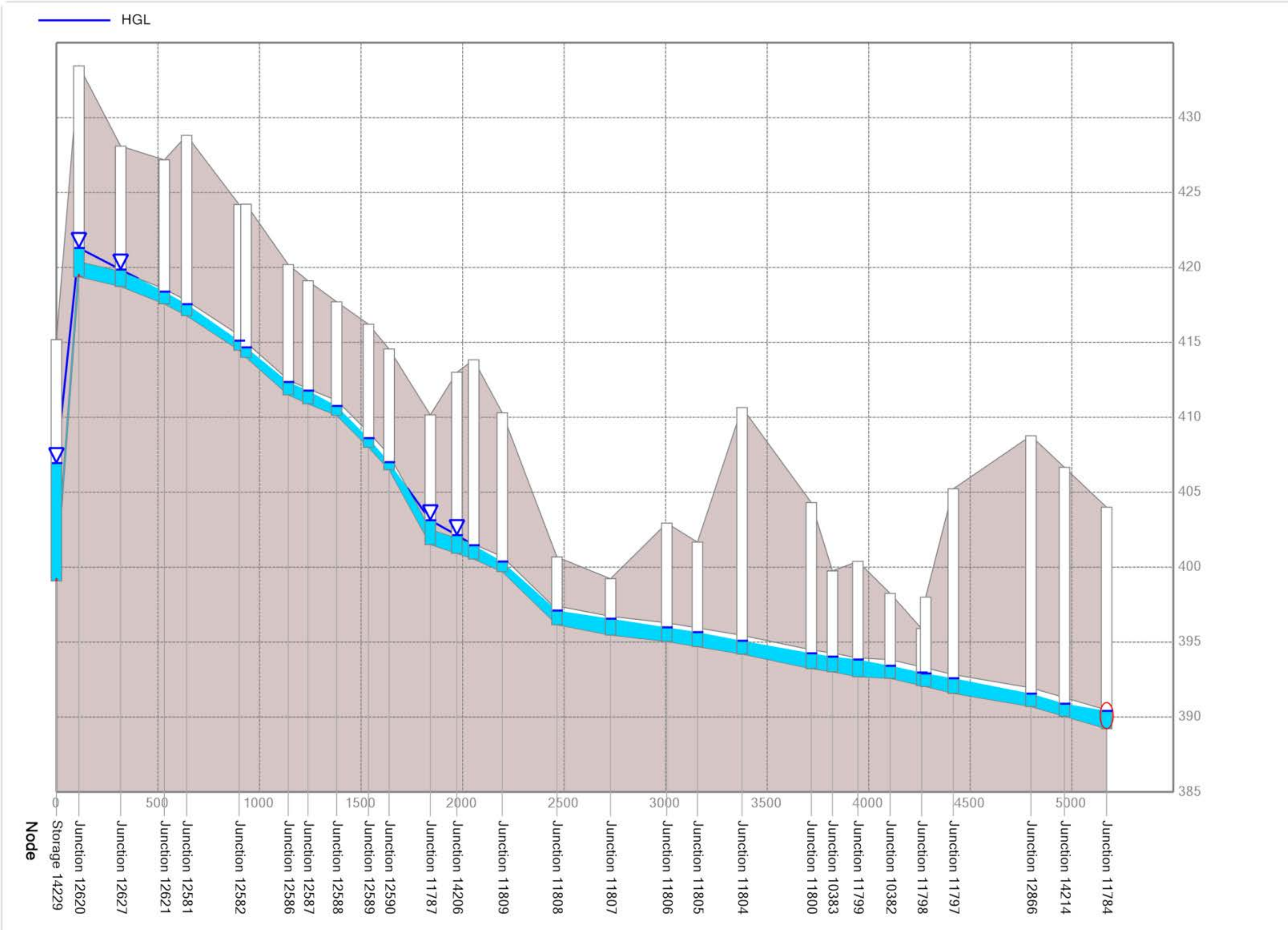



**Figure 28. Settler's Point sewer profile, 1- in 10-year storm event**

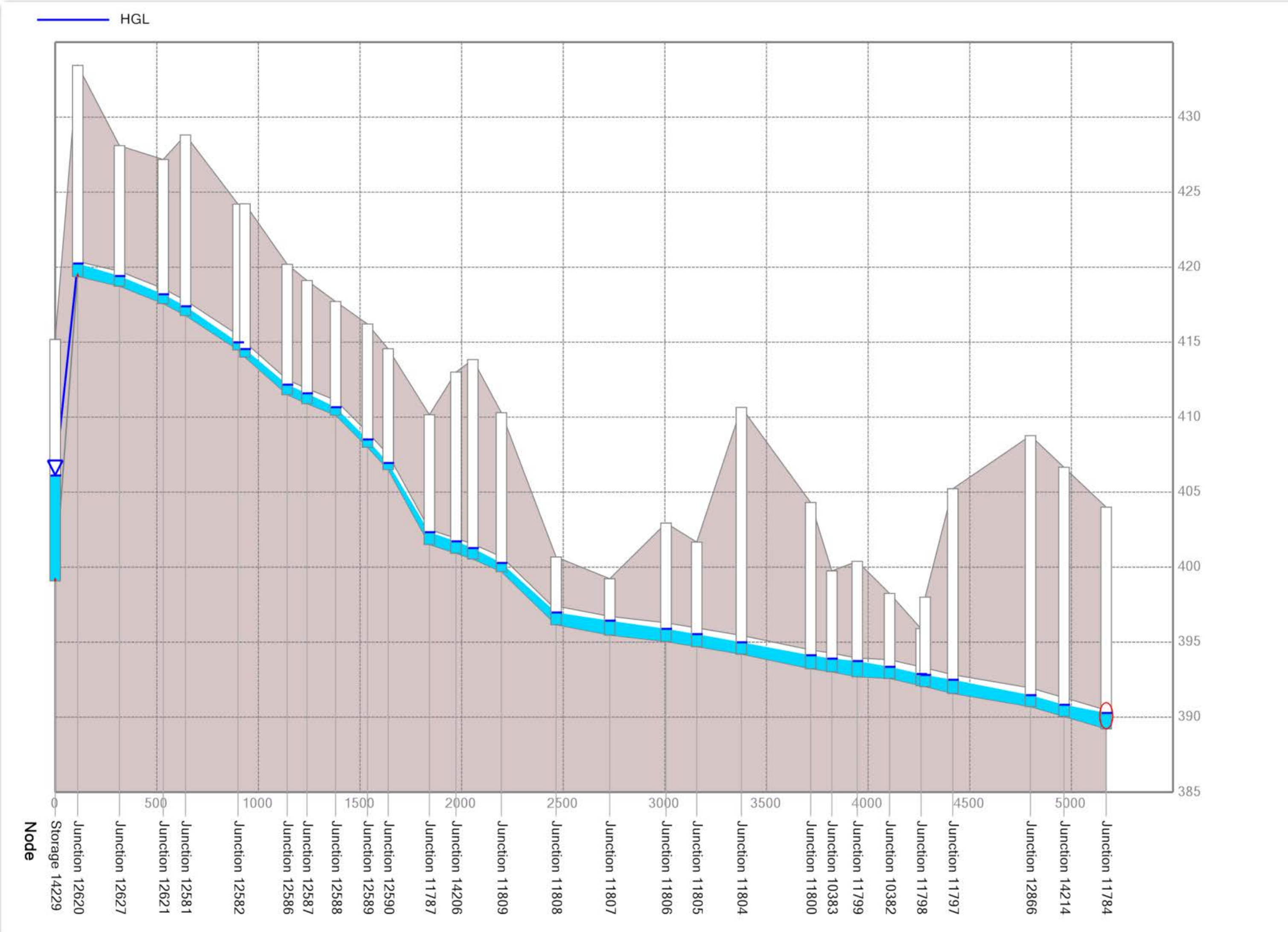



**Figure 29. Settler's Point sewer profile, 1- in 5-year storm event**

# Section 4: Recommendations Summary

The sewers described in Section 3 were reviewed in more detail based on capacity constraints identified in the SSMP. The gravity sewers at Linn Avenue, Hazelwood Avenue, 12th Street, 13th Street, and Division Street are all undersized for existing conditions, including the 1- in 5-year and 1- in 10-year storm events. The Settler's Point Pumping Station is also undersized for existing condition flows. The capacity of sewers and the Settler's Point Pumping Station described in this TM need to be increased and/or the flows need to be reduced via an I/I abatement program to meet existing condition flows. Portions of the Linn Avenue sewer are undersized and currently operating beyond existing capacity. Any additional flows introduced into these sewers and pumping station prior to implementation of the capital improvement recommendations **will increase surcharging and increase the potential for flooding and/or basement backups in the area.** The sizing of replacement sewers should be based on the recommendations of the SSMP as determined to convey the 1- in 10-year storm event under the future conditions scenario.

# Appendix L: City/TCSD Agreements and Amendments

AGREEMENT

THIS AGREEMENT is executed this 18th day of February, 1982, between TRI-CITY SERVICE DISTRICT ("District"), and the City of Oregon City, a municipal corporation of the State of Oregon ("City").

