Brown AND Caldwell

REPORT | Prepared for
SDIC and City of Troutdale

SDIC

THE CITY OF TROUTDALE OREGON

Drainage Master Plan

November 12, 2020
updated January 2021

North Troutdale and Sandy Drainage Improvement Company Drainage Master Plan

Prepared for

Sandy Drainage Improvement Company and City of Troutdale

November 2020

Updated January 2021

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Note regarding revisions for the January 2021 update of the Drainage Master Plan (DMP):

The update consists of new language on page 6-8 following Table 6-3. The new language more clearly explains the nature of the data provided in Table 6-3; the table format was modified slightly to improve readability. New text summarizing the data results presented in Tables 6-1, 6-2, and 6-3 of this DMP was also added.

The Troutdale City Council incorporated the updated language in its adoption of the DMP in December 2020.

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- Port of Portland
- Multnomah County

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List of Abbreviations

BC	Brown and Caldwell
CCTV	closed-circuit television
CCDD	Columbia Corridor Drainage Districts
CFR	Code of Federal Regulations
CIP	Capital Improvement Program
CLOMR	Conditional Letter of Map Revision
CoT	City of Troutdale
CSZ	Cascadia Subduction Zone
DMP	Drainage Master Plan
FEMA	Federal Emergency Management Agency
FIRMs	Flood Insurance Rate Maps
GIS	geographic information system
GPM	gallons per minute
HDPE	high-density polyethylene
HSG	hydrologic soil group
ID	identifier
IGAs	intergovernmental agreements
LF	linear foot/feet
LOMR	Letter of Map Revision
MCDD	Multnomah County Drainage District No.1
MS4	Municipal Separate Storm Sewer System
NASSCO	National Association of Sewer Service Companies
NAVD88	North American Vertical Datum of 1988
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
ODOT	Oregon Department of Transportation
ORS	Oregon Revised Statues
PACP	Pipeline Assessment Certification Program
PEN1	Peninsula Drainage District No. 1
PEN2	Peninsula Drainage District No. 2
PSWMM	Portland Stormwater Management Manual (2016)
PVC	polyvinyl chloride
SCADA	Supervisory Control and Data Acquisition
SCS	Soil and Conservation Service
SDC	System Development Charge
SDIC	Sandy Drainage Improvement Company
TRIP	Troutdale Industrial Park
UIC	underground injection controls
USACE	United States. Army Corps of Engineers
WQ	stormwater quality

Executive Summary

The Sandy Drainage Improvement Company (SDIC) and the City of Troutdale (CoT) (referred to collectively as "the Stakeholders" as needed) are developing a Drainage Master Plan (DMP) that provides a clear understanding of the existing internal drainage system and an outline of improvements to address both existing and future needs. The internal drainage system includes the conveyance network and pump station, inside the levee system and upland areas outside the floodplain, that move surface water through and out of the SDIC and CoT into the Columbia River.

The Multnomah County Drainage District (MCDD), who administers the SDIC, has an adopted mission to enhance community safety and support the region's vitality. The MCDD reduces flood risk by maintaining a levee system, managing drainage, and responding to emergencies. This DMP addresses operations and flood management capacity for the pump station and conveyance system infrastructure within the CoT and SDIC area. This DMP contains the following goals:

- Systematically investigate the current condition, along with existing and future projected capacity of the conveyance network and pump stations.
- Evaluate alternative solutions to address drainage problem areas.
- Identify capital investments to address internal drainage issues and present conceptual project solutions to be considered in the Stakeholders' Capital Improvement Plan process.
- Recommend operations and maintenance adjustments to reduce risk of failure of pump stations and other conveyance features.
- Maintain and improve water quality across the study area.

This DMP provides recommendations that support the region's economic, environmental, and community needs.

Study Area Overview

The study area for this DMP includes all areas that drain by gravity to the Sandy Pump Station, including Arata and Salmon Creek and areas west of NE 223rd Ave. These areas are primarily composed of North Troutdale and SDIC, with some contributing area within unincorporated Multnomah County and the cities of Fairview and Wood Village. The study area is bounded to the North by a federally authorized levee, which separates the internal drainage area from the Columbia and Sandy rivers. The southern edge of the study area reaches southward into North Troutdale and Wood Village and include tributary areas to Arata and Salmon creeks.

Several developed sites, in the southwest of the study area, drain to the north under the Union Pacific railroad. Blue Lake, while outside SDIC boundary, is hydraulically connected to SDIC by a cross-levee culvert. The eastern boundary of the study area is delineated by the levee system and drainage infrastructure in NW 257th Avenue[1] operated by Cot and Multnomah County. Poor draining soil conditions and high seasonal groundwater render stormwater infiltration systems ineffective for most sites in the study area, and as a result most stormwater runoff generated in the basin is discharged to the public collection and conveyance systems. The movement of surface water and piped conveyance through the study area is primarily driven by gravity, although some infrastructure

[1] At the time of publication, the north-south segment of NW Graham Road is undergoing a name change to NW 257th Avenue. References to NW 257th Avenue include area associated with the former north-south segment of Graham Road.

at lower elevations is affected by backwater conditions from the Sandy Pump Station. All water within the study area is pumped out to the Columbia River via the Sandy Pump Station. Drainage infrastructure owned and operated by the Oregon Department of Transportation (ODOT) bisects the study area with some draining to the Sandy River and other conveying drainage from south to north.

The project study area includes the Troutdale Airport, the Troutdale-Reynolds Industrial Park (TRIP), Blue Lake, Blue Lake Park, and residential and industrial/commercial developments to the South of Interstate 84. A map showing the extents of the study area is included in Figures 1 and 2, Appendix A.

Because the study area encompasses areas within the SDIC and CoT, the Stakeholders have agreed to a collaborative and integrated approach to analyzing stormwater and drainage issues, to better meet the needs of the two entities, citizens, property owners, and partner agencies.

Ownership and maintenance responsibilities of drainage infrastructure segments within the study area are, in some cases, unclear. It should be noted that establishing ownership and maintenance responsibilities in such cases was not a function of this study, was not incorporated into the study, nor is it an outcome of this study.

This DMP concentrates primarily on a defined critical conveyance network, where the SDIC focuses its operations, and less on the other drainage elements maintained by CoT. The city's drainage systems within the study area are primarily localized to serve city roadways and adjoining development, and these city systems discharge to the critical conveyance network. A significant portion of the SDIC's operational activities and capital project expenditures for the critical conveyance network are focused on the removal of debris and blockages that impede the movement of water through open channels and pump stations. A map of the SDIC-defined critical conveyance network is included in Figure 4, Appendix A.

Background and Stakeholders

The conveyance of surface water through the study area is important to protect the economic health of the region. The four drainage districts, PEN1, PEN2, MCDD and SDIC, along the Columbia River provide $16 billion of annual economic activity and $7.3 billion in assessed property value. The levees associated with these four drainage districts reduce flood risk from the Columbia River, and the internal drainage network and pump stations move surface water through the District to protect public and private property from flooding during and after storm events.

This DMP provides a detailed plan of projects, programs, and further areas of study to operate an internal drainage system and efficiently move surface water through SDIC and CoT. It is likely that the Stakeholders will need to secure additional funding to adequately manage the drainage system. Costs are rising, flows are increasing, and the drainage system is deteriorating with age and use. The Stakeholders will need to be proactive in maintaining and replacing aging infrastructure, including the pump station and the conveyance network consisting of pipes, culverts, and open channels. The Stakeholders also need additional planning to address emergency response and system redundancy as the region experiences increased uncertainty and potential risks related to a changing climate and predicted seismic events.

The Stakeholders are heavily reliant on partner agencies (e.g., City of Fairview, ODOT, the Port of Portland, and Multnomah County) and private landowners for management and maintenance of the conveyance infrastructure. Many of the projects proposed in this DMP will require joint attention to fund and construct the required upgrades. Resources are limited, and the Stakeholders are working to establish formal agreements with partner agencies and landowners, related to conveyance system maintenance and rehabilitation responsibility.

The Stakeholders also need a mitigation strategy to offset the cost incurred as development expands across the study area and in upstream contributing areas, leading to increased flows. Increased flows from developing areas impact the conveyance and pump station infrastructure and has an incremental impact on the Sandy pump station, but the sum of all potential development is likely to require pump station and conveyance system upgrades. It is challenging to identify a “tipping point” project that is solely responsible for a pump station improvement, so the incremental impacts and resulting costs should be distributed among all who develop within the contributing area. The Stakeholders must continue development review activities to evaluate any new drainage infrastructure and investigate a mitigation strategy to recoup the costs associated with impacts that accumulate from development over time.

DMP Process

Figure ES-1 illustrates the master planning process, used for this study and previous studies for MCDD and PEN2, including the development of criteria used to evaluate the conveyance system and the pump station within the study area. The criteria address the condition and the capacity of the existing systems and set guidelines for design of capital projects.

Technical analyses and investigations were conducted to develop an understanding of the basin including water quality retrofit opportunities and, the overall drainage system, including the conveyance system and pump station that move water through and out of the SDIC and CoT. The primary technical analyses to support this DMP are discussed in Sections 4 through 7 and include:

- A pump station condition evaluation, including development of condition ratings for mechanical, electrical, communications, piping, and structural systems at the Sandy pump station.
- A conveyance system condition evaluation, including evaluation of age, material, and known defects of the pipes and culverts that form the primary *drainage* pathways through the study area.

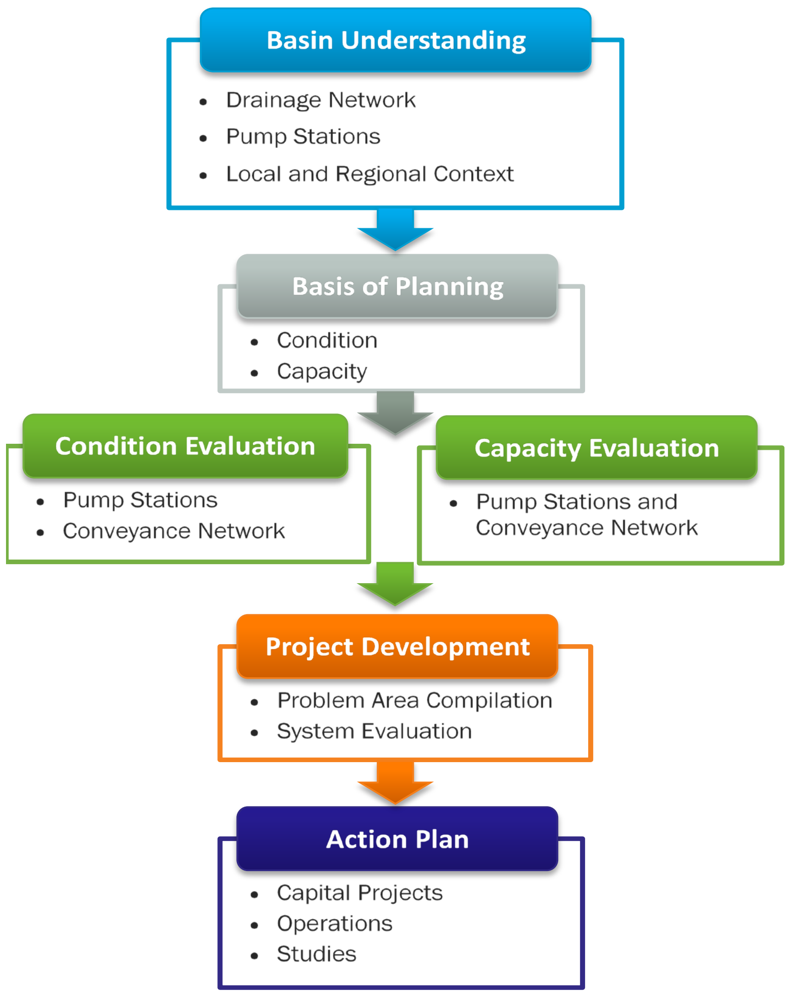

Figure ES-1. DMP process

- A pump and conveyance system capacity analysis, including updating the existing XP-SWMM hydrologic and hydraulic model for the study area to simulate the drainage network under current conditions and predict how the system might function in the future.
- A water quality retrofit assessment to assist the City in complying with their NPDES permit. The CoT's current NPDES Municipal Separate Storm Sewer System (MS4) Phase II General Permit outlines stormwater requirements to reduce the discharge of pollutants to waters of the state to the maximum extent practical, to protect water quality, and satisfy the appropriate water quality requirement of the Clean Water Act.

The technical analyses were primarily completed in 2019 and 2020. Following the technical analyses, the project team compiled problem areas, evaluated potential project solutions, and developed an action plan of capital projects, operational adjustments, programs, and future studies.

The master planning process also included public outreach through surveys to landowners, SDIC and CoT staff, coordination with partner agencies (Port of Portland, Multnomah County, and ODOT), and presentations to the SDIC Board and CoT Council members for input and direction.

Recommended Actions

This DMP considers an integrated approach to managing the conveyance and pump station systems throughout the SDIC and larger North Troutdale Basin. The recommended actions provide a long-term strategy to manage the storage and movement of water. Based on the technical analyses it is recommended that the Stakeholders:

- Replace or rehabilitate failing or undersized conveyance infrastructure in the critical conveyance network.
- Plan for capacity increases at the Sandy Pump Station.
- Plan for redundancy improvements at the Sandy Pump Station.
- Address structural and mechanical deficiencies at the Sandy Pump Station.
- Improve debris management (e.g., debris barriers and trash rakes)
- Actively manage sediment and erosion issues.
- Continue to leverage and develop new intergovernmental agreements to encourage cooperation between jurisdictions to manage contributing stormwater, sediment, and pollutant loads within the study area.

Table ES-1 below summarizes the capital projects that are recommended for the Stakeholders. Project locations are shown in Figure 3, Appendix A. These are the actions that will help enable the Stakeholders to operate an internal drainage system that efficiently moves surface water and provides flood protection during peak storm events.

Table ES-1. Recommended Capital Projects					
Time Frame (years)	CIP Number	CIP ID (Problem area ID)	Project	Location	Preliminary Cost Estimate
1-5	1	C-1A	Pump Station (Structural/Operational)	Sandy Pump Station	$182,000
1-5	2	C-1B	Pump Station Outfall (Pipes/Infrastructure)	Sandy Pump Station	$904,000
5-10	3	C-1C	Pump Station Capacity (Replacement)	Sandy Pump Station	$13,200,000
1-5	4a	C-2A	Salmon Creek Marine Dr. Culvert (Condition Assessment)	Salmon Creek at Marine Dr. and NE 223rd Ave.	$15,000
5-10[a]	4b	C-2B	Salmon Creek Marine Dr. Culvert (Replacement)	Salmon Creek at Marine Dr. and NE 223rd Ave.	$4,039,000
5-10	5	I-1	Arata Creek Culverts (Knapheide/Airport)	Arata Creek at 2500 Marine Drive and west of Troutdale Airport Runway	$687,000
5-10	6	E-3	Arata Creek Culverts and Bank Stabilization Along Marine Dr.	Arata Creek along Marine Dr. by I-84 Corporate Center	$2,329,000
1-5	7	F-9	Columbia River Hwy.	Underpass of Columbia River Hwy. at Union Pacific RR	$1,331,000
10-20	8a	I-2A	Gate Tower Decommission	Gate tower, culvert through levee	$1,866,000
10-20	8b	I-2B	Gate Tower and Culvert Replacement	Gate tower, culvert through levee	$2,754,000
5-10	9	C-7	Arata Creek Culverts (Sundial Rd./ Rogers Cir.)	Arata Creek at Sundial Road and Rogers Cir.	$1,450,000
1-5	10	F-12	Dunbar Avenue Feasibility Study	Dunbar Avenue neighborhood	$50,000

a. Timing dependents somewhat on completion of CIP 4a and results of condition assessment.