RECITAL:

Tri-City Service District, Clackamas County, Oregon, was organized pursuant to Chapter 451, Oregon Revised Statutes, for the purpose of providing sewerage works, including all facilities necessary for collecting, pumping, treating and disposing of sanitary or storm sewage within the boundaries of the above named City. The District is committed to pursue the regional sewage disposal plan for the area encompassed by City. In furtherance of the foregoing, District is to operate, integrate and administer the existing sewage disposal plants currently in operation by and for City. As part of this agreement by the District to lease existing sewage plants, the parties agree to institute regional sewage rates, and to share the rates collected by each party. The parties agree to make provisions for the transfer of certain employees. This agreement addresses the foregoing.

The parties agree as follows:

Section 1. DEFINITIONS

As used in this agreement, definitions set forth below shall



EXHIBIT "A"

prevail unless expressly stated otherwise:

BOARD: Board of County Commissioners of Clackamas County acting as the governing body of the Tri-City Service District.

CITY: City of Oregon City.

CONNECTION CHARGE: An amount of money charged for connection to or use of the public sanitary sewer system.

COUNTY: Clackamas County, Oregon.

EQUIVALENT DWELLING UNIT (EDU):

Service Charge: A unit, based on water consumption and strength of sewage of a single-family dwelling, by which all users of sanitary sewers are measured.