Table ES-2 summarizes the program recommendations for the Stakeholders. These are the operational actions with an annual funding need to be implemented by the Stakeholders to track the condition of the conveyance system, perform preventative maintenance on pump stations, prepare for emergencies, and plan for future replacements before systems reach failure conditions. Detailed information about these programs and studies is provided in Sections 8 and 9 of this DMP.

Table ES-2. Recommended Programs

Ongoing Programs			
Program	Total Cost	Timeline	Cost Estimate (annual)
Open Channel Sediment Control Program	$50,000	5 years	$10,000
SDIC-CCTV Inspection and Condition Assessment Program	$286,000	5 years[a]	$82,200
Troutdale-CCTV Inspection and Condition Assessment Program	$543,000	5 years[a]	$133,600
Flow Control Requirements Evaluation	$10,000	NA	NA
Pump Station Testing and Monitoring	$4,800	Annually	$4,800
Pump Station Maintenance Program	$8,100	Annually	$8,100
Pump Station Structural Program	$10,000	Annually	$10,000
District-Wide Debris Barrier Program	$1,195,000	10 years	$119,500
Portable Generator Acquisition Program	$427,000	10-year timeline to acquire all generators– Potentially shared by four districts	$42,700
Water Quality Retrofit Program	$50,000	Annually	$50,000
Operations and Maintenance Collaboration[b]	NA	NA	NA
Design Review and Permitting Coordination[b,c]	NA	NA	NA
System Reinvestment and Rehabilitation Program	NA	NA	NA

a. *Complete initial inspection in 5 years then repeat every 10 years.*

b. *Project costs are assumed to be incorporated into normal operation costs and staff time.*

c. *The City of Troutdale currently has a system reinvestment and rehabilitation program in place based on annual asset depreciation.*

An important next step for the Stakeholders will be to establish plans for funding projects and programs. Current funding may support some or portions of the programs listed in Table ES-2.

Section 1

Background/Overview

The Sandy Drainage Improvement Company (SDIC) and City of Troutdale (CoT) (hereafter referred to collectively as "the Stakeholders") developed this joint North Troutdale and Sandy Drainage Improvement Company Drainage Master Plan (DMP) that provides a clear understanding of the existing internal drainage system and an outline of improvements to address both existing and future needs. The internal drainage system includes the conveyance network and a pump station (Sandy Pump Station) that collects and moves surface water through and out of the study area to the Columbia River. The overlap of jurisdiction within this area between the CoT and SDIC is significant, see Figure 1, Appendix A, for a map. Coordination between the two agencies is critical to successful management of assets and provision of services. This DMP addresses operations and flood management capacity for the pump station and conveyance system infrastructure under the Stakeholders' management that contributes to the Sandy Pump Station.

The Stakeholders are striving to enhance community safety and support the region's vitality. The Stakeholders reduce flood risk within the study area by maintaining a levee system, managing drainage infrastructure, and responding to emergencies. This DMP is focused on the internal drainage system with the following goals:

- Systematically investigate the current condition of the conveyance system and pump station as well as the existing and future projected capacity.
- Evaluate alternative solutions to address drainage problem areas.
- Identify capital investments to address internal drainage issues and present conceptual project solutions to be considered in the Stakeholders' Capital Improvement Programs.
- Recommend operations and maintenance adjustments to reduce risk of failure of the pump station and conveyance features.
- Provide water quality retrofit analysis and project recommendations.

The landscape of the SDIC and North Troutdale Basin has evolved substantially in the last century. Flood-risk management infrastructure is aging with time and use. Other factors such as increasing flows due to development, a changing climate, and rising costs to maintain, repair and replace infrastructure are straining existing resources. This DMP provides an action plan of projects, programs, and further areas of study to operate an internal drainage system and efficiently move surface water through and out of the Stakeholders' management areas.

1.1 History

Figure 1-1. The Stakeholders work with partner agencies to manage the drainage system.

Prior to the formation of SDIC and the construction of the levee system, much of the study area was Columbia River floodplain. It contained a natural system of stream channels, lakes, and wetlands that flooded annually. For hundreds of years, Native Americans relied on the floodplain for trade, travel, and seasonal food-gathering. The Lower Chinookan tribes (Clackamas, Multnomah, and Cascades) used the area to hunt, fish, and gather for food and weaving. They seasonally camped on the riverbank and traveled on trails between the Willamette and Columbia Rivers through the shallow waters of the floodplain.

In 1902, Congress passed the federal Reclamation Act, authorizing the government to aid with the development of irrigation projects for agricultural purposes. In 1910, C. F. Swigert and H. C. Campbell, principal owners of the Sundial Ranch at the mouth of Sandy River, began some experiments looking toward diking their lands. To protect the land from annual flooding, in 1917 farmers and other locals in the area began building embankments and established four drainage districts along the South Shore of the Columbia River: Peninsula Drainage Districts Nos. 1 and 2, (PEN1 and PEN2), the Multnomah County Drainage District No. 1 (MCDD), and the Sandy Drainage Improvement Company (SDIC). SDIC continued to reclaim all the land between Fairview and the Sandy River, by constructing embankments that were built to protect 1,530 acres of farmland from the flood level equivalent to the 1876 flood event.

The 1936 Flood Control Act made the U.S. Army Corps of Engineers (USACE) the primary federal agency responsible for flood control regulations and standards which included levee standards. After 1936, at different points in time, the USACE built out and improved the region’s levee system. In 1940 and 1941, the USACE reconstructed a majority of the existing levee and constructed about 1.2 miles (6,340 feet) of new levee, a pump house, and a tide box. The existing pump and an additional pump were installed in the new pump house. In 1953 and 1954, the SDIC strengthened the existing levee on the landward side and installed Type 2 toe drains along the levee at various locations.

Today, the SDIC levee crest widths vary between 8—22 feet and the upstream elevation is 48.1 feet (NAVD88) and downstream is 47.3 feet. The leveed area within the SDIC boundaries expanded over time to include approximately 1,556 acres of industrial, commercial, and undeveloped public and private properties located within the cities of Fairview and Troutdale in mid-Multnomah County, Oregon.

Figure 1-2. Flooding in Portland during 1948 historic event

Since their formation, the drainage districts have experienced four "100-year events" and one "500—year event." Historic events were recorded in May 1948, June 1956, December 1964, and February 1996. These events generally occur when heavy precipitation combines with thawing snowpack in the upper watershed, raising water levels across the region. The May 1948 event resulted in levee/embankment breaches in PEN1, PEN2, and MCDD. The Districts' systems performed well in the other recorded historic events. Although these events primarily impact the levee system because they are driven by water levels in the Columbia River, the interior drainage system plays a critical function in moving surface water out of the Districts.

In the latter half of the 20th century and the early part of the 21st, CoT annexed area within the North Troutdale basin and expanded its drainage system to serve development and local streets, interconnecting with the SDIC and other partner agencies' systems, see Figure 1, Appendix A, for map of SDIC and CoT boundary overlap.

Today, the SDIC and CoT work together and with partner agencies, including the cities Fairview and Wood Village, and government agencies such as the Oregon Department of Transportation (ODOT), Port of Portland (Port) and Multnomah County, to maintain and operate the drainage system. Partner agencies have representatives on the SDIC Board and staff participate in multiple work groups with staff from the partner agencies.

1.2 Community

The study area, bisected by I-84, is comprised of primarily industrial and commercial properties to the north, with a mixture of commercial and some residential areas to the south of the interstate. Properties and areas of economic, cultural, ecological, and recreational community value include:

- Troutdale Airport
- Troutdale-Reynolds Industrial Park (FedEx, Amazon, others)
- McMenamin's Edgefield
- Blue Lake Park
- Chinook Landing Marine Park
- West Sundial Wetlands
- Hyster-Yale Group

1.3 Study Area Overview

The study area for this DMP includes all areas that drain by gravity to the Sandy Pump Station, including Arata and Salmon Creek and areas west of NE 223rd Ave. These areas are primarily composed of North Troutdale and SDIC, with some contributing area within unincorporated Multnomah County and the cities of Fairview and Wood Village. The study area is bounded to the North by a federally authorized levee, which separates the internal drainage area from the Columbia and Sandy rivers. The southern edge of the study area reaches southward into North Troutdale and Wood Village and include tributary areas to Arata and Salmon creeks. Several developed sites, in the southwest of the study area, drain to the north under the Union Pacific railroad. Blue Lake, while outside SDIC boundary, is hydraulically connected to SDIC by a cross-levee culvert. The eastern boundary of the study area is delineated by the levee system and drainage infrastructure in NW 257th Avenue[1] operated by Troutdale and Multnomah County. Poor draining soil conditions and high seasonal groundwater render stormwater infiltration systems ineffective for most sites in the study area, and as a result most stormwater runoff generated in the basin is discharged to the public collection and conveyance systems. The movement of surface water and piped conveyance through the study area is primarily driven by gravity, although some infrastructure at lower elevations is affected by backwater conditions from the Sandy Pump Station. All water within the study area is pumped out to the Columbia River via the Sandy Pump Station.

1.3.1 Study Area Features

The major drainage pathways through the study area are Salmon and Arata creeks. These two creeks convey water primarily from the North Troutdale and SDIC service areas but also some portions of Wood Village, and flow northwards through the SDIC and the Troutdale Airport, and then turn west into Fairview, before terminating at the Sandy Pump Station.

1.3.2 Climate and Rainfall

The Pacific Northwest climate is characterized by cool wet winters and warm dry summers. Most rainfall occurs between October and April. On average, November is the wettest month with an average of 9.3 inches of rainfall. July and August are the warmest and driest months with average high temperatures above 80 degrees Fahrenheit and less than 1 inch of rain per month. The average annual precipitation for Troutdale is 45 inches, with an average of 4.7 inches of snowfall annually.

In December 2015, the Portland metro area experienced a large rainfall event that delivered more than 5 inches of rain over a 3-day period and 2.81 inches in one, 24-hour period. This event was estimated to be between a 50- and 100-year frequency event because of the intensity and nature of the rainfall. These “severe” events are expected to occur more frequently as a result of climate change.

1.3.3 Topography

Nestled between the Sandy and Columbia Rivers, the topography of the lower portion of the study area consists of flood plain areas, generally flat or rolling in slope. The SDIC boundary includes this lower portion of the study area, with elevations ranging from approximately 10 to 30 feet (NAVD 88). The upper portion of the study area, south of Interstate 84, begins to see larger elevation gains into hilly terrain. In this upper area are the McMenamins Edgefield property and growing residential neighborhoods, all within an elevation range of approximately 30 up to 330 feet (NAVD 88).

[1] At the time of publication, the north-south segment of NW Graham Road is undergoing a name change to NW 257th Avenue, which includes the former north-south segment of Graham Road.

1.3.4 Soils

The National Resources Conservation Service (NRCS) Soil Survey online tool was used to gather soils information for the study area. Soils are an important watershed characteristic for evaluating potential runoff rates and volumes. Soils are generalized into four categories or hydrologic soil groups (HSG), which approximate soil runoff potential. These groups are A, B, C, and D, where A soils are characterized by high rates of infiltration and low runoff potential and D soils are characterized by low rates of infiltration and high potential for runoff.

Most of the soils in the study area are HSG Type C soils with pockets of A and B/D type soils. Table 1-1 lists the NRCS hydrologic soil groups by percent coverage within the basin boundary.

Table 1-1. Soil Type within the Study Area

HSG	Acres	Percent
A	12	0.5
B	229	10.0
C	1,821	79.2
B/D	145	6.3
C/D	92	4.0
Total	2,300	100

1.4 Drainage System Overview

The conveyance system in the study area transports surface water through contributing tributaries, primarily Salmon and Arata creeks, via open channels, pipes, and culverts, terminating at the Sandy Pump Station, see Figure 2, Appendix A, for a map of the drainage. The southern and upper portion of the study area has more undeveloped land and residential land use, while the northern portion has more industrial and commercial land use activities. Interstate 84 acts as a demarcation of the overall study area slope where south of the highway is generally steeper and north has a generally flatter slope. The only hydraulic exit from the study area is the Sandy Pump Station and a gravity flow pipe when the Columbia River water surface elevation is low.

1.4.1 Key Drainage Features

The key drainage features across the study area are listed below, roughly from south to north.

- The McMenamin's Edgefield property and the surrounding areas contribute runoff to Arata Creek. This area has been largely vacant is but is now rapidly developing and will contribute increased runoff into the SDIC.
- The SW Halsey Street stormwater collection system will eventually intercept/collect the area south of Halsey Street and convey water eastward out of the study area and to the Sandy River. Currently, water passes pass under SW Halsey Street and flow northward.
- Union Pacific railroad tracks and I-84 create significant hydrologic and hydraulic divides.
- Marine Drive is culverted to carry Salmon Creek at the 223rd overpass. The crossing has an uncertain condition and is likely structurally unstable.
- The culvert under Marine Drive where Arata Creek is conveyed under the roadway is under capacity.
- Sandy Pump Station is the only pump station in the study area.

Appendix B provides photographs of the study area taken during fieldwork and used to develop an understanding of the drainage system.

1.4.2 Pump Station

The terminus of all drainage in the study area is the Sandy Pump Station, operated by the SDIC. The pump station currently houses two pumps which are responsible for conveying the runoff from approximately 2,400 acres of land. The CoT and SDIC conveyance systems transport stormwater runoff to the northern boundary of the study area by gravity where the water ponds. These gravity systems are sized based on traditional sizing methods using a design storm. Once the ponded area, located at the bottom of the gravity system reaches a predetermined elevation, the Sandy pump station is activated and pumps the ponded water over the northern levee into the Columbia River.

The pump station is controlled with the assistance of a Supervisory Control and Data Acquisition (SCADA) system that allows SDIC staff to monitor water levels and manage pump station operations. The pump station's current condition is addressed in further detail in Section 4.2 and project recommendations for the pump station can be found in Section 4.6.

1.4.3 Critical Conveyance Network

In October 2018, SDIC staff identified the need to map all district-maintained infrastructure and define the critical conveyance routes for internal drainage systems. The resulting critical conveyance network has been used as a filter to identify infrastructure to be considered for improvements under the Stakeholders' Capital Improvement Programs.

The mapped critical conveyance network was developed by members of the SDIC's Operations and Engineering teams through a collaborative workshop process, which is documented in a technical memorandum, *Defining Critical Conveyance Routes within Internal Drainage Systems in PEN1, PEN2, MCDD, and SDIC* (MCDD December 28, 2018).

The SDIC internal drainage system has mixed—and often unclear—ownership and maintenance responsibilities. Identification of the critical conveyance network was not based on nor intended to define or establish ownership of any infrastructure, but simply to define where the SDIC does work and what parts of that drainage system are most critical to moving surface water through the area. The critical conveyance network includes portions of the piped conveyance system, open channels, culverts, and the pump station.

A map of the critical conveyance network is included in Figure 4, Appendix A.

1.4.4 Recent Projects

The Stakeholders routinely work to upgrade existing drainage system elements and replace deteriorated infrastructure. Drainage-related projects completed by SDIC, CoT, partner agencies, or private property owners within the last 10 years are listed in Table 1-2 below.