Connection Charge: A unit, based upon a single-family dwelling unit or its equivalent, as defined in Order No. 80-2273 of the Board of County Commissioners of Clackamas County, acting as the governing body for District, dated October 30, 1980, and as may be subsequently defined by ordinance or rules and regulations adopted by the District.

INDUSTRIAL WASTES: Any liquid, gaseous, radioactive or solid waste substance, or a combination thereof, resulting from any process of industry, manufacturing, trade or business, or from the development or recovery of any natural resources, or as defined by Oregon State Department of Environmental Quality or the United States Environmental Protection Agency.

LOCAL COLLECTION FACILITIES: All sewerage facilities other than major facilities as defined in Exhibit A.

MAJOR FACILITIES: Named in Exhibit A, attached hereto and by reference made a part hereof.

OPERATION AND MAINTENANCE (O&M): The regular performance of work required to assure continued functioning of the sewerage system and corrective measures taken to repair facilities to keep them in operating condition. It may include occasional replacement of defective pipe or parts, but does not include widespread replacement of facilities.

PERMIT: Any written authorization required pursuant to District rules and regulations or any regulation of a City for installation of or connection to any sewerage works.

REIMBURSEMENT PAYMENTS: Regular payments by the District to City for sewerage facilities of City acquired by the District or abandoned facilities owned by City as of or subsequent to the date of this agreement.

SEWAGE: Water-carried human, animal or vegetable waste from residences, buildings, industrial establishments or other places, together with such groundwater infiltration and surface water as may be present. The admixture with sewage of industrial wastes or water shall also be considered "sewage" within the meaning of this definition.

SEWAGE TREATMENT PLANT: Any arrangement of devices, pumps, equipment and structures used by the District for treating sewage.

Section 2. <u>OPERATING PROCEDURES AND RELATIONSHIPS</u>

The intent and purpose of this section is to establish procedures to assure uniformity between all parties in the application of all standards, rules and regulations as may be adopted or amended by the District, from time to time. Notwithstanding any other provision of this agreement, the City agrees to:

A. Adopt and enforce the standards and rules and regulations governing the use of the sanitary sewerage system promulgated by the District.

B. Prepare bills and collect District revenues as prescribed by the District.

C. Forward to the District for review and comment, based upon conformity with District's rules and regulations, any permit application for other than residential use.

D. Not enter into any contract or agreement for sewage service extension outside City's jurisdiction without the express written consent of the District.

E. Forward to the District for review and comment the plans and specifications of the City's sewerage collection system proposed to be constructed.

F. Not construct any new City sewerage facilities or make changes in existing City facilities without first notifying or consulting with the District.

G. Grant the District right of access to any sewerage facilities within the City for the purpose of inspecting such facilities or taking samples for analysis.

H. Take such remedial or corrective action as may be required by the District to maintain District standards.

Section 3. LEASE OF PROPERTIES

With respect to the City's sewage plants currently in operation, the City and District agree that:

A. Effective March 1, 1982, the District shall lease all sewage treatment plants which the City owns, together with the land on which such facilities are situated, and associated laboratory facilities and equipment. From and after the last named date, City will relinquish responsibility for the operation and maintenance of the facilities thus leased. The consideration for this lease is the agreement of District to operate and maintain the sewage treatment plants and the transfer of certain employees from City to District.

B. The City will retain title to its local collection facilities, treatment plants, and land on which such facilities are situated.

C. When a sewage treatment plant is decommissioned, the District shall be responsible for clean up, including, but not limited to, the treatment and final disposal of sludge material in any tanks or lines.

Section 4. ABANDONMENT OF SEWAGE PLANTS BY DISTRICT

At such time as the parties agree, the District agrees to compensate the City for the abadonment of the City's existing sewage treatment plants, as identified on Exhibit A, attached hereto and by reference incorporated herein. For purposes of this agreement, the term "abandonment" shall be defined as the time sewage treatment plants are decommissioned. The amount of compensation shall be based upon investments by the City up to the date of this lease agreement, in accordance with the adopted Sewerage Facilities Plan, Volume 3 - Financing, dated December, 1979, set forth as Exhibit "C" to Board of County Commissioners Order No. 80-323. The parties anticipate that any improvements after the date of this lease agreement shall be made at the cost and expense of the District, but if any improvements are made by the City after the date of this lease agreement, they shall not be taken into account when determining any compensation upon subsequent purchase by the District.

A. No Bonds Assumed: During the period of this lease agreement and after any subsequent abandonment of the City's sewage treatment plants, the City will continue to pay its own local debt service on outstanding bonds.

B. Reimbursement Payments: The parties agree that upon the determination of the amounts due and owing from the District to the City for abandonment of sewage treatment plants or other sewage facilities, the parties shall enter into a plan for annual installments of the debt, plus such interest as is set forth in the adopted facility's plan.

Section 5. TRANSFER OF EMPLOYEES

With respect to the status of present employees of the City engaged in work related to the foregoing sewage treatment plants, the City and the District agree as follows:

A. The following employees, as set forth in Exhibit B, attached hereto and incorporated by reference, shall be transferred to District under the provisions of Oregon Revised Statutes 236.610, et seq. The Board of Commissioners of Clackamas County, acting as the governing body of District, hereby consents to the transfer of these City employees to the District.