Table 1-2. Recently Completed Drainage-Related Projects	
Project	Year Completed
Troutdale Reynolds Industrial Park (TRIP) Phase 1	2009
TRIP Phase II/III	2017
TRIP Weir and Sundial wetlands	2017
NW 7th Street Storm Main Extension, I-84 Corporate Center Truck Court	2017
NW 7th Street Storm Main Extension, Power Rents Site	2019
Howard Estates Subdivision Public Storm Mains	2020
Lancaster Park (Kennedy Park) Subdivision Public Storm Mains	2020
Eastwind Drive Storm Main Extension (Northwest Freight Site)	2018

1.5 Development Patterns

The study area is currently in a period of growth and extensive development is currently underway. Several properties along SW Halsey Street and adjacent to the McMenamin's Edgefield property are expected to be built out into commercial and residential developments in the near future with several subdivisions currently under development.

The lower portion of the study area, within the SDIC, is comprised of the Troutdale Reynolds Industrial Park (TRIP) area as well as the Troutdale Airport. TRIP properties are developing rapidly, and the Port has plans to redevelop airport facilities to create additional developable land along the frontage on NW Graham Road.

The SDIC does not currently have land use authority to set design standards or establish conditions of approval for new development and redevelopment projects. The SDIC is included in the CoT's land use and permit review processes and has recently adopted its own review manual that outlines the design criteria and processes that District staff will follow when reviewing proposed development for drainage system impacts (OTAK 2018).Drainage-related design standards implemented for new development and redevelopment are established by the partner agencies.

New development will add impervious surface and runoff to the drainage system. The CoT's current standards require development in the SDIC to provide water quality treatment. No flow control is required in the North Troutdale basin in keeping with SDIC's conveyance and stormwater management strategy. CoT collects stormwater System Development Charges (SDCs) on new development, and stormwater utility fees from properties in the North Troutdale basin, to fund its stormwater system costs. The SDIC does not have a mechanism to offset the costs to their conveyance system or pump station.

1.6 Operations

The Stakeholders share the responsibilities of maintaining and operating the drainage infrastructure across the study area and have an established intergovernmental agreement (IGA) for the coordination of and contracting of some activities related to operations and maintenance. This is typically exercised when one entity is better equipped or has better expertise to perform needed tasks. By operating in this manor, the Stakeholders complement each other by sharing the burdens of their interrelated missions.

SDIC staff are responsible for maintaining the pump station, open channels, and movement of water through the study area (within SDIC boundary) that is defined as the critical conveyance network.

SDIC operations staff routinely repair and rebuild pump station components to extend the life of pumps and continually engage in projects to improve pump station structures.

The CoT is responsible for maintaining infrastructure that is more localized, included any serving city streets and private properties that drain to the critical conveyance network. CoT staff provide routine maintenance of local drainage infrastructure, as allowed through their NPDES permit, ensuring clear passage of runoff from upland areas. Additionally, CoT focuses on enhancing and maintaining the water quality across the city, which has significant overlap with the SDIC.

The Stakeholders' operations staff maintains over 8 miles of ditches, sloughs and culverts that make up the critical conveyance network within the study area. These infrastructure elements are often connected or interrupted by culverts at roadway crossings and closed conveyance (pipe) systems across private properties. All conveyance system elements need to be maintained for long-term performance.

Figure 1-3. Debris prevention and removal is a major focus of District operations related to the drainage system.

The Stakeholders have a seasonal maintenance program that is followed throughout the year. Routine activities are listed below.

- Regular inspections/maintenance of pump stations and pump station infrastructure
  - Outfall/intake inspection
  - Electrical review and inspection
  - Debris removal at the intake
- Maintaining all moving parts Maintenance of ditches and sloughs
  - Brush removal
  - Mowing and general upkeep of the vegetation
  - Removing, modifying, working with blockages caused by wildlife (e.g., beaver dams) or debris
- Identifying areas of potential sedimentation and planning accordingly
  - Inspection of culverts/pipes and other conveyance infrastructure
  - Removal of debris at inlets
- Regular inspection of passive infrastructure such as diversions, weirs, beaver deceivers, etc.
- Annual review of critical conveyance elements such as the cross-levee culverts and gates

The SDIC owns very little land and as a result, establishes maintenance and access easements for all pump station and conveyance system features with partner agencies. The SDIC relies on the cooperation of property owners and partner agencies to provide continued operation and maintenance of the critical conveyance network. In addition to the CoT, these partner agencies include Multnomah County, Port of Portland, Oregon Department of Transportation, and numerous private property owners.

The recommendations in this DMP are focused on projects and programs to best manage and maintain the primary conveyance and pump station systems within the SDIC and the CoT boundaries. Recommendations made in this DMP are independent of ownership and maintenance responsibility.

Section 2

Basis of Planning

2.1 Background

The services provided by SDIC and the CoT are essential as numerous economic centers including the Troutdale Airport, Amazon, and FedEx, as well as critical infrastructure elements, such as Marine Drive and Interstate 84 (I-84) exist within the study area and rely on the drainage infrastructure to remain operational and free from inundation. The CoT and SDIC conveyance systems transport stormwater runoff to the northern boundary of the study area by gravity where the water ponds. These gravity systems are sized based on traditional sizing methods using a design storm. Once the ponded area, located at the bottom of the gravity systems, reaches a predetermined elevation the Sandy pump station is activated and pumps the ponded water over the northern levee into the Columbia River.

Several pipes and culverts within the lowest portion of the conveyance system do not meet the criteria for gravity flow design, as they operate primarily under backwater conditions. During larger storm events, the backwater condition extends upstream into portions of the conveyance system that typically only experience gravity flow. Due to this unique system configuration, special consideration is given to the evaluation and design criteria for the pump station and the conveyance network.

2.2 Planning Framework

Current regulatory documents do not provide design standards for drainage systems that are inundated. The movement of water within the study area is controlled, in part, by the pump station. In the development of this DMP, SDIC and CoT established a methodology for evaluating the existing and future condition and capacity of the drainage system, when impacted by backwater from the pump station, and the design of future improvements for these scenarios.

As part of the DMP development, Brown and Caldwell (BC) reviewed legal documentation, local design requirements, and intergovernmental agreements (IGAs) relevant to the drainage system within the study area. Based on this information, professional judgment, and input from SDIC and CoT staff, BC developed a planning framework for this master planning effort.

The planning framework outlines the process for establishing evaluation criteria by evaluating condition and capacity of the existing drainage system components (e.g., pump station, pipes, open channels) against established evaluation criteria. Evaluation criteria help establish a level of service for existing infrastructure to identify when capacity, water surface levels, or infrastructure constitute a problem. These evaluations identify deficiencies—existing and anticipated—that should be addressed through capital projects, programs, or operational actions. The evaluations performed for this project were determined based on the regulatory obligations of SDIC and the CoT, as well as known physical conditions and operational needs.

The planning framework also outlines design criteria that represent the target level of service for proposed projects, also referred to as the basis of design. The design criteria inform the level of service that proposed projects will accommodate. The design criteria may differ in different parts of the study area, depending on who has ownership or operational control of a piece of infrastructure.

For example, a culvert crossing through Oregon Department of Transportation (ODOT) property may be subject to a different design standard than a similar culvert located in a city roadway. The planning framework outlines a consistent method for applying design criteria for future capital projects.

It should be noted that ownership and maintenance responsibilities of drainage infrastructure segments within the study area is, in some cases, unclear, and it's important to note that establishing ownership and maintenance responsibilities in such cases is not a function of this study and was not incorporated into the study or an outcome of this study.

Where such cases are found, the Stakeholders and other partner agencies should collaborate to clarify such responsibilities to remove uncertainty.

These two elements—condition and capacity—underpin the overall planning framework for developing the DMP. More details are provided in Sections 3.

2.3 Regulatory Framework

Multiple governmental entities including the Port of Portland, City of Fairview, City of Wood Village, Multnomah County, and ODOT, operate in the geographic area that falls under the jurisdiction of SDIC and CoT. Across these agencies, there is no single set of standards that would dictate the basis of evaluation or the planning framework related to level of service for the DMP. The following documents, standards, and regulations influenced the development of the DMP's planning framework.

2.3.1 Legal Authority

On behalf of the SDIC Board, SDIC services are administered by MCDD staff through an IGA between SDIC and MCDD. SDIC is authorized under Chapter 554 of the Oregon Revised Statutes (ORS) to operate as a corporation and, among other services, protect life and property from flooding risks through drainage and flood control measures, including the management of an interior drainage area inside the levees that protect the area from the Columbia River in Multnomah County. Additional explanation of authority in this area can be found by consulting the Development Review Handbook (January 15, 2018) and the statutes found in ORS Chapter 554. SDIC, therefore, has the legal obligation to provide service to property owners and other relevant parties within its boundaries. These obligations include compliance with ORS and/or IGAs with other partner agencies.

Applicable ORS include 554, which provides the legal framework for corporations (such as SDIC) irrigation/drainage systems, water supply or flood control. SDIC authority includes:

- Planning and coordinating the urban service with other urban services (ORS 195)
- Planning and construction activities
- Maintaining service facilities
- Determining authority of a drainage district for irrigation/drainage (ORS 554)

The CoT's current Phase II National Pollutant Discharge Elimination System (NPDES) General Permit outlines stormwater requirements to reduce the discharge of pollutants to waters of the state to the maximum extent practical, to protect water quality, and satisfy the appropriate water quality requirement of the Clean Water Act. The CoT implements the NPDES Municipal Separate Storm Sewer System (MS4) permit, effective March 1, 2019, throughout the city boundary, which encompasses much of the study area, as shown on the maps included in Appendix A.

The MS4 permit requires the CoT to address six elements:

1. Public Education and Outreach
2. Public Involvement and Participation
3. Illicit Discharge Detection and Elimination
4. Construction Site Runoff Control
5. Post-Construction Site Runoff for New Development and Redevelopment
6. Pollution Prevention and Good Housekeeping for Municipal Operations

Under the permit the City has legal authority to operate and maintain the drainage infrastructure and require water quality treatment for new and redevelopment. Furthermore, the CoT's stormwater- and drainage-related obligations are outlined in ORS 468, OAR 340 and Troutdale Municipal Code Chapter 12.06 and 12.09. CoT also has land use planning obligations under ORS 197.

2.3.2 Partner Agencies

Local partner agencies that fall within SDIC and the CoT jurisdiction include the Port of Portland (Port), the cities of Wood Village and Fairview, and Multnomah County. Other state and federal agencies that routinely work within this jurisdiction include the U.S. Army Corps of Engineers (USACE) and ODOT. SDIC does not own, or take ownership of, most conveyance infrastructure within their jurisdiction. As such, it relies on the CoT and other partner agencies to maintain, repair, or replace conveyance infrastructure assets and ensure they are designed and sized appropriately. However, SDIC does maintain overall responsibility for the conveyance network by operating the major conveyance channels and the Sandy pump station, which serves as the outfall for the study area and pumps all stormwater out of the SDIC management area and into the Columbia River.

2.3.3 Intergovernmental Agreements

IGAs and legal agreements with local partner agencies, including MCDD, the Port, Multnomah County, and Fairview, provide additional guidance for facility O&M. However, they provide little guidance for the design and capacity of the conveyance systems managed by the District. For the most part, IGAs guide the level of maintenance, pump station activities, and some water level requirements, but do not outline requirements related to the design or evaluation of pump stations or conveyance features.

2.3.4 State Agency Guidance

At the state level, the ODOT *Hydraulics Manual* (2014) is the guiding document for designing drainage facilities associated with state highways. ODOT identifies the recurrence interval of the design storm to be used for design of each type of drainage feature (i.e., bridges, culverts, piped conveyance systems, energy dissipators, etc.). In addition to having designated design storm recurrence intervals, all culverts and bridges are required to be analyzed for impacts during the base flood (100-year recurrence interval); the 100-year design flood recurrence interval should be used for facilities in floodplains subject to federal National Flood Insurance Program regulations (ODOT, 2014). Section 3 of this DMP outlines the criteria used for evaluation of the drainage infrastructure.

Design guidance is not provided for pump stations, as ODOT policy is to convey water along, or away from, highways using gravity conveyance. Refer Section 4.2 for pump station design guidance.

2.3.5 Federal Agency Guidance

CoT is a National Flood Insurance Program community which adopts the Code of Federal Regulations (CFR) §44 65.10(b)(6) that provide floodplain management criteria. Section 44 requires that the areas inundated during the 100--year flood be identified and protected and that the water surface elevation for all areas where flood waters have a depth of more than 1 foot be identified. Flood Insurance Rate Maps (FIRM) for SDIC and CoT, effective February 1, 2019 identifies the 100-year flood inundation and shows the 100-year water surface elevation (WEST Consultants 2018). The map indicates that the area behind the levee is theoretically protected during such a storm event. In addition, the CoT participates in the Community Rating Systems program, a FEMA program which encourages communities to adopt higher flood management regulatory standards. Some of the activities which the City pursues include Stormwater Management Regulations and Drainage System Maintenance.

USACE has several guidance documents that are applicable to. the DMP. The USACE has jurisdiction over the levee system and therefore the interior drainage area included in the study. Pertinent documentation has been reviewed and is summarized below:

- USACE Engineer Manual (EM) 1110-2-1413, Hydrologic Analysis of Interior Areas states that the interior drainage system is to enhance the national economy, and secondarily enhance the environment, social wellbeing, and regional development. The manual does not outline specific standards for evaluating or designing the interior drainage system beyond the requirement to maintain the maximum water surface elevations below the base flood elevations during the 100--year design event.
- USACE EM 1110-2-2902, Conduits, Culverts, and Pipes includes design considerations for recommended piping materials that should be considered in conjunction with local agency standards when designing new conveyance systems.
- USACE EM 1110-2-3102, General Principles of Pumping Station Design and Layout guidelines recommend the number and size of stormwater pumps at a given pump station to be determined by an economic study. The study should consider the risk and impacts of a pump failure and the need for redundancy in the pumping system (i.e., whether the pump station should be designed with full pumping capacity, even in the event of a single pump failure.) EM 1110-2-3102 also includes guidelines for pump controls, sump (wet well) design, trash racks, pressurized discharge lines, and station auxiliaries.
- USACE EM 1110-2-3104, Structural and Architectural Design of Pumping Stations provides general guidance for architectural design and specific design guidance for structural loading.
- USACE EM 1110-2-3105, Mechanical and Electrical Design of Pumping Stations is a detailed guideline for selecting equipment and designing the systems within flood-control pumping stations. This guideline is an important reference for the District when upgrading pump stations or pump station components.

2.3.6 Stakeholder Directives and Design Standards

The various design standards and operational objectives for each of the Stakeholders are outlined below.

Sandy Drainage Improvement Company

SDIC's operations are closely aligned with activities taking place at MCDD, and MCDD recently developed a *Mission, Vision, and Values,* which documents a series of service directives. It clarifies the purpose and guiding principles for the SDIC as both a drainage district and an organization. Staff fulfilling duties within SDIC operate under these mission, vision, and values.

At the forefront, the MCDD mission states:

> To enhance community safety and support the region's vitality, MCDD reduces flood risk by maintaining our levee system, managing drainage, and responding to emergencies.
>
> *MCDD, Mission, Vision, and Values*

This DMP focuses on managing internal drainage. The evaluation criteria has incorporated the need to access roadways, property and areas for levee maintenance and emergency response. These are key aspects in developing the reference points and critical water elevation levels described in Section 4.2.