The City and the District may each need extra help, from time to time, that might be supplied by the other; in such case, the City or the District, in utilizing services of an employee of the other, shall pay the lending entity, for the time worked, the actual cost and expense, including overhead, of the employee's salary rate currently in effect.

Section 6. FUNCTIONAL RESPONSIBILITY

A. With respect to the administration, operation and maintenance of local collection facilities within the City boundaries and the performance of functions related thereto, the City and the District agree as follows:

1. Processing and review of permit applications, collection and accounting for permit fees, inspection of connections, and all record-keeping attendant thereto: The City will perform each and all of the above functions. The City agrees to adopt standards of materials and construction established by the District and to inspect each connection for conformance therewith.

2. Operation and maintenance of all local collection facilities: The City will continue to operate and maintain all local collection systems within its boundaries or systems outside its boundaries for which it has contracted to provide service, except as the parties may otherwise agree.

3. Billing and collection of sewer service accounts and associated record-keeping, accounting and delinquency follow-up: The City will continue all regular billing, collect monies, adjust complaints, keep records and perform associated accounting and delinquency follow-up. In performing this function, the City agrees to adopt and follow the rules and regulations as may be promulgated by the District. The District may, at any reasonable time, inspect and audit the books of the City, but with respect to this financial and administrative function only.

B. With respect to the administration, operation and maintenance of regional sewerage facilities and the performance of functions related thereto, the City and District agree as follows:

1. Operation and maintenance of treatment plants and associated laboratory facilities: The District will, as a condition of the lease of the sewage treatment plant and associated land and laboratory facilities and sewerage facilities associated therewith, and in consideration thereof, assume full responsibility for their administration, operation and maintenance.

Section 7. SERVICE AND OTHER AGREEMENTS

If City has entered into any service agreement or other agreement with third persons, groups or entities relating to the sewage treatment plants, City agrees to transfer or obtain consent to transfer any and all such agreements to District.

Section 8. APPLICATION, PERMIT AND INSPECTION PROCEDURE

A. The City shall continue responsibility for application, permit and inspection procedures.

B. No person shall connect to any part of the sanitary sewer system without first making an application and securing a permit from the City for such connection, nor may any person substantially increase the flow or alter the character of sewage, without first obtaining an additional permit and paying such charges therefor as may be fixed by the City.

C. Upon approval of the application and payment of all charges, the City will issue a sewer connection permit for the premises covered in the application. The application and permit shall be executed on forms provided by the City and approved by the District.

D. All costs and expenses incident to the installation and connection of any sewer or other work for which a permit has been issued shall be borne by the owner. The owner shall indemnify the City and the District from any loss or damage that may directly or indirectly be occasioned by the work.

Section 9. RATES AND CHARGES FOR SEWERAGE SERVICES.

A. The City will continue to collect and retain permit, plan check, inspection and other associated fees required by the City.

B. A regional connection charge has been authorized by Order No. 80-2273 of the Board of County Commissioners of Clackamas County, sitting as the governing board of the District. The charge will be levied on all property connecting to the regional sewerage system.

1. The charges will be collected by the City and forwarded to the District on the fifth day of each month, and will be One Thousand Dollars ($1,000) per EDU from November 1, 1981, until June 30, 1982, and escalating One

Hundred Dollars ($100) per EDU annually on the first day of July of each succeeding year.

2. The District, in its discretion, may escalate or defer escalation.

C. A service charge will be levied on all sewer users connected to the sewerage system served by the sewage treatment plant.

1. The charge, collected bimonthly by the City, initially will be Six Dollars ($6.00) per EDU, per month.

2. Initially an amount of Two Dollars and Fifty Cents ($2.50) per EDU, per month, will be retained by the City for sewer collection O&M, and the remainder will be forwarded to the District on the 20th day of the next month following the City's billing.

3. The District will review the service charge annually with the City, and may adjust it according to the needs of the City and the District.

Section 10. <u>OTHER PROVISIONS</u>

A. Notwithstanding any other provisions of this agreement, the City and the District agree that:

1. The City and the District will each utilize their offices to support and enforce the standards and provisions of this agreement, and the rules and regulations of the City and the District.

2. Any provision of this agreement declared invalid by a court of competent jurisdiction shall not affect the validity of the remaining provisions.

Section 11. MAINTENANCE AND REPAIR

Citv shall not be responsible for any maintenance or repair of the sewage treatment plant. District agrees to maintain the plant structures, equipment and machinery in good order and condition, reasonable wear and tear excepted. City hereby consents to alterations of the sewage treatment plants, equipment and machinery, as may be determined by the District to be necessary to fulfill its obligations under this lease.

Section 12. INDEMNIFICATION AND LIABILITY INSURANCE

City shall in no event be liable for any accident or injury to property or persons whatsoever occurring in or about the leased sewage treatment plants, and District shall indemnify and hold City harmless from any liability or any claim for any such accident or injury. In any suit or action for damages against City arising out of District's activities or use of said premises, District agrees, at District's own expense and cost, to defend City in such suit or action. District agrees to save the City and hold City harmless from any costs, expenses, liability, claims, and/or judgments that may be asserted against or obtained against the City by reason of the District's activity in or about the premises resulting in any injury to the person or damage to the property of others, and to carry liability insurance for such purposes with limits of not less than those set forth in the Oregon Tort Claims Act. Further, any insurance policies shall contain a protective clause naming City as additional insured.

Section 13. TERMINATION AND DEFAULT

This lease is upon the express condition that if District shall fail to keep and perform at the time and in the manner herein provided any of the terms, covenants and conditions to be performed, time being declared to be of the essence of this agreement, then thirty (30) days after District has received written notice of default as to any provisions hereof, City shall have the right to declare this lease terminated and at an end, and re-enter the premises, or any part thereof, and expel the District without any liability for damage and without any waiver of rights which City might have.

Section 14. NOTICES AND PAYMENT

Any payment or notice to which District shall be entitled under this lease shall be delivered or sent to:

Tri-City Service District
902 Abernethy Road
Oregon City, Oregon 97045

Place of notice for the City shall be at:

City of Oregon City
City Hall
Oregon City, Oregon 97045

The place for notices or payment may be changed by written notice from the party changing its address.

Section 15. <u>LITIGATION COSTS</u>

If any suit, action, or proceeding is brought in connection with any covenant or condition of any portion of this lease, the prevailing party in such suit or action, including any appeal therefrom, shall be entitled to recover from the unsuccessful party such sum as the Court may adjudge reasonable as attorney's fees in said suit or action.

IN WITNESS WHEREOF, the parties have executed this agreement on the date first above written, effective March 1, 1982.

BOARD OF COUNTY COMMISSIONERS
OF CLACKAMAS COUNTY, OREGON

By: Ralph Groener
Chairman

By: [illegible]
Commissioner

By: ______________________
Commissioner

CITY OF OREGON CITY -
A Municipal Corporation of
the State of Oregon

By: Joan M Cartales
Mayor

By: Jean K. McNulty
Recorder

Exhibit A

Description of Sewage Treatment Plant area which is to be leased to Tri-City Service District:

A parcel of land in the Hiram Straight Donation Land Claim No. 42 in Section 30, Township 2 South, Range 2 East of the Willamette Meridian, Clackamas County, Oregon, and more particularly described as follows:

Beginning at a point on the west boundary of the right-of-way of the East Side Super-Highway which point is the northeast corner of Parcel "A" as described in deed from Ostrander Railway and Timber Company to Crown Zellerbach Corporation, a Nevada Corporation, dated November 28, 1945, and recorded in Book 358, Page 61 of the Deed Records of Clackamas County; thence tracing the west boundary of the East Side Super-Highway, south 3° 49' east, 270 feet to a point; thence north 85° 17' west to a point on the realigned westerly right-of-way line of said East Side Super-Highway and the true point of Beginning; thence continuing north 85° 17' west to the easterly right-of-way line of Clackamette Drive as described in Deed 76-14088 recorded in Clackamas County Deed Records; thence northerly and easterly tracing the easterly and southerly right-of-way line of said Clackamette Drive to the westerly right-of-way line, as realigned, of the East Side Super-Highway; thence southerly following the realigned westerly right-of-way line of said East Side Super-Highway to the true point of Beginning.

Excepting that portion which is fenced, enclosing the Fire Department Training Tower and building, which is the paved portion of the northerly portion of the above described property, being approximately 150 feet wide in the east-wes direction and 155 feet in the north-south direction containing approximately 0.5 acres. This portion is to be retained by the City of Oregon City as part of the Sewage Treatment Plant lease described above. The City of Oregon City grants to Clackamas County Tri-City Service District an access across the above Fire Department Training Tower property for sludge removal from the Sewage Treatment Plant.

All located in Section 30, T. 2S., R. 2E., of the W.M. Clackamas County, Oregon.

EXHIBIT "B"

CITY EMPLOYEES TRANSFERRED TO DISTRICT

Robert Hall

Karl Rousett

Ova Cox

Kenneth Miller

Howard Wilcox

Max Klaetsch

Robert Sullivan

ADDENDUM TO AGREEMENT

THIS ADDENDUM TO AGREEMENT ("Addendum") is executed this 18th day of February, 1982, between TRI-CITY SERVICE DISTRICT ("District"), and the Cities of OREGON CITY and GLADSTONE, municipal corporations of the State of Oregon ("City").

RECITAL

The parties to this Addendum and the City of West Linn, municipal corporations of the State of Oregon, have each entered into an Agreement dated the 18th day of February, 1982, wherein the District has agreed to operate, integrate and administer the City of Gladstone's pump station and force main, and the existing sewage disposal plants in operation by and for the Cities of West Linn and Oregon City. In consideration of the assumption by the District of these duties, the parties to this Addendum further agree as follows:

1. The City of Oregon City hereby releases the City of Gladstone from any further responsibility or financial obligation incurred by reason of any agreements wherein Oregon City provided sewage treatment facilities for the City of Gladstone. These parties hereby declare that no further sums of money or other obligations of any kind are owed. Any further obligation for the operation of sewage treatment facilities shall be governed by the Agreement between the District and the Cities.