In conjunction with the *Mission, Vision, and Values*, MCDD synthesized information in its existing documents to define and establish levels of service (see files in MCDD Project #10076). These documents outline the SDIC's responsibilities and key activities to maintain levees, manage drainage, and respond to emergencies. The directives, which are separate from the levels of service, define what the SDIC is not responsible for—activities that are the responsibility of partner agencies or property owners. The directives related to the DMP include:

- Pump station inspection and maintenance
- Managing water levels in ditches, pipes, and culverts
- Vegetation management, debris removal, wildlife management, and bank stabilization in ditches to prevent drainage obstruction
- Monitoring risk areas during high-water events

The SDIC does not manage stormwater runoff across properties, address water quality issues, or manage water in privately owned drainage systems; however, private property conveyance does impact SDIC operations, so some areas of the privately-owned drainage systems have been included in the evaluation and analysis for the DMP.

Privately-owned drainage systems, included in the evaluation, have been identified based on integration with the primary drainage infrastructure and the critical conveyance infrastructure. A map is included in Figure 4, Appendix A.

City of Troutdale

CoT has design standards for public and private development to ensure infrastructure is designed to a minimum standard. These standards are outlined in a series of interim design standards dating from 1999 with revisions and adoption of additional standards ongoing.

- **Conveyance.** Public conveyance lines are required to be designed to convey the 25-year storm event. Additionally, the minimum pipe size for any public pipe is 12 inches.
- **Detention.** Private development is required to control the 2-year 24-hour post development peak flow rate to the pre-development erosion-initiating rate (one-half of 2-year, 24-hour flow rate). Control post-development flows from the 5-, 10-, and 25-year, 24-hour peak flows to the 5-, 10-, and 25-year, 24-hour pre-development flow rates. However, the City exempts lands within the SDIC from these flow control standards per SDIC's conveyance and stormwater management strategy.

- **Water Quality.** The 2016 Stormwater Management Manual, City of Portland Bureau of Environmental Services (PSWMM) has been adopted for stormwater treatment standards applied within the City. The PSWMM provides a simplified approach and performance approach for facility sizing and design, both methods are acceptable. The performance approach may be used when the simplified approach is not permitted. The presumptive approach calculator (PAC) may not be used for facility sizing and design in Troutdale due to Portland's differing rainfall depths that are hardwired into the PAC.

Section 3

Evaluation Criteria–Condition and Capacity

System condition is a factor of both age and deterioration. Condition assessments require inspection, monitoring, and evaluation. Utilities and service districts can implement asset management systems to track and monitor condition to determine the optimal time to upgrade or replace system components or pieces of infrastructure. In the absence of robust asset management data, system age provides a baseline guide to identify systems that are more likely to be degrading; however, age alone cannot determine which system components are at risk of failure or need replacement.

The criteria used to evaluate system condition for this DMP are specific to pump stations, pipes and culverts, and open channels, as described below.

3.1 Pump Station Condition Evaluation Criteria

Pump station condition is dependent on many factors. Pump station components deteriorate at different rates, based on the age, amount of use, pump cycling, stresses, and maintenance activity. Identifying varying deterioration rates for different pump station components requires a site-specific analysis to evaluate the condition of each pump station component.

For the DMP, condition ratings for pump station system components were developed based on the USACE condition rating system from *Best Practices in Asset Management 2013-R-08* (USACE 2013). The system uses an alphabetical ranking system (A through F) and allows the SDIC to determine the condition of different pump station system components relative to each other. The pump station condition assessment included the compilation of the individual component ratings into a composite score for the Sandy pump station. This ranking and scoring approach is consistent with the previous MCDD and PEN2 master plans.

Table 3-1 below outlines the evaluation criteria used to assess the condition of pump station system components. More detailed information about the scoring and ranking of components using this evaluation criteria is included in the *Pump Station Condition Assessment* (Parametrix 2016).

Table 3-1. Pump Station Condition Evaluation

System Component	Evaluation Criteria
Electrical	• Physical condition of the electrical enclosures • The type and condition of the voltage of the incoming services as well as stepdown voltage used in the pump station (PS) • The presence and condition of a transfer switch that would allow for connection of a portable generator • The presence and condition of a standby power source
SCADA/ Communications	• Presence of a SCADA panel or screen that allows for user interface in the field • Presence and condition of the primary level instrumentation that is used to control the pumping system, as well as provide level data of the drainage district waters for the systemwide SCADA system • Presence and condition of secondary level controls and alarms used for level control redundancy, as well as alarm communication back to the systemwide SCADA system • Presence, condition, and type of communication system used to connect district staff into the PS for control and observations purposes • Type, presence, and condition of flow monitoring used on the discharge piping
Wet Well	• Presence and condition of the PS intake, including intake pipes when readily viewable • Type, presence, and condition of the debris screen used at the head of the intake • The structural condition of the intake components • The type and presence of ventilation used in the wet well
Valves	• Presence, condition, and type of valve vault used outside of the PS • The type, presence, and condition of valves used on the discharge pipes either inside or immediately outside of the PS
Piping	• The type and condition of the discharge piping from the pump outlet to immediately outside of the PS • The type, presence, and condition of pipe supports used on the discharge piping • The type, presence, and condition of vacuum and air relief valves, check valves, and isolation valves • The type, presence, and condition of outfall and discharge structures, including energy-dissipating components
Pumping Systems	• The number, type, condition, and nameplate data available for the pumps and motors used in the PS • Presence and condition of pressure gauges used on the discharge piping or pumps • Observations of pump operation • Access to the pumps for on-site maintenance or removal
Site	• Type and condition of PS access • Presence, type, and condition of site's exterior lighting • Observations of the stormwater runoff drainage paths relative to the PS location • Type, presence, and condition of site security measures
Building	• Where possible, the type and condition of the roof, including any signs of previous or current leakage • The type and condition of the building structure above the foundation • The presence and condition of windows, interior walls, heating, lighting, and ventilation • The condition of the foundation where visible, including PS floor • The presence and condition of internal or external stairs and access walkways • The presence or evidence of pest infestation, primarily from district staff's first-hand accounts during site visit • The presence, condition, and certification of fall-protection measures for intake cleaning and roof access during pump removal

3.2 Pipe and Culverts Condition Evaluation Criteria

The condition evaluation for pipes and culverts across the SDIC and the CoT focus on the identified critical conveyance network. See Figure 4, Appendix A, for a map of the critical conveyance network.

SDIC is currently, as of the writing of this DMP, evaluating potential methods for the development of a Strategic Asset Management Plan (SAMP). Two existing programs under evaluation include ODOT's *Culvert Inspection Handbook* and the Multnomah County's Culvert Program.

The CoT currently does not have an active method for evaluating infrastructure condition. However, CoT has purchased and commissioned a video inspection truck and intends to use the NASSCO PACP inspection and rating methodology in conjunction with an asset management software package to manage stormwater and sanitary system assets. Inspection and development of a stormwater asset management program will occur once the sanitary system evaluation is complete.

Depending on pipe material, stormwater conveyance infrastructure is generally assumed to have a useful life of 50 to 100 years. Corrugated metal pipe and steel pipe are generally assumed to have a shorter lifespan than clay, concrete, and polyvinyl chloride (PVC) or high-density polyethylene (HDPE).

Under normal operating conditions, pipes and culverts used primarily for storm and surface water drainage have the potential to outlast industry standards for useful life because they are not subject to the same stresses that may be placed on wastewater conveyance systems. However, SDIC operates pressurized conveyance (pumped) systems associated with the Sandy Pump Station. Pipes operating under pressure are more susceptible to cyclical stresses and deterioration than standard gravity pipes.

A robust condition evaluation program for pipes and culverts should consist of visual inspections, photos or video documentation, inspection reports with grading scores, and engineering evaluations to determine replacement or rehabilitation recommendations. The evaluation will consist of these elements to the extent data is available.

The industry standard is to follow guidance from the National Association of Sewer Service Companies (NASSCO) when evaluating underground infrastructure. NASSCO provides standard and consistent methods to evaluate pipes, including observations coding and scoring.

When applying the Pipeline Assessment Certification Program (PACP) grading systems, pipe segments are scored on a scale of 1 to 5, with a score of 1 or 2 indicating a pipe in good condition. Scores of 3 or higher indicate that defects have been identified. A score of 5 indicates that a pipe segment has failed or is likely to fail within 5 years; however, further engineering evaluation is required to investigate the cause of the grading score, identify the remaining useful life for a pipe segment and determine the recommended pipe rehabilitation or replacement strategy. Figure 3-1 shows examples of the scoring system.

A simplified alternative rating system presented as a possibility for the CoT and SDIC would include a three-tiered system of low, medium, and high. While this is not the industry standard implementing a simplified version may be more practical.

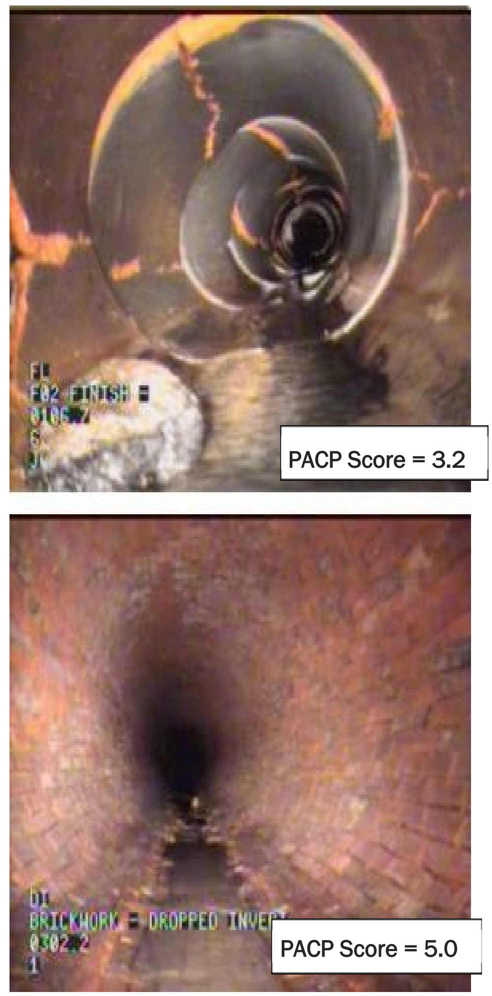

Figure 3-1. The PACP score does not tell the whole story. Engineering investigation is needed to determine rehabilitation needs.

Source: OWEA, 2011

In the absence of a robust condition evaluation program, due to insufficient data, this DMP relies on existing, available data to evaluate the general condition of the drainage conveyance system. This was completed primarily based on Stakeholder feedback of known issues and the general overall age of infrastructure in the study area as documented in the GIS data. The DMP recommends projects to replace or rehabilitate known deteriorated or failing infrastructure and programmatic activities to build the CoT's and SDIC condition evaluation program in the future. Refer to Section 9 for a discussion regarding the recommended CCTV programs for SDIC and the CoT.

3.3 Open Channel Condition Evaluation Criteria

Currently, there is not an industry-standard condition rating for open channels and ditches. Instead, open channels and ditches must be assessed on a case-by-case basis through visual inspection. Observed problems may include:

- Channel bank erosion
- Acute erosion at pipe outfalls
- Evidence of piping of flow and fine sediment in banks around outfalls and culverts
- Channel degradation or incision (lowering of the channel bed through downcutting)
- Channel aggradation through sediment accumulation
- Overgrowth of vegetation

In general, evaluating the condition of open channels should be tied to larger goals, such as preventing erosion to reduce the sediment load to the downstream pump station, maintaining channel storage capacity through sediment removal, maintaining conveyance capacity through vegetation removal, and/or repairing acute failures around outfalls or structures.

As with pipes and culverts, condition evaluation should be focused on channels and drainage ditches within the District's identified critical conveyance network and locations of known concern. A comprehensive open channel evaluation was not completed as part of this DMP. Some specific areas have been identified which suggests a more comprehensive evaluation is needed. Infrastructure outside the critical conveyance network should be evaluated once all critical conveyance elements have been evaluated. Refer to Section 9 for a description of the open channel sedimentation control program to evaluate and correct any open channel issues that are identified.

3.4 Capacity Evaluation Criteria

Local and regional agencies set standards to evaluate and design drainage systems. These standards, however, are not applicable to all drainage infrastructures within the Stakeholders' drainage system. The Stakeholders' drainage systems are an atypical conveyance network, largely controlled by a single pump station which results in backwater where typical means of evaluation do not apply. Therefore, gravity flow equations cannot solely be used to evaluate all piped infrastructure in the study area because the system regularly operates under backwater conditions. Capacity problems due to backwater conditions may be addressed through adjustments to the pump station settings. It is critical to evaluate capacity in a way that considers the performance of the whole system.

Given the unique characteristics of the study area, different design criteria are applied to areas where backwater conditions develop, and system capacity cannot be evaluated based on gravity flow. In areas where gravity flow is the driving force, the conveyance system can be evaluated based on the CoT or other appropriate standards as outlined in Sections 2.3, 5.2, and below in this section.

3.4.1 The USACE Feasibility Study

At the time this DMP was developed, the USACE was conducting an integrated feasibility report to identify opportunities and the feasibility of actions to reduce flood risk, increase resiliency, and improve levee performance. The Feasibility Study paralleled this DMP. Each study developed means and methods independently and approached the interior flood risk of the SDIC interior drainage differently. In each report, the Sandy Pump Station was the overlapping interest and the resulting recommendations are similar, as the Sandy Pump Station serves as a critical piece of infrastructure, highlighted in both studies as being inadequate when looking to future flood and risk scenarios.

3.4.2 Local Design Standards

Local agency design standards suggest a combination of storm events may be considered to evaluate conveyance system capacity. A summary of the local agency design standards for conveyance is included in Table 3-2. These standards typically apply to new installations of pipe, culverts, and open channel ditches and can be used when evaluating existing conveyance networks. Standards identified in Table 3-2 are focused on gravity flow systems and may not address capacity needs for a drainage system that operates under backwater/pump system conditions.

Table 3-2. Guidelines by Jurisdiction from Design Standards

Jurisdiction	Pipe Design Storm Event	Culvert Design Storm Event	Open Channel Design Storm Event
Port of Portland	10-year	10-year	10-year
Multnomah County	25-year	25-year	25-year
Wood Village	10-year	25-year	25-year
Fairview	25-year	25-year	25-year
CoT	25-year	25-year	25-year
ODOT	10-year	25-, 50-, 100-year	25-, 50-, 100-year

Differing standards have the potential to create inconsistencies when evaluating the existing drainage and conveyance system. No single design standard applies to all the contributing open channels, pipes, and culverts that fall within SDIC and CoT combined or separate jurisdiction.

SDIC operates one pump station to move water through SDIC and ultimately into the Columbia River. The primary capacity requirements of the pump station are to ensure water surface levels are maintained below the elevations identified in the FEMA FIRMs and to maintain water-surface levels identified in the various IGAs; however, the water-surface levels outlined in the FEMA FIRMs are based on pump station settings and pumping capacity at the time of FIRM development. There is no evaluation criteria other than the existing capacity of the pump stations to establish the water-surface levels. This suggests that an alternate approach may be needed to evaluate the capacity of the Sandy Pump Station system as not all conveyance elements are controlled by the pump station. Section 3.4.2 outlines the establishment of critical elevations for a more comprehensive water surface level evaluation.

3.4.3 Critical Elevations

For the DMP, to address areas of the system that may operate under backwater conditions, the capacity evaluation implements an unconventional methodology of establishing reference points and comparing modeled water levels to critical elevations across the District. This critical elevation approach is used to evaluate the capacity of the Sandy Pump Station and conveyance infrastructure. This approach will be the primary capacity indicator for the pump station, which is evaluated based on the 100-year event. This approach identifies elevations across the study area where a water level exceedance would be particularly problematic due to flooding or operational concerns. Critical elevation locations have been developed in coordination with the Stakeholders and is documented in a technical memorandum (SDIC October 2019).

The reference points and critical elevations are used to determine if the surrounding infrastructure or downstream pump station are adequately sized to move runoff downstream without water surface elevations rising to unacceptable levels.

Reference points were identified through three primary methods:

- **Operational Elevations**. SDIC staff assessed the Sandy Pump Station to identify the water level at which pump station building access would be restricted. They also assessed frequently accessed locations to determine where the ability to remove debris from key collection points during large storm events would be restricted. Operational elevations include an elevation of 1 foot above the deck of the Sandy Pump Station. Operational elevations also include an elevation of 1 foot above the crown of culverts that frequently need to be cleared during storm events (SDIC October 2019).
- **Structural Comparison.** SDIC and CoT provided the consultant team with known finished floor elevations across SDIC. The FEMA standard requires buildings constructed in the floodplain to have a finished floor elevation at least 1 foot above the 100-year water surface elevation. Reference points were established to be 1 foot below the lowest finished floor at various locations across SDIC.
- **Physical Markers**. BC reviewed problem-area data, transportation routes, and commonly identified areas of concern to pinpoint controlling locations in the drainage network. These are “watch points” during storm events and points that will help compare the effect of potential alternatives.

Reference points, with critical elevations, are listed in Table 3-3. A map showing their locations is included in Figure 5, Appendix A.

Table 3-3. Reference Points and Critical Elevations

Location	Elevation	Type	Basis/Justification	Map ID
Sandy Pump Station	16.69	Operational	Critical elevation at Sandy Pump Station	Y
NE 223rd Ave.	23.36	Physical	Roadway flooding elevation	Z
Chinook RV Storage	17.64	Structural	1' lower than lowest finished floor at storage facility	AA
Airport runway culvert	20.44	Operational	1’ above culvert crown	BB
Structures along NE Marine Dr.	27.63	Structural	1' lower than lowest finished floor	CC
CoT Sanitary Pump Station	27.00	Operational	Critical elevation at sanitary pump station	DD
Low point on I-84	34.02	Physical	Highway flooding elevation	EE
Motel 6 roadway culvert	29.84	Operational	1'above culvert crown	FF
Historic Columbia River Highway	53.50	Physical	Roadway flooding elevation	GG
Marine Drive Double Culvert near Sandy Pump Station	13.95	Operational	1' above culvert crown	HH
Marine Drive Culvert near west end of airport runway	27.47	Operational	1' above culvert crown	II
PGE Transmission Station	16.71	Structural	Facility elevation	JJ
Sundial Road NE of intersection with NW Marine Dr.	25.67	Physical	Roadway flooding elevation	KK

Note: All elevations based on NAVD88.

3.4.4 Hydraulic Evaluation

The capacity of the conveyance network and pump station was evaluated using a hydraulic computer model. A series of storm events and land use conditions were evaluated in the hydraulic model, and water surface elevations were recorded at each of the reference points in Table 3-3. When the modeled water surface elevations are estimated to exceed the critical elevation, the surrounding system (conveyance network and possibly the downstream pump station) will be considered under capacity for the given storm event.

For the DMP, design storms will be evaluated within the model, for the 5-, 10-, 25-, and 100-year recurrence intervals to develop an understanding of the current and projected future capacity in each area of the drainage district. This suite of events is used to address nuisance flooding, during the 5 or 10-year events, the 25-year design event, and the 100-year major flood event. Systems that are not shown to provide 100-year capacity will be flagged as potential problem areas but are not required to pass the 100-year event without flooding. Only the Sandy pump station is evaluated and expected to move the 100-year event without flooding.

3.5 Design Criteria

When designing projects for flood protection, requirements are guided largely by FEMA FIRMs. However, protection from flooding, as it relates to this DMP, includes smaller events that may not be the 100-year event. Protecting SDIC and the CoT from nuisance flooding or flooding due to conveyance irregularities also informs the level of service.

Events or conditions that may result in flooding include but are not limited to:

- Pump station under capacity
- Pump station condition failure
- Pipe or culvert under capacity
- Pipe or culvert condition failure
- Beaver dam blockage
- Culvert or pipe inlet blockage
- Significant sediment accumulation in ditches (partially or fully blocked ditch)

SDIC and the CoT are charged with managing these systems such that the instances listed above do not increase the risk of flooding that could cause damage to public or private infrastructure.

Design criteria applicable to this DMP includes both a design event, to assess the capacity of existing infrastructure and identify potential project alternatives, and design standards, to ensure that a project follows local, state, and federal codes, standards, and permitting requirements. Final design of any project alternative will require a more detailed review of the proposed project concepts and incorporate more detailed topography and localized information. The final design modeling should look at the larger range of flows and consider upstream and downstream impacts in more detail.

3.5.1 Design Event

The 25-year event has been selected as the design event for potential project development, as this is the design event for CoT. The 100-year event will still be used to verify proposed project concepts, regardless of ownership, do not result in flooding. This design event will apply to all infrastructure not influenced by backwater and driven by gravity.

For project development in both backwater areas and gravity areas, water surface elevations during the design event will be compared to the reference points and critical elevations, as described in Section 4.2. Design event water levels will also be compared to the nearest finished floor elevation and nearby structures to verify that the proposed project concept meets local, state, and federal standards.

Changes in infrastructure or pumping capacity are likely to impact the ability of the SDIC to pump out the 100-year event. During final project design, the evaluation must also verify that there will not be an increase to the 100-year water surface elevation, which could impact the mapped floodplain. When capital projects have the potential to impact the floodplain, the preferred solution will be modeled for the 100-year event and compared to the water surface elevation in the latest FEMA FIRMs. This additional verification will identify whether any proposed project could require a Conditional Letter of Map Revision or Letter of Map Revision application, which may increase development costs.

3.5.2 Design Standards

Projects to address system condition assessments, conveyance system rehabilitation, pump station functionality and operation, structural integrity, and system redundancy should identify the guiding standards prior to design as the appropriate design standards and guidelines for each project will vary and is complex with local, state, and federal agencies all represented. Regardless of a project's purpose, the design standards referenced for potential projects should be the most stringent of the local, state, or federal design standard in place. For conveyance system projects (gravity pipes, culverts, and open channels), the CoT design standards are adhered to when projects fall within the CoT's jurisdiction. Projects outside the CoT follow partner agency stormwater manuals and codes (Multnomah County, ODOT, Port of Portland [Port]). However, coordination between agencies is critical to ensure capacity is maintained throughout the study area.

When projects include open channels, additional consideration should be given to meeting requirements of the USACE, Oregon Department of Fish and Wildlife, and Department of State Lands, as those agencies are often involved with open water permitting. Municipal zoning requirements also influence project designs in these areas. Projects to upgrade pump stations or replace pump station components should follow the USACE Engineer Manual guidelines, the relevant documents are EM 1110-2-3102, 1110-2-3104, and 1110-2-3105, as described in Section 2.4.

3.6 Additional Considerations

The evaluation criteria presented below are based primarily on existing requirements and design standards. Other factors could influence the evaluation and design of the drainage system including climate change, infrastructure resiliency, continued involvement by partner agencies, modified reference elevations, and other outside influences. Climate change and resiliency are discussed further below.

3.6.1 Climate Change

CoT and multiple agencies in the region are working on programs and initiatives to evaluate and address the impacts of climate change on drainage systems and how resiliency can be integrated into planning efforts. Partner agencies are taking different approaches that may impact the study area infrastructure and operations.

The Port completed a stormwater master plan for the Portland International Airport in 2015. Based on the findings from the International Panel on Climate Change, the Port does not expect to experience much change that would impact operations based on the goals of minimizing flooding during the 10-year event. The Port's master plan summarized the climate-related changes expected in the future (i.e., the year 2060) as:

- Significant increase in number of hot days and nights
- Decrease in number of cold days
- 10 percent increase in rainfall total for long-duration events and in number of heavy rain days per year
- Decrease in snow and frost days
- Increase in duration of extended dry days

Based on these expected changes, the Port elected not to adjust master planning design storms to account for climate change.

The USGS completed a study in 2018 and determined future flood stage elevations based on climate change (USGS 2018). The study predicts an increase in peak water surface elevations ranging from 4.13 feet to 5.40 feet above the measured 1996 peak flood stage.

Additionally, although outside the study area, the City of Portland is evaluating numerous climate models to inform an approach to manage and plan for infrastructure updates in the future, which may provide valuable information for the Stakeholders. The models indicate a number of possible climate-related outcomes in the region as the climate changes. As a result, Portland is taking an approach of conducting vulnerability analyses and developing robust solutions based on multiple potential failures.

Moving forward, it is recommended that model updates consider climate change assumptions and revised assumptions are tracked and reviewed every 5 years. The study of climate change is evolving quickly, and results will likely become less varied and provide more certainty of potential changes that may impact CoT and SDIC. As this occurs, SDIC and the CoT may need to adjust standards, O&M protocols, planning horizons, and their overall approach to managing drainage infrastructure.

3.6.2 Seismic Resiliency

SDIC is responsible for management of the levee system as well as the interior drainage area (which is defined as the area inside the levees) that both mitigate the risk of flooding the area. Troutdale Airport, heavy rail and transportation infrastructure, and economic centers rely on SDIC and the CoT drainage infrastructure and levee system to remain operational and free from inundation.

In the event of a Cascadia Subduction Zone (CSZ) earthquake, the integrity of the conveyance system and ability to pump water out of the interior drainage area will be critical to the recovery of the region. The Troutdale Airport may be an essential operational center for the short-term recovery of the area, as it may be used for moving goods in and out of the region during recovery from a large CSZ event. Much of the low elevation areas may be subject to liquefaction and not be functional for some time following a large CSZ event.

A seismic resiliency evaluation is beyond the scope of the DMP. The Stakeholders may consider future action to create a seismic resiliency plan for the critical conveyance network. The scope of a seismic resiliency evaluation could include the following steps:

- Establish recovery level of service goals following a CSZ seismic event. The Oregon Resiliency Plan and National Institute of Standards and Technology provide some guidance on structuring recovery goals

- Complete seismic hazards evaluation for the critical network to refine seismic hazards based on DOGAMI, USGS, and locally available data
- Evaluate vulnerability of critical network infrastructure including the pump station and open channel conveyance
- Develop a hazard mitigation plan to achieve level of service goals and incorporate recommendations into the Capital Improvement Program.
- Specific to a seismic resiliency evaluation, the Sandy Pump Station and the critical conveyance network should be included and specific scope items regarding the pump station could include: Structural performance of Sandy Pump Station
- Structural performance of key conveyance structures, including pipes, culverts, and bridges
- Mechanical and electrical systems, including power and backup power for Sandy Pump Station
- Mechanical systems and key replacement parts to have available
- Access to the pump station during emergency events
- Pump station redundancy

Prior to a seismic resiliency evaluation, the capital projects recommended in the DMP should incorporate seismic resiliency improvements during the final design phase to improve structural integrity and increase redundancy and/or resiliency of existing systems and structures.

Section 4

Condition Evaluation–Pump Station

The condition evaluation for pump stations uses a composite condition rating score to assess deficiencies. Evaluation criteria, presented in Section 3.1, provided the planning framework used to determine the scoring and inform pump station upgrade needs, as well as a long-term maintenance and replacement strategy.

The Sandy Pump Station, shown in Figure 4-1 was upgraded in 1998 and is currently in poor condition. Pump station components deteriorate at different rates, based on the age, amount of use, pump cycling, stresses, and maintenance activity. Deficiencies identified during the field inspection include the lack of standby power or transfer switches, and a deteriorating wet well structure. Pump vibrations were also observed which may contribute to system deterioration. Background

Figure 4-1. The Sandy Pump Station in 2019

4.1 Background

The condition evaluation for the Sandy Pump Station was performed through a series of field investigations and technical analyses. Record drawings and interviews with staff were also used to document the conditions of pump station system components (mechanical, structural, electrical, site/access, and outfalls) and the functional performance (pumping capacity) of the pump station.

In addition, an outfall condition assessment (Section 4.3) included a more detailed assessment of the pump station discharge (force main), gravity, and outfall pipes. Pump testing (Section 4.4) was performed to evaluate the deterioration of the pump station, compared to the expected performance.

4.2 Condition Assessment

The findings from this assessment can be used to conduct a criticality analysis that includes an evaluation of the risk and consequence of failure. The outcomes also provide a list of deficiencies that can be used for capital project planning and to inform the development of long-term maintenance and replacement strategies.

The evaluation criteria for the Sandy Pump Station components, outlined in Section 3.1, considered the following:

- Is the component present?
- Is there redundancy for the component?
- Are record drawings and data available for the component?
- Component maintenance history

- Component upgrade history
- Component age
- Maintenance access
- Pump operation
- Obvious safety issues
- Reported security issues

Details on the process used to complete these evaluations is included in the *Pump Station Condition Assessment* (Parametrix 2016). The 2016 condition assessment ratings were based on the USACE guidance for best practices in asset management (USACE 2013), which uses an alphabetical rating system (A through F) to determine the condition of various pump station system components (see Table 4-1).

The alphabetical scores were translated to numerical values using A=5, B=4, C=3, D=2, and F=1. These numerical scores translate to excellent, good, poor, inadequate, and failing/failed, respectively. The District and the consulting team then worked together to establish a weighting system that would result in a composite condition rating score for the pump station. These weighting factors, listed in Table 4-1, were selected based on assumptions regarding the relative importance of each system component to the proper operation of the pump station.

Table 4-1. Sandy Pump Station System Component Condition Criteria and Weights

Component	Weighting Factor
Electrical	0.17
SCADA/Communications	0.10
Wet Well	0.10
Valves	0.03
Piping	0.10
Pumping Systems	0.25
Site	0.03
Building	0.22
Total	1.00

Combining pump station system component ratings (see *Pump Station Condition Assessment*, Parametrix 2016) with the associated weighting factor resulted in a composite rating score of 3.6 for the Sandy Pump Station. This indicates that the current overall condition of the pump station is poor.

In addition to the composite scoring, the condition assessment also documented pump station deficiencies. Additional analyses were subsequently recommended to better understand the overall pump station operation. These additional evaluations included an outfall condition assessment (Section 4.3) and pump capacity testing (Section 4.4).

4.3 Pump Outfall Condition Assessment

As part of this DMP, a more extensive condition assessment was performed on the discharge pipes and associated outfall components of the Sandy Pump Station. The original piping assessment

(Parametrix 2016) included only the section of discharge pipe within the station. This led to the piping system component of the overall station receiving a rating of 4.0, as shown in Table 4-2.

Table 4-2. Piping System Component Rating from the 2016 Condition Assessment (previous work)

Component	Grade	Score	Weight	Weighted Score
Piping	B	4	0.75	3.0
Pipe Supports	B	4	0.25	1.0
			1.0	**4.0**

The field investigation associated with the outfall condition assessment found the discharge force mains and outfall pipes were in generally good condition. However, the gravity outfall pipe had significant corrosion on a section of corrugated metal pipe at the end of the discharge line and rust on the outfall flap gate which did not seat flush. Additionally, there was some minor leakage past the isolation gates at the intake to the gravity discharge. Therefore, based on the outfall condition assessment conducted on October 8, 2019, the piping system component of the overall pump station was revised to a score of 3.7, as shown in Table 4-3.