EXHIBIT "A"

2. The District agrees to assume the maintenance and operation of the sewage pumping station at West Clackamas Road and Barton Street maintained by the City of Gladstone, as part of the District's assumption of existing sewage disposal plants set forth by the Agreement. However, the City of Gladstone agrees to provide all telementry tests that may be required by and according to the rules and regulations now or hereafter adopted by the District.

IN WITNESS WHEREOF, the parties have executed this Addendum to Agreement the date first above written, and which is effective March 1, 1982.

BOARD OF COUNTY COMMISSIONERS
OF CLACKAMAS COUNTY, OREGON

By: Ralph Groener
Chairman

By: [signature]
Commissioner

By: Stan Skoko
Commissioner

CITY OF OREGON CITY -
A Municipal Corporation of
the State of Oregon

By: Joan M. Cartales
Mayor

By: [signature]
Recorder

CITY OF GLADSTONE -
A Municipal Corporation of
the State of Oregon

By: H. Wade Byers, Jr.
Mayor

By: Bernice Marlow
Recorder

AGREEMENT FOR OPERATION OF

SEWAGE COLLECTION SYSTEM PUMP STATIONS

THIS AGREEMENT is executed this 18th day of February, 1982, between CLACKAMAS COUNTY ("County"), and the City of OREGON CITY, a municipal corporation of the State of Oregon ("City").

RECITAL

The City and the Tri-City Service District have entered into certain agreements designed to affect a regional sewage system encompassing the boundaries of Oregon City, West Linn and Gladstone, Oregon. In order to further those agreements, County and City wish to enter into an agreement whereby County will operate the sewage collection system pump station for each City.

In consideration of the covenants set forth below, the parties agree as follows:

1. Definition of "Sewage Collection System Pump Stations": For purposes of this agreement, the term sewage collection system pump stations ("pump stations") shall mean the facilities described in Exhibit "A," attached hereto and incorporated by reference. A pump station is a structure or enclosure containing a mechanical device for lifting sewage from a lower elevation to a higher elevation, and for the purpose of further conveyance.

2. Ownership of Pump Station: During the term of this agreement, the City shall retain title to the moving machinery,



EXHIBIT "A"

equipment, site and works of the pump station, and any building structure and the surrounding grounds.

3. Covenant of County: County agrees to provide labor and to operate and maintain the pump station, in good order and condition, reasonable wear and tear excepted, until this agreement is terminated. For purposes of this agreement, the term operation or maintenance, and labor rendered pursuant thereto, shall mean the regular performance of work required to assure continued functioning of the pump station and corrective measures taken to repair equipment to keep them in operating condition. It may include occasional replacement of defective machinery or parts, but does not include widespread replacement of facilities. In the event alterations to the pump station are necessary for the County to fulfill its obligations under this agreement, County shall submit its recommendations and cost estimates to City for City's approval.

4. Covenant of City: In consideration of County's provision of labor, and operation and maintenance of the pump station, City agrees to pay monthly the actual cost to the County for any materials, labor or other costs incurred by the County. City agrees to pay to County for the time worked the actual costs and expense, including overhead, of the employees' salary rate currently in effect.

On the 10th day of each month, County shall deliver to the City a statement of the actual cost incurred for labor, operation and maintenance of the pump station for the previous thirty (30) days. Said amount shall be due and payable within thirty (30) days. City may inspect the County records relating to costs incurred in the County's operation of the pump station at any reasonable time.

5. Insurance: As further consideration for District's covenants hereunder, City agrees to maintain fire and liability insurance for the entire pump station premises, including the areas under the control of County, and County shall be named as an insured upon all policies. County shall not be liable to the City for any interruption in service or any loss or damage to property or injury to or death of persons occurring on the premises of the pump station or in any manner growing out of or connected with the County's maintenance and operation of the pump station or the condition thereof, whether or not caused by the negligence or fault of the County or its or their respective agents, employees, subtenants, licensees or assigns. This release shall be in effect only so long as the applicable insurance policies of the City contain a clause to the effect that this release shall not affect the right of the City to recover under such policies. Such clauses shall be obtained by the City whenever possible. In the event the City does not provide complete insurance coverage required hereunder so that

County must provide coverage, County will charge City for the cost of such insurance and City agrees to pay such cost.

6. <u>Termination and Default</u>: Each party shall have the unilateral right to terminate this agreement upon written notice to the other party. In the event of default by City in the payment of costs incurred by County, then after thirty (30) days, upon written notice of default, County may terminate the agreement and relinquish control of the pump station to City. If County shall fail to keep and perform at the time and in the manner herein provided, any of the terms, covenants and conditions to be performed, time being declared to be of the essence of this agreement, then thirty (30) days after District has received written notice of default as to any provision hereof, City shall have the right to declare this agreement terminated and at an end and re-enter the premises, and expel District without any liability to damage and without any waiver of rights which City might have. The parties agree that if the County terminates this agreement for reasons other than the City's non-payment of costs incurred, after a reasonable time which allows City to take over and operate the pump station, the County shall relinquish control.

7. <u>Notices and Payment</u>: Any payment of notice to which County shall be entitled under this agreement shall be delivered

or sent to:

Clackamas County Department of
Environmental Services
Utilities Division
902 Abernethy Road
Oregon City, Oregon 97045

Place of notice for the City shall be at:

City of Oregon City
City Hall
Oregon City, Oregon 97045

The place for notices or place of payment may be changed by written notice of the party changing its address.