Table 4-3. Updated Piping System Component Rating (the current work)

Component	Grade	Score	Weight	Weighted Score
Piping	B	4	0.45	1.8
Outfall Structure/Valve	C	3	0.35	1.1
Siphon Breakers/Air Vents/Isolation Valves	B	4	0.10	0.4
Valve Structure	B	4	0.10	0.4
			1.0	**3.7**

When the revised piping system score of 3.7 was incorporated into the overall pump station rating (using the weighting identified in Table 4-1), the updated composite rating for the Sandy Pump Station resulted in a score of 3.6, the same as the score identified in the previous work.

The *Sandy Drainage Improvement Company Force Main and Outfall Condition Assessment–Addendum No. 2 to the Pump Station Condition Assessment* (Parametrix 2020) includes a detailed description of observed conditions and deficiencies.

4.4 Pump Testing

The current pumping capacity of the pumps at the Sandy Pump Station were evaluated as part of this DMP. The pump testing was initiated to establish hydraulic pump curves for incorporation into the hydraulic model. The pump testing and data analysis also increases the understanding of current pump operations and leads to additional project and operational recommendations. These evaluations are documented in the *Sandy Pump Station Testing and Pump Curve Development Technical Memorandum* (Parametrix 2020).

Pump testing was performed in October 2019 on both pumps (No. 1 and No. 2) at the Sandy Pump Station. The data collected through pump testing were analyzed, along with pump reports and manufacturing formation to develop representative pump curves (Parametrix 2020). The pump curves were incorporated into the hydraulic modeling developed for this DMP (BC 2019).

Pump capacity is typically expected to deteriorate at a rate of 0.5 percent to 1 percent per year. However, excessive pump cycling can contribute to premature aging and reduced capacity of pumps. There are numerous potential causes of pump cycling, which are discussed in more detail in Section 6.5.4. Pump No. 1 was installed in 2018 and some components on Pump No. 2 were replaced in 2018 (Pump No. 2 was originally installed in 1998). Pump No. 1 was found to have a field test performance curve matching that of the manufacturer-published curve, as expected given the pump age. Pump No. 2 had some apparent reduction in performance to the left of the curve, but this resulted in only approximately a 3 to 5 percent reduction in pump capacity. Tested pump capacities compared to original discharge capacity are presented in Table 4-4.

Table 4-4. Sandy Pump Station Pump Test Results

Pump No.	Discharge Rate per Pump, gpm		Percentage of Original Performance	Notes
	Original	Current		
1	18,000	18,000	100	Pump is new; replaced in Fall 2018
2	15,200	14,300	95	Some pump components replaced in 2018

4.5 Findings and Recommendations

Although the pumps at the Sandy Pump Station are in new or good condition, the overall rating of the Sandy Pump Station (Rating = 3.6) is considered poor. Table 4-5 below summarizes the identified deficiencies. The identified deficiencies included items that prevent proper maintenance and condition monitoring at the pump station. Some deficiencies may have been corrected since the time of the assessment (October 2019).

Recommended improvement projects at the Sandy Pump Station include the following elements:

- Repair wet well substructure (and/or station replacement)
- Install new automated trash rack(s)
- Provide variable frequency drives on existing pumps
- Install a third pump and discharge force main to increase station capacity
- Provide backup power
- Replace flap gate on gravity outfall pipe
- Replace corrugated metal pipe section upstream of flap gate at outfall
- Replace isolation gates at gravity discharge influent structure
- Slip line/CIPP aging gravity outfall pipes (80 to 100 years old)

In addition, it is recommended that general maintenance such as surface recoating, exercising valves, and replacement of minor components be continued. Refer to Section 9 for program recommendations.

Finally, recurring pump testing is also recommended to evaluate and monitor pump operations. Recommended testing includes pump performance and capacity testing every 3 to 5 years (or more frequently) to track pump wear and ensure pump rebuilds are scheduled such that the pumps do not operate in a significantly degraded state, decreasing overall pump life.

Table 4-5. Sandy Pump Station Condition Assessment
Composite Rating = 3.6
Summary of Deficiencies[a]

Electrical

- Minor corrosion on exterior electrical enclosures
- Pump station reportedly receives “dirty” electricity periodically
- No transfer switch or standby power

SCADA/Communications

- Float switches not operating properly
- SCADA communications down due to failed PLC
- Flow meter measurements are reported to not be reliable/accurate
- No SCADA panel/screen

Wet Well

- Timber wet well perimeter intake structure partially rotted and deteriorating- signs of spot repairs observed; Structure supports pump room operating floor slab
- Anti-cavitation platform partially rotted
- Anti-cavitation steel baffles have significantly deteriorated or no longer present

Valves

- N/A (valves that are part of the outfall system included in “Piping”)

Piping

- West force main siphon breaker not seating completely during full siphon flow; requires adjustment
- Rust on gravity outfall discharge flap gate; gate does not seat flush
- No isolation or check valves on discharge pipes (but not required for current operation)
- No access manway on discharge pipes for maintenance
- Surface rust on metal piping, flanges, bolts, valves, and vent screens
- Minor spalling of concrete at gravity outfall discharge structure
- Some leakage into gravity outfall piping, past isolation gate valve, through wall anchor penetrations
- Southeast gravity outfall pipe has a 16-inch spalled out area at the 11th joint
- Southwest gravity outfall pipe has uneven joint cracking after 9th joint, and damage at the 16th joint where steel reinforcing wire is visible
- Minor crack on lid of siphon breaker vault; east force main

Pumping System

- No pressure gauges on pumps
- Combined pump capacity reported to not be capable to keep up with large storm events

Site

- Steep grade on gravel road difficult/unsafe for crane access to pump station
- Exterior lighting reported to not be sufficient to safely perform night work
- Erosion of driveway observed by southeast corner of pump station and wet well intake structure due to runoff drainage
- Security camera not operational
- Wood walkway over outflow pipes on north side is severely weathered and deflects excessively

Building

- Minor cracking and loose grout under pump bases
- Chipped concrete and exposed steel pipe in NW corner of floor
- Hole in exterior siding above electrical panels on east side
- Wood platform over debris grating is severely weathered and deflects excessively
- Debris tie-off is not certified
- Certified roof tie-off not installed
- Unsafe pump access on roof due to no roof tie-off and steep grade around pump station for crane and man-lift
- History of mice infestation

a. Deficiencies identified as of September 2016 (Pump Station) and October 2019 (Discharge pipes and Outfall). Some items may have been addressed at or since the time of this plan.

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Section 5

Condition Evaluation–Conveyance Systems

The Stakeholders' conveyance system includes open channels, culverts, and piped conveyance networks. As the conveyance system ages, the Stakeholders would like to establish a proactive program to understand the condition of the conveyance system and work with partner agencies to repair, rehabilitate, or replace highest priority pipes and culverts.

Ideally, a robust condition evaluation program for pipes and culverts would consist of visual inspections, photographs, or video documentation, Pipeline Assessment Certification Program (PACP) reports, PACP grading scores, and engineering evaluations to develop replacement or rehabilitation recommendations. As mentioned in Section 3.2, in the absence of a robust condition evaluation program and/or records, this Drainage Master Plan (DMP) relies on other sources of existing data such as GIS pipe age data and staff condition reports to evaluate the general condition of the drainage conveyance system and make project and program recommendations.

This DMP recommends projects to replace or rehabilitate deteriorated or failing infrastructure based on the reported general condition of the conveyance system, and programmatic efforts to develop condition evaluation programs for the Stakeholders in the future.

5.1 Background

From a conveyance system standpoint, the Stakeholders are responsible for moving water through and out of the drainage system to protect properties from flooding. The SDIC has not historically installed conveyance system infrastructure and does not own the conveyance network. The City of Troutdale (CoT) does install infrastructure and owns pipes and culverts within city limits. From an operational perspective, pipes and culverts have been constructed by private owners and partner agencies, including CoT, to facilitate development of property or allow for construction of roads. The SDIC visually inspects open channels and large culverts (Figure 5-1) to identify debris blockages and other conditions that may restrict the movement of water. The SDIC also operates pumps in "pre-storm" settings which lowers the water surface elevations and pulls debris through the conveyance network in advance of large storm events. CoT and partner agencies or private owners address underground infrastructure problems on an as-needed basis when failures or flooding occur.

Figure 5-1. The District regularly performs visual inspection of large culverts

As is typical across the Portland Metro region, drainage infrastructure is aging, and pipes and culvert systems are likely reaching the end of their design life. The Stakeholders' operations and capital projects have been primarily focused on maintaining pump stations and removing debris and other barriers in the conveyance system. However, the Stakeholders understand that more infrastructure replacement will be needed in the next several decades and is actively working with partner agencies to establish ownership and maintenance agreements regarding the drainage network.

The Stakeholders would like a strategy to prioritize inspections of the conveyance system and communicate inspection needs to partner agencies so that partner agencies can implement conveyance system rehabilitation/replacement projects when needed.

5.2 Existing Conveyance System Information

The goal of a traditional conveyance system condition assessment is to review existing condition information to identify areas of current or imminent failure as well as areas that are rapidly deteriorating. To date, there has not been a widespread assessment of buried stormwater infrastructure across the CoT, SDIC, or the areas where there is overlap. Establishing study area-wide baseline data would require a significant investment of financial resources. Therefore, a goal of this DMP is to outline a strategy that the Stakeholders can pursue to start collecting condition data to inform future capital project decisions.

5.2.1 Data Management

The SDIC has undertaken a significant data management effort to assemble a comprehensive GIS database of the conveyance infrastructure within SDIC boundary which includes significant portions of the CoT. This effort required merging of stormwater system mapping databases from multiple partner agencies, review of as-builts and other records, incorporation of survey data, and field investigations to resolve discrepancies. The SDIC now has standardized nomenclature and abbreviations for pipe materials, structure types, and channel types within the larger GIS framework that merges the nomenclature and abbreviations provided by the partner agencies.

The MCDD, on behalf of the four districts, is also working to establish its own asset identification and hierarchy to catalog and track the conveyance infrastructure within the District. This naming convention will allow the District to develop a larger asset management framework. However, because the naming convention is not tied to those of the partner agencies, District staff will need to routinely review partner agency data sets for changes and modifications and incorporate those changes into the District's database.

The SDIC is also in the early stages of developing an asset management program to further document infrastructure and develop a path forward for maintaining assets within their boundary.

The CoT is also making strides in understanding their infrastructure condition and managing the data. The CoT has a GIS for tracking infrastructure inventory, attribute data, storm drainage "trouble spots", and certain maintenance activities that is regularly updated and maintained. The inventory does include infrastructure that partner agencies own and manage such as the Port of Portland, ODOT and Multnomah County. The SDIC and CoT work together to maintain independent GIS data but coordinate to ensure the data is shared.

5.2.2 Critical Conveyance Network

The SDIC identified, as part of a previous study, the critical conveyance network which includes over 15,400 linear feet (LF) (2.9 miles) of pipe and culvert segments and 26,600 LF (5.0 miles) of open channel conveyance. These systems are largely owned by partner agencies or private property owners. Through data sharing with partner agencies, field investigations, and field survey, the SDIC has cataloged pipe material for portions of the critical conveyance network, as shown in Table 5-1 below. However, approximately 13,700 LF of the piped network (nearly 90 percent of the pipe and culvert system) does not have a recorded material type.

Table 5-1. Critical Conveyance Material Summary	
Material Type	Total Length, LF
Corrugated metal pipe (CMP)	1,116
Corrugated steel pipe (CSP)	154
Concrete	206
Steel	91
High density polyethylene (HDPE)	23
Unknown	13,685
Open channel	26,600

Table 5-2 lists the range of pipe and culvert sizes in the critical conveyance network. Pipe diameter has been recorded for most of the critical conveyance system. Where the pipe size is unknown, it is assumed to be 12-inch-diameter or smaller because mapping efforts have been focused on the larger portions of the drainage network. Assuming unknown pipes are 12-inch or smaller has been done to ensure the pipes are included in the database but do not overestimate the size. The largest culverts are 72-inch-diameter culverts under NE Marine Drive at the off ramp to NE 223rd Avenue.

Table 5-2. Critical Conveyance Size Summary		
Pipe Diameter	Number of Segments	Total Length, LF
<12 inch or unknown	80	13,816
15–18 inch	4	85
21–24 inch	0	0
30–36 inch	7	255
42-48 inch	16	709
54+ inch	9	484
Total pipe/culvert	116	15,349

5.2.3 Age of Infrastructure

The CoT has maintained pipe age for areas north and south of I-84 in the study area. Major lines within the CoT have pipe age data. The areas outside the CoT may not have information on the pipe age. There is a general understanding that most of the existing pipes and culverts were installed when development occurred; however, information regarding development age is not always available.

Pipe age in the CoT is generally recorded for public roadway projects and developments from 1970 and forward (see Figure 7, Appendix A, for a map showing infrastructure age). However, there are large portions of the SDIC where storm drainage systems were installed prior to electronic record keeping or installed by private owners without records. The oldest pipes and culverts in the SDIC are least likely to have recorded age information, and the most likely to be experiencing deterioration.

5.3 Existing Condition Data

Pipe information and age data can only provide basic clues as to the likely condition of stormwater infrastructure. Understanding the true condition of pipes and culverts requires visual inspection and engineering assessment. As is typical across the region, the Stakeholders have not collected or generated pipe condition data. Therefore, no assessment was completed.

5.3.1 CCTV Inspections

SDIC has an on-call contract to request the collection of closed-circuit television (CCTV) inspections. To date, CCTV efforts have been focused on pipes that impact the levees and other specific locations where there are concerns about blockages or deteriorated systems. Through the on-call contract, the SDIC receives inspection videos, and inspection reports with NASSCO PACP scores. At the time of this DMP, the SDIC had collected CCTV of critical conveyance infrastructure in one portion of the study area: the culvert under the levee connecting MCDD drainage to SDIC drainage.

CoT recently purchased a truck capable of collecting CCTV video and will begin collecting data and documenting their stormwater system once efforts to CCTV and document condition for the sanitary system is complete. The City will combine this data with their current GIS database to track scoring of pipes and infrastructure in a dedicated asset management platform.

The available CCTV inspection report for the levee culvert identify pipe and culvert segments with PACP scores of 4 and 5 (poor). However, further investigation of the CCTV report indicates that the scores are based on problems in isolated areas, primarily deformation or deterioration at the ends of the culverts. In case of the levee culvert, the video inspection was not able to proceed through the full length of the culvert due to debris or sediment blockages, so the PACP scores do not reflect the true condition of a pipe segment. This underscores the need for follow-up engineering assessments to develop a complete understanding of whether pipes need to be rehabilitated or replaced.

ODOT was not able to provide any CCTV or pipe condition data for pipes or culverts in the study area.

5.3.2 Engineering Assessments

As described in Section 3.2, CCTV and PACP scoring are only the first step in assessing pipe condition. All pipes with high PACP scores also need to be assessed by engineering evaluation to investigate the cause of the grading score, identify the remaining life of each pipe segment, and determine the recommended pipe rehabilitation or replacement strategy. To date, follow-up engineering assessments have not been performed on pipes in the study area critical conveyance network.

5.4 Findings and Recommendations

The Stakeholders intend to develop a strategy to prioritize inspections of the conveyance system, communicate inspection needs to partner agencies, and implement conveyance system rehabilitation/replacement projects where they are most needed. This strategy must consider both immediate needs for rehabilitation and an ongoing program to conduct regular CCTV inspections and condition evaluation/rating for the critical conveyance network. Refer to Section 9, Table 9-2 for program recommendations.

5.4.1 Pipe Rehabilitation

A short-term priority, once a CCTV data collection program implemented, is to rehabilitate or replace failing infrastructure that is within the critical conveyance network. This effort should focus on pipes that have already been inspected and identified as being in potentially poor condition. With no data to base rehabilitation work on, information including pipe age, firsthand accounts, and other metrics must be used. Based on staff reports and surveys, culverts suspected to need rehabilitation or replacement include:

- Double culverts (72-inch) under NE Marine Drive
- Double culverts (42-inch) under the cross-levee
- Piped system from Blue Lake to the outfall north of NE Blue Lake Road

During the project development process, described in Section 6, these pipes were added to the problem area table and considered for inclusion in the capital project list. The pipes within the Stakeholders critical conveyance network, NE Marine Drive, and levee culverts, are recommended for further assessment to determine whether the Stakeholders should support a capital project related to rehabilitation or replacement. The Stakeholders should support rehabilitation or replacement when engineering assessment identifies that the pipe or culvert is at risk of failure, or when the hydraulic model shows a pipe or culvert is under capacity and impeding the movement of water through the District.

5.4.2 Condition Assessment Program

At the time of this evaluation, existing condition data per CCTV inspections is not sufficient to outline a long-term rehabilitation and replacement program with an annual rehabilitation budget recommendation. Instead, it is recommended that the Stakeholders focus on the collection of widespread condition data to document baseline (current) conditions and track the deterioration of pipes and culverts over time. Long-term tracking through repeat inspections and condition ratings will provide the Stakeholders an understanding of which pipes are actively deteriorating, which pipes have stabilized with useful life remaining, and which pipes need immediate rehabilitation.

Figure 5-2. The Stakeholders need systematic CCTV data for the pipes and culverts in the critical conveyance network.

The condition assessment program should include pipe cleaning, CCTV inspection, NASSCO PACP ratings, and engineering evaluation of the pipes and culverts in the critical conveyance network (see Section 3.2). PACP rating scores can then be incorporated into the risk tool, developed as part of the MCDD and PEN2 master planning process, to understand the relative risk and consequent of failure which allows for the prioritization of infrastructure projects. The program should cover the 15,400 LF of pipes and culverts within the critical conveyance network, as shown in Table 5-2. Inspection costs are expected to be inflated in the study area, due to the quantity of large diameter culverts that will likely require significant sediment and debris removal prior to inspection.

Using SDIC's current on-call CCTV contract and pricing structure, the cost to clean, inspect, and develop rating scores for the entire critical conveyance network is included in the SDIC CCTV program. Refer to Section 9, Table 9-2 and Appendix F for program information. Once this program is initiated, the critical conveyance network should be the priority. It is recommended the critical conveyance evaluation be repeated every 10 years to monitor changes in pipe condition. There may be a cost savings from working with the Stakeholders to complete the condition assessment CCTV evaluations, as CoT owns CCTV equipment and has a shared interest in understanding the condition of the drainage infrastructure.

The critical conveyance network contains large quantities of CMP pipe and culverts of 36-inch-diameter and larger, which should be priorities for the inspection program. Pipes and culverts should also be higher priority for inspection if they are located across or adjacent to high traffic roadways, which is the case for culverts in the vicinity of Marine Drive, I-84, and NW Sundial Road. Finally, prioritizing culverts in proximity to buildings, railroad corridors, and other higher risk areas should be considered.

Section 6

Capacity Evaluation

The evaluation of the conveyance system for capacity includes pipes, culverts, open channels, weir, and pump station. These elements are the critical components necessary for moving water through and out of the study area. Due to the nature of this system, one collection system element not sized properly can create significant issues.

As a flood management agency, the SDIC is primarily focused on protecting properties from flooding during the 100-year event. The SDIC must also pay attention to the operation of pump stations and conveyance networks during smaller storm events and daily operations. The CoT is primarily focused on maintaining a collection network that meets their local design standards and reduces/ addresses localized flooding exceeding the 25-year design event.

The goal of this capacity evaluation was to identify areas of the drainage system that do not have capacity to convey a specified design event and to understand cause and severity of capacity concerns. In the long term, the District would like to provide 100-year conveyance through all parts of the drainage system while the CoT is focused on the 25-year conveyance. The capacity analysis shows that some pipes, culverts, and the pump station are well below meeting the current standard of the 25-year event. The pump station capacity evaluation is based on critical elevations for all events.

6.1 Background

Currently, the Stakeholders do not have a consistent list of criteria or standards for determining when individual parts of the conveyance system are inadequate or undersized. As part of this DMP, the Stakeholders updated the XP-SWMM hydrologic and hydraulic model of their system, as documented in the technical memorandum, *SDIC and North Troutdale Hydrologic and Hydraulic Model Update* (BC May 2020). The updated 2019 XP-SWMM model enables the Stakeholders to identify pipes, culverts or pump station that do not meet the minimum capacity requirements. The capacity analysis is one of the tools used in this study to identify deficiencies within the conveyance system and pump station infrastructure.

The capacity analysis covered the whole conveyance system in the Stakeholders XP-SWMM model, though project recommendations are focused on the areas of the identified critical conveyance network.

6.2 Conveyance System Capacity Methodology

The capacity analysis used the updated XP-SWMM hydrologic and hydraulic model (BC May 2020) to identify locations where the drainage system is not expected to meet the minimum capacity criteria of the 25-year design event as outlined in Section 3. Multiple evaluations were performed to evaluate whether the existing drainage system (conveyance network and pump station) is expected to have the capacity to convey select design storms. The evaluation also focused on identifying the cause of capacity problems, identifying whether a conveyance pipe or culvert is undersized or if the Sandy Pump Station is causing the restriction.

The following system evaluations included the identification of problem areas in the current drainage system and led to recommended project actions to correct system deficiencies. This evaluation assumed the Sandy Pump Station was operating given the operational settings documented in Section 5.

- Conveyance system capacity evaluation
- Pump station capacity evaluation

Each of the analyses assumed that the conveyance system was free of accumulated debris or other blockages that could restrict the flow of water. Debris accumulation is an ongoing challenge for Stakeholder operations and likely reduces the capacity of the drainage system. Further discussion of the effects of debris accumulation are included in Section 6.6.2.

The evaluations in this section relied on existing land use and associated percent impervious area per land use and the anticipated future land use and associated percent impervious area per land use designation. Percent impervious calculation were not completed for this study, rather an area weighted curve number was determined based on the various land use designations for each subcatchment and associated curve number for each land use designation. The area weighted curve number for existing and future conditions are 71 and 91 respectively for the entire modeled basin. For the initial assessment of drainage system capacity of both the conveyance system and the pump station, multiple storm events were modeled, including the 5-, 10-, 25-, and 100-year SCS Type IA 24-hour rainfall events. Existing and future development scenarios were run for these storm events. For the definition of existing and future land use, curve number development, percent impervious per land use and design storm hydrologic calculations, refer to the *SDIC and North Troutdale Hydrologic and Hydraulic Model Update* (BC May 2020).

6.3 Conveyance System Capacity Evaluation Method

The typical mechanism for analysis of a conveyance system that was used in this evaluation is to run multiple design events through the model to identify where the system has deficiencies. The typical method calculates the rate water moves through the system, and confirms whether the current capacity of the pipes, culverts, and channels is sufficient to move the water through the system. To assess capacity/flooding, the water surface elevations simulated in the model were compared to the elevation of structure rims, adjacent roadways, and critical elevations as outlined in Section 3.

Most commonly, this approach assumes that conveyance capacity is driven by gravity and the slope of the conveyance infrastructure. However, flow capacity in the Stakeholders' conveyance system is driven by gravity and by the pump station at the outfall. Therefore, the rate at which water moves through the system is a function of the pump station capacity, near the bottom of the system, and mostly gravity in the upland portions of the system.

6.3.1 Model Analysis

The single design event selected to evaluate the capacity of the conveyance system is the 25-year event with the existing land use. Locations under-capacity for the 25-year event are assumed to be under capacity for larger storms. The pump station capacity evaluation was measured for all events including the 100-year event. Flooding was defined as the modeled water surface elevation exceeding the rim of the manhole, or the ground elevation at the top of bank of a channel or culvert. Locations where the model shows flooding are displayed on the problem area map on Figure 6, Appendix A.

A flooding problem identified by the model may or may not reflect a pipe that is undersized. Instead, the cause of the flooding could be a result of backwater resulting from poor pumping, a low point in the system, or a downstream structure causing backwater effects.

This analysis provides an overall understanding of areas that are likely to have flooding issues. Capital improvement projects have been identified using this information to help focus on and highlight those areas that appear to be most problematic. Tabulated model results for existing and future model runs are provided in Appendix C.

6.3.2 Conveyance System Capacity Results

With current pump station conditions and current pump station settings and future land use conditions, the conveyance system analysis showed conveyance-related capacity concerns in the following locations:

- The low point along the Historic Columbia River Highway under the railroad tracks
- Arata Creek at siphon under I-84
- Arata Creek at the railroad tracks (this is outside the SDIC and CoT boundary) south of Carl Diebold Lumber
- NW Dunbar Avenue, various locations
- Arata Creek south of NW Marine Drive to Carl Diebold Lumber
- Arata Creek from NW Marine Drive north to Rogers Circle
- Salmon Creek at the Troutdale Airport runway

6.4 Pump Station Capacity Evaluation

The pump station capacity evaluation included use of the 2019 XP-SWMM model to perform a critical elevation water surface comparison. The exercise included simulating a series of rainfall events to compare the resulting water levels to critical elevations across the study area. Rather than looking only at points where design storms exceeded rim or roadway elevations, the evaluation was based on the reference points and critical elevations (see Section 3.4.2). The pump station capacity evaluation established the current operation water surface elevations for the 5-, 10-, 25- and 100--year events with current pump curves and evaluated whether that level of service could be maintained under future land use conditions.

6.4.1 Model Evaluation

The critical elevations are the primary mechanism to assess pump station capacity. For this analysis, each of the design storms were routed through the 2019 XP-SWMM model and the peak water surface elevations at the pump station was compared to the critical elevations. If the water surface elevation exceeded the critical elevation during the 25-year event but remained below the critical elevation during a 10-year event, the pump station was considered to provide 10-year rainfall event level of service. The analysis included running the hydraulic model and conducting the capacity evaluation for the 5-, 10-, 25-, and 100-year design storms for both existing and future land use scenarios.

6.4.2 Pump Station Capacity Results

The pump station capacity evaluation showed that the Sandy Pump Station provides varying levels of service. Under current conditions the Sandy Pump Station has the capacity to convey the 100-year event and maintain water surface elevations below the critical elevations under future conditions (2035), storms larger than the 5-year event would likely result in some critical elevations being exceeded resulting in flooding. These evaluations assume an idealized condition where all conveyance systems are flowing free, without debris blockages at culverts or at the pump station intake. Blockages in the conveyance system or at the pump station will reduce the capacity below what is simulated through this model evaluation.

Additional pump station capacity will be necessary to protect infrastructure and property from inundation based on the modeling for the future full build out (2035) scenario. Modeled scenarios to assess additional capacity reflect the addition of pumps (with the same capacity as the current Pump 2) to reduce the water surface elevation below the critical elevation at the pump station for all modeled events up to the 100-year event. Based on this analysis, two additional pumps, each with the same capacity as Pump 2 (or the equivalent capacity with one larger pump) will be necessary to provide sufficient pump capacity for future conditions. This additional capacity results in a peak water surface elevation of 15.9 feet, 0.79 feet below the critical elevation of 16.69 feet.

6.5 System Evaluations

Several model scenarios were explored in more detail to investigate the capacity of the existing system. These model evaluations included situations to investigate potential corrective measures or systems that required a focused evaluation. The modeled alternatives or investigations carried out are included below with a brief explanation of the evaluation.

6.5.1 Pump Settings Evaluation

An evaluation was performed in 2019 for MCDD and PEN2 which included modelling the current conditions infrastructure with pump stations at "pre-storm" settings and "winter" settings to understand the effectiveness of the pre-storm settings and to assess which settings should be used for DMP alternatives evaluations.

The pre-storm settings reduce the water surface elevations below winter settings to provide additional capacity prior to a large storm and to ‘pull’ debris through the system so it can be removed prior to an event. Modeling for MCDD and PEN2 shows that pre-storm settings did not make a meaningful difference in water surface elevations during peak storm events, though continued use of pre-storm setting as a means to collect debris is recommended. The current operating modes will remain as the standard settings and the winter setting was determined to be the basis for evaluating potential project solutions.

While this evaluation was not performed for the SDIC and North Troutdale study area, the MCDD and PEN2 studies suggest that evaluating alternatives with the higher WSE “winter” settings is correct.

6.5.2 Blue Lake Flood Storage Evaluation

The connection between SDIC and Multnomah County Drainage District #1 (MCDD) through the cross-levee at NE 223rd was evaluated to determine the available flood storage within the Blue Lake Regional Park and surrounding vicinity currently used by SDIC during large events. This evaluation focused on the benefit of the flood storage to SDIC and did not consider management of the daily contribution of MCDD drainage to SDIC. To simplify this model and isolate the impact of Blue Lake park, the Troutdale Industrial Park (TRIP) weir was not included in this evaluation.

The area west of the cross-levee falls within the MCDD jurisdictional boundaries while the area to the east is part of the SDIC analysis area. Two, 42-inch culverts provide a hydraulic connection between MCDD and SDIC. Originally, a sluice gate was put in place for the purpose of closing the culverts in the case of an emergency. This gate is no longer functional and has been permanently set in the open position. The area within MCDD drains naturally to the two culverts and ultimately to the Sandy

Pump Station. When the pump station is unable to pump the volume of water out at a rate equal to or greater than the runoff rate, the water rises and the MCDD area west of the levee is used by SDIC for additional flood storage.

The watershed area contributing to the Sandy Pump Station, from MCDD is approximately 263 acres. This is roughly 11 percent of the total 2,380 acres that drain to the Sandy Pump Station. The area includes Blue Lake, some residential areas, Blue Lake Regional Park, the surrounding area, and associated roadways. A significant portion of the area is pervious while the lake, homes and roadways are impervious and expected to remain unchanged for the planning horizon.

Additional details on the storage volume available, infrastructure, and general layout of the area west of the cross-levee is outlined in the MCDD memorandum titled, *Development of the Storage Curve for Blue Lake Drainage Basin*, dated November 25, 2019. The information provided in that memorandum was incorporated into the model for this study. The 42-inch culverts under the cross-levee have accumulated debris which limit flow to at least 50 percent of their capacity, however, these have been modeled for this study as 100 percent open to understand the full potential of the system.

Table 6-1 lists the results of the evaluation for the WSE at the Sandy Pump Station for the 5-, 10-, 25-, 50-, and 100-year 24-hour events when comparing both the existing and future model with and without the Blue Lake storage area. The 50-year event was included in this Blue Lake evaluation to provide an additional data point for comparison of the WSE with and without the Blue Lake storage.

Table 6-1. Blue Lake Flood Storage Impacts

Flood Storage Scenario[a]	Sandy Pump Station[b] Water Surface Elevation per Design Event				
	5-year	10-year	25-year	50-year	100-year
Existing model with Blue Lake	14.5	15.2	15.6	16.0	16.6
Existing model w/o Blue Lake	14.3	15.1	15.5	15.8	16.4
Future model with Blue Lake	17.5	18.2	18.5	18.9	19.5
Future model w/o Blue Lake	17.7	18.5	18.9	19.4	20.2

a. All model runs were completed without the TRIP Weir.

b. Sandy Pump Station critical elevation is 16.69 feet.

The existing model reveals only minor changes in the WSE for all events when comparing the two-flood storage scenario; differences vary from 0.2 to 0.1 feet. The model without Blue Lake flood storage shows slightly lower WSE. These elevation differences are insignificant compared to the water surface elevation differences during the events that vary by more than 2 feet.