8. Litigation Costs: If any suit, action or proceeding is brought in connection with any covenant or condition of any portion of this agreement, the prevailing party in such suit or action, including any appeal therefrom, shall be entitled to recover from the unsuccessful party such sum as the Court may adjudge reasonable as attorney's fees in said suit or action.

IN WITNESS WHEREOF, the parties have executed this agreement on the date first above written.

BOARD OF COUNTY COMMISSIONERS
OF CLACKAMAS COUNTY , OREGON

By: Ralph Groener
Chairman

By: 
Commissioner

By: Stan Skoko
Commissioner

CITY OF OREGON CITY -
A Municipal Corporation of
the State of Oregon

By: Joan M Cartales
Mayor

By: Jean K. McNulty
Recorder

# ADDENDUM TO AGREEMENT

This Addendum to Agreement ("Addendum") is effective this first day of July, 1985, by and between TRI-CITY SERVICE DISTRICT ("District") and THE CITY OF OREGON CITY, a Municipal Corporation of the State of Oregon ("City").

RECITAL:

On or about February 18, 1982, these parties entered into an Agreement regarding, inter alia, division of monthly sewer service charges per Equivalent Dwelling Unit ("E.D.U.") levied by the District and collected by City. On or about May 23, 1985, by Order No. 85-519, the Board of County Commissioners of Clackamas County, Oregon, acting as the governing body of District, increased the monthly sewer service charge per E.D.U. to $7.00. The parties have agreed to amend the Agreement as follows:

1. Paragraph 9(c) is amended to read as follows:

"*** (c) A service charge will be levied on all sewer users connected to the sewerage system served by the sewage treatment plant.

"1. The charge, collected bi-monthly by the City, will be $7.00 per E.D.U., per month.

"2. An amount of Three Dollars ($3.00) per E.D.U., per month, will be retained by the City for sewer collection O & M, and the remainder will be forwarded to the District on the 20th day of the next month following the City's billing.



EXHIBIT "A"

"3. The District will review the service charge annually with the City, and may adjust it according to the needs of the City and the District."

2. In all other respects, the Agreement dated February 18, 1982, is in full force and effect.

IN WITNESS WHEREOF, the parties have executed this Addendum to Agreement effective July 1, 1985.

THE CITY OF OREGON CITY, a Municipal Corporation of the State of Oregon

By: Don Andersen
Mayor

By: Jean K. McNulty
Recorder 8-8-85

BOARD OF COUNTY COMMISSIONERS OF CLACKAMAS COUNTY, OREGON

By: Dale Harlan
Chairman

By: ______________________
Commissioner

By: ______________________
Commissioner

ADDENDUM TO AGREEMENT

This Addendum to Agreement ("Addendum") is effective this first day of July, 1986, by and between TRI-CITY SERVICE DISTRICT ("District") and THE CITY OF OREGON CITY, a Municipal Corporation of the State of Oregon ("City").

RECITAL:

On or about February 18, 1982, these parties entered into an Agreement regarding, inter alia, division of monthly sewer service charges per Equivalent Dwelling Unit ("E.D.U.") levied by the District and collected by City. On or about May 22, 1986, by Order No. 86-473, the Board of County Commissioners of Clackamas County, Oregon, acting as the governing body of District, increased the monthly sewer service charge per E.D.U. to $8.00. The parties have agreed to amend the Agreement as follows:

1. Paragraph 9(c) is amended to read as follows:

"*** (c) A service charge will be levied on all sewer users connected to the sewerage system served by the sewage treatment plant.

"1. The charge, collected bi-monthly by the City, will be $8.00 per E.D.U., per month.

"2. An amount of Three Dollars and 25/100 ($3.25) per E.D.U., per month, will be retained by the City for sewer collection O & M, and the remainder will be forwarded to the District on the 20th day of the next month following the City's billing.

"3. The District will review the service charge annually with the City, and may adjust it according to the needs of the City and the District."



EXHIBIT "A"

2. In all other respects, the Agreement dated February 18, 1982, is in full force and effect.

IN WITNESS WHEREOF, the parties have executed this Addendum to Agreement effective July 1, 1986.

THE CITY OF OREGON CITY, a Municipal Corporation of the State of Oregon

By: Don Andersen
Mayor

By: Jean K. McNulty
Recorder

BOARD OF COUNTY COMMISSIONERS OF CLACKAMAS COUNTY, OREGON

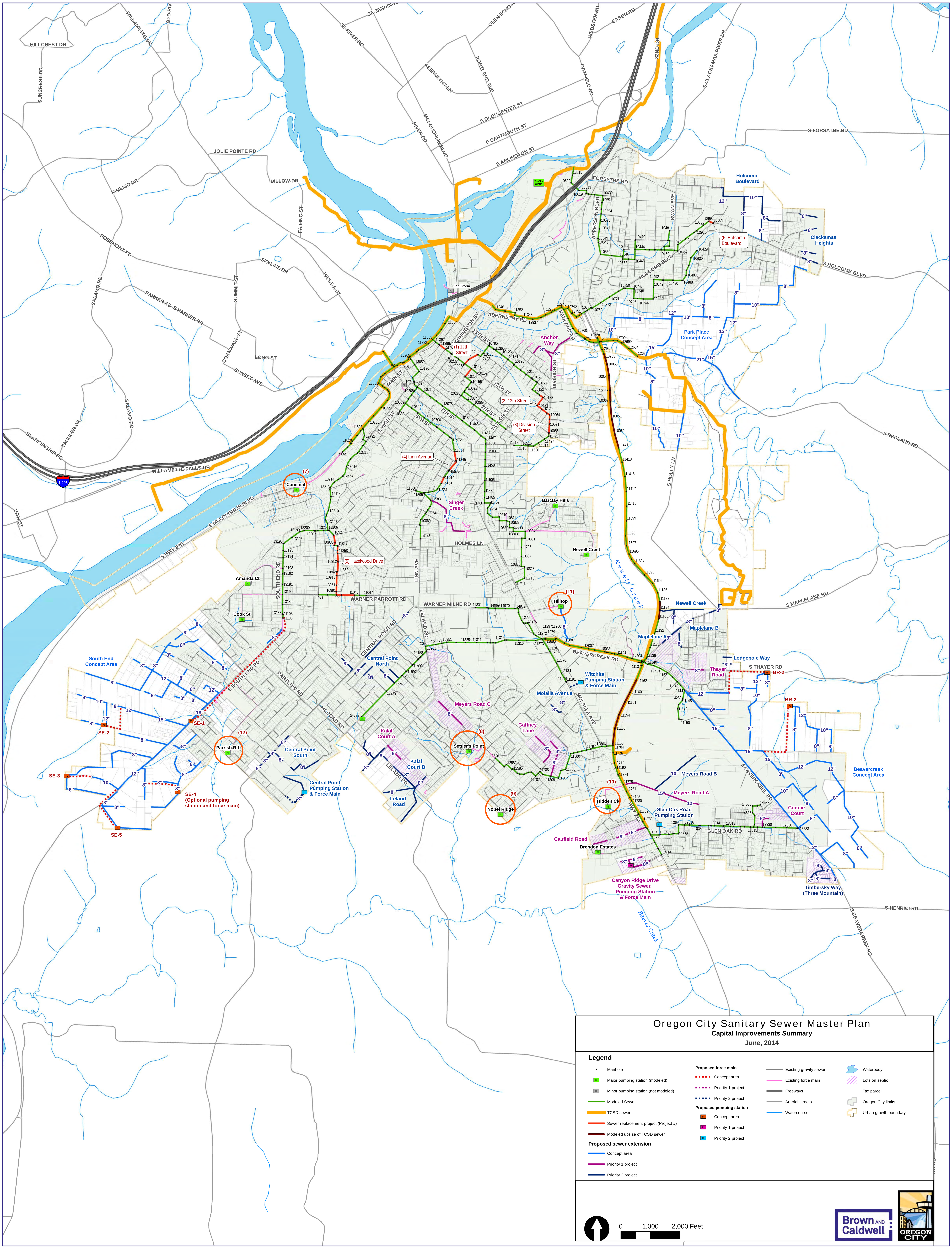
By: ______________________
Chairman

By: Ed Lindquist
Commissioner

By: ______________________
Commissioner



EXHIBIT "A"



Oregon City Sanitary Sewer Master Plan
Capital Improvements Summary
June, 2014
Legend
Manhole
Major pumping station (modeled)
Minor pumping station (not modeled)
Modeled Sewer
TCSD sewer
Sewer replacement project (Project #)
Modeled upsize of TCSD sewer
Proposed sewer extension
Concept area
Priority 1 project
Priority 2 project
Proposed force main
Concept area
Priority 1 project
Priority 2 project
Proposed pumping station
Concept area
Priority 1 project
Priority 2 project
Existing gravity sewer
Existing force main
Freeways
Arterial streets
Watercourse
Waterbody
Lots on septic
Tax parcel
Oregon City limits
Urban growth boundary
0 1,000 2,000 Feet
Brown AND Caldwell
OREGON CITY
Holcomb Boulevard
Clackamas Heights
(6) Holcomb Boulevard
Park Place Concept Area
Anchor Way
(1) 12th Street
(2) 13th Street
(3) Division Street
(4) Linn Avenue
(5) Hazelwood Drive
(7) Canemah
Singer Creek
Barclay Hills
Newell Crest
Amanda Ct
Cook St
(11) Hilltop
Newell Creek
Maplelane A
Maplelane B
Lodgepole Way
Thayer Road
BR-2
Witchita Pumping Station & Force Main
Molalla Avenue
Central Point North
Central Point South
Central Point Pumping Station & Force Main
South End Concept Area
SE-1
SE-2
SE-3
SE-4 (Optional pumping station and force main)
SE-5
(12) Parrish Rd
Kalal Court A
Kalal Court B
Leland Road
Meyers Road C
(8) Settler's Point
Gaffney Lane
(9) Nobel Ridge
(10) Hidden Ck
Meyers Road B
Meyers Road A
Glen Oak Road Pumping Station
Caufield Road
Brendon Estates
Canyon Ridge Drive Gravity Sewer, Pumping Station & Force Main
Connie Court
Beavercreek Concept Area
Timbersky Way (Three Mountain)