The future conditions model shows the flood storage would likely provide more benefit than the existing conditions model. The water surface elevation differences increase without the Blue Lake flood storage for all events; varying from 0.2 to 0.7 feet. The greatest water surface differences occur during the 100-year event.

The future model represents more development creating a higher percent impervious area, which will result in increased peak flows reaching the pump station in a shorter period of time when compared to existing conditions. Blue Lake flood storage appears to alleviate some of the impact development has on the Sandy Pump Station, as observed by the lower WSE.

While the flood storage available from Blue Lake provides some storage volume for the future scenario in the SDIC to alleviate backwater conditions, the 263 acres of runoff also provides significant input to the system. Based on the modeling the current water surface at the Sandy Pump Station is higher with Blue Lake than without. However, in the future, as additional development occurs and the SDIC drainage area becomes more impervious, the additional storage provided by Blue Lake reduces the WSE at the pump station by a maximum of 0.7 feet during the 100-year event.

Currently, SDIC receives no flood storage benefit from the Blue Lake area and begins to receive a flood storage benefit during the 5-year event under future conditions.

More study may be necessary to understand the costs associated with any decision made to modify the current SDIC and MCDD infrastructure, and how the resulting change in water surface elevation may impact properties in the area. Refer to Section 9 for projects informed by this evaluation.

6.5.3 Preliminary TRIP Weir Evaluation

The TRIP Flow Control Structure known as the “TRIP Weir”, includes an adjustable weir and a 60-inch culvert with a circular gate valve. This structure was constructed by SDIC in coordination with the Port of Portland, CoT, and Multnomah County, to manage water surface elevations within the West Sundial Wetlands. The wetlands serve as mitigation for the Port’s development of the TRIP. The wetland also provides flood storage for SDIC.

To establish the wetland, Salmon Creek was split into two channels shortly after merging with Arata Creek. The northern reach (also referred to as, the Sundial Channel) flows through the West Sundial Wetland. The other reach, which drains to the west, represents the original Salmon Creek channel. It conveys stormwater through culverts under Marine Drive twice before the two reaches join again in the forebay of the Sandy Pump Station.

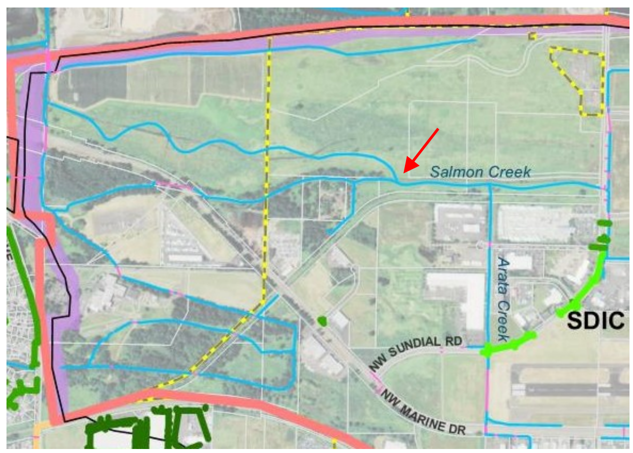

Figure 6-1. Salmon Creek split location

Red arrow highlights Salmon Creek split

Prior to construction of the West Sundial Wetland and the TRIP Weir, the wetland area was a shallow grass-filled basin that was not directly connected to Salmon Creek. Rainfall contributions either infiltrated or flowed west into the Sandy Pump Station forebay via two, 4-foot-diameter culverts located where the TRIP Weir now sits. During high-water events, water could overtop the north bank of Salmon Creek channel and spill into this area. SDIC could close the tide-gates on the two, 4-foot culverts allowing the basin to store water until it could be slowly released into the Sandy PS forebay.

Table 6-2 lists the results of the 2019 XP-SWMM model comparison of the system, reflecting conditions with and without the TRIP Weir, and the resulting WSE at the Sandy Pump Station for the existing and future models. The 50-year event was included in this Salmon Creek evaluation to provide an additional data point for comparison of the WSE with and without the Blue Lake storage. For the model runs completed with the weir, all culverts associated with the weir were closed and the water was forced over the weir when the WSE reached 19.0 feet.

Table 6-2. TRIP Weir impacts on Water Surface Level Evaluation at Sandy Pump Station[a]					
Model Scenario[b]	Event, feet				
	5-year	10-year	25-year	50-year	100-year
Existing Model–no weir	14.5	15.2	15.6	16.0	16.6
Existing Model–weir included	13.5	14.6	14.9	15.3	15.9
Future Model–no weir	17.5	18.2	18.5	18.9	19.5
Future Model–weir included	16.6	17.2	17.5	17.7	18.1

a. Sandy Pump Station critical elevation is 16.69 feet.

b. All model runs completed with Blue Lake flood storage included.

The existing conditions model shows the weir reduces WSE by 0.6 to 1.0 feet depending on the design event. The largest reduction occurs during the 5-year event. The future model evaluation shows the weir reduces WSE by 0.9 to 1.4 feet. This suggests as the drainage area develops and becomes more impervious the weir will provide more benefit than under existing conditions, especially during the larger events as the greatest benefit occurs during the 100-year event. While this future condition weir benefit is not advantageous given the current critical elevation of the pump station, the benefit of the weir would be realized for future conditions if the pump capacity is increased.

Additional review of the model dynamics suggests the 5-foot culvert (near All Wood Recyclers) under Marine Drive, while undersized, is providing some benefit. The WSE across the culvert is much higher at the upstream end than the downstream end. This suggests the culvert is acting as an orifice restricting water from moving downstream via Salmon Creek, and instead is forcing water north into the Sundial Channel. This is true for all events modeled.

Further study would be required to develop options for additional optimization of the TRIP weir. Additional water could likely be stored in Sundial Wetlands, in a more controlled manner, by providing a control mechanism or gate at the 5-foot Marine Drive culvert (near All Wood Recyclers) to maximize the storage behind the TRIP weir. Potentially, equipment could be installed to allow for real-time monitoring and optimization of the storage at any given time. This scenario could enable SDIC to store water up to the critical elevation of 16.71 feet which is the critical elevation at location JJ for the PGE Transmission station.

6.5.4 Blue Lake Flood Storage Evaluation with TRIP Weir Closed

Sections 6.5.2 and 6.5.3 provide results of the Blue Lake storage and the TRIP weir individual evaluations. This section combines these evaluations to better understand how the infrastructure interacts and to evaluate the water surface elevations for all modeling scenarios.

Based on the outcome of Sections 6.5.2 and 6.5.3 the current water surface elevations do not change significantly based on the storage volume provided in Blue Lake, refer to Table 6-1. As a result, only the future development scenario has been evaluated. These results are presented below in Table 6-3.

Additional critical elevation locations have been included to provide water surface elevation data across the study area for locations that may be impacted by the backwater associated with the pump station.

Table 6-3. Blue Lake Flood Storage Impacts with TRIP Weir–Future Model Scenario

Flood Storage Location	Critical Elevation	Water Surface Elevation per Design Event									
		5-year		10-year		25-year		50-year		100-year	
		Blue Lake Area Storage									
		With	Without	With	Without	With	Without	With	Without	With	Without
Sandy Pump Station (critical elevation location Y)	16.96	16.6	16.7	17.2	17.5	17.5	17.9	17.7	18.2	18.1	18.7
Marine Drive Double Culvert (critical elevation location HH)	13.95	16.77	16.80	17.32	17.62	17.60	18.06	17.85	18.36	18.18	18.78
PGE Transfer Station (critical elevation location JJ)	16.71	16.80	16.83	17.35	17.64	17.63	18.07	17.87	18.37	18.20	18.78
Sundial Road (critical elevation location KK)	25.67	26.59	26.59	27.30	27.30	27.40	27.40	27.45	27.45	27.55	27.55
NE 223rd Avenue (critical elevation location Z)	23.36	16.77	NA	17.32	NA	17.60	NA	17.84	NA	18.16	NA
Chinook RV Storage (critical elevation location AA)	17.64	16.80	16.83	17.35	17.64	17.63	18.07	17.87	18.37	18.20	18.78

Table 6-3 highlights the limits of the Blue Lake area to provide flood storage to this watershed, based on the changes to WSEs at critical locations in the system. Only the site east of Marine Drive is unaffected by removal of the Blue Lake area from the system (see Site KK along Sundial Road in Figure 5, Appendix A). All other sites included in Table 6-3 are located downstream (south or west) of Marine Drive and experience an increase in WSE as a result of the removal of the Blue Lake area from the system.

The results documented in Tables 6-1, 6-2, and 6-3 also demonstrate the benefit of the TRIP Weir. The TRIP Weir, and the associated wetland, enabled redevelopment at the TRIP property by reducing WSEs at the Sandy Pump Station, by an amount equivalent, to or greater than, the reduction that occurs with storage from the Blue Lake storage area. The data in Table 6-1 indicates that the Blue Lake area provides up to a 0.7 foot reduction in water elevation at the Sandy Pump Station for the 100-year future event (20.2 feet to 19.5 feet).

Per Table 6-3, when the TRIP Weir is included in the evaluation, the 100-year WSE at the Sandy Pump Station is reduced by 0.6 feet (18.1 feet to 18.7 feet) with and without the Blue Lake area for flood storage. The 5-year WSE at the Sandy Pump Station is reduced by 0.1 feet (16.6 feet to 16.7 feet) with and without the Blue Lake area for flood storage.

The data in Table 6-2 suggests the TRIP weir itself provides storage sufficient to reduce WSEs for these events by 0.9 feet (17.5 feet to 16.6 feet for the future 5-year event) and 1.4 feet (19.5 feet to 18.1 feet for the future 100-year event) at the Sandy Pump Station, potentially providing greater storage benefit than the Blue Lake area.

6.5.5 Potential Beaver Dam Impact

Beaver dams are prevalent across the study area and impact the movement of water downstream through the areas driven by gravity and have the potential to impact the pump station. An evaluation was performed in MCDD as part of the previous master planning effort to review how the beaver dams impact the conveyance of water and whether pump stations are affected. By building a beaver dam, or multiple dams, into the model, a conveyance channel has a higher water surface elevation. During small events or dry periods, the dams hold water and release it slowly to the next impounded water body. This prevents channel from fully draining and takes a much longer period of time to drain. Additionally, due to the slow movement of water downstream, pump stations are prone to cycling on and off more frequently. Frequent pump cycling can contribute to premature aging and reduced pump capacity. Beaver dams can also impact open channels, culverts, and pipes by reducing the conveyance capacity and reducing the ability of the system to move water downstream.

During larger events the beaver dams have little impact on the movement of water as the dams are submerged and water can move freely over them. Figure 6-2 shows the calibration results with and without, a beaver dam.

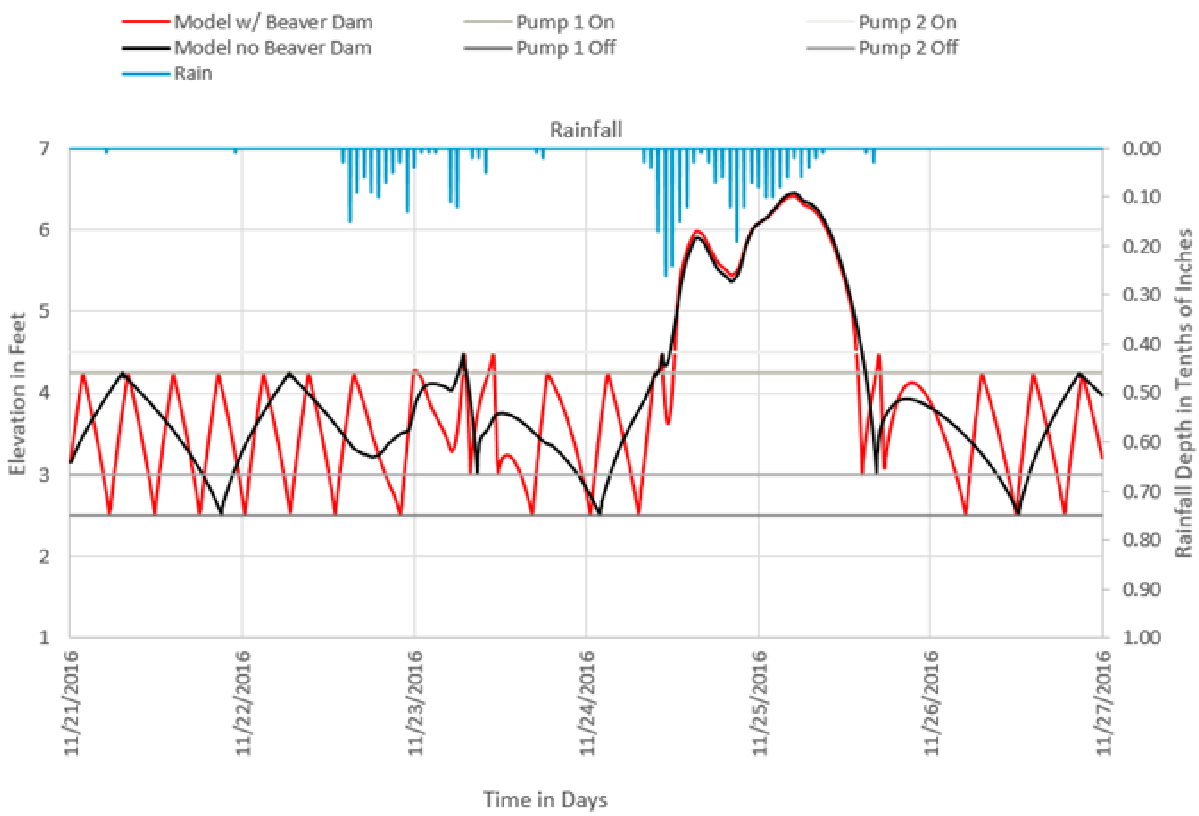

Figure 6-2. Impact on pump cycling frequency: areas with beaver dams vs. open channels

Beaver dams (red line) result in frequent on/off cycling of pumps, compared to open channels (black line)

The Stakeholders should manage the beaver population within the study area following the beaver management program, making sure to consider the beaver proximity to the pump station and the potential impact to the drainage system.

6.6 Sandy Pump Station Replacement

USACE initiated a Feasibility Study (October 2018–October 2021), focusing on Flood Risk Management of the Portland Metro Levee System in partnership with the Columbia Corridor Drainage Districts (CCDD) Joint Contracting Authority. The CCDD is comprised of four drainage districts: PEN1, PEN2, MCDD, and SDIC. A draft report was issued in January 2020 and includes an integrated plan to address potential system failures, meet current levee safety standards, and identify potential impacts from future changes including system consolidation, changing water flow conditions and potential operational changes to the Columbia River System.

USACE's final report will include a recommended replacement of the Sandy Pump Station at a higher elevation. While several deficiencies and subsequent recommended improvement projects have been identified based on the Sandy Pump Station condition assessment effort, a large portion of the recommendations could be most efficiently and comprehensively addressed combined into one overall pump station replacement project as recommended by USACE. Replacement would address key vulnerabilities, including the station's low elevation, it's relatively shallow storage pool, and narrow range of critical operating elevations, by relocating to higher ground. It would also address undersized intake deficiency, incorporate intake screening measures to increase reliability, and allow for potential capacity increase (see Section 6.4). The feasibility study process is anticipated to be completed in the Fall of 2021.

Following completion of the Feasibility Study, USACE recommendations will need to be approved under the Water Resources Development Act of 2020. Once authorized by Congress, there is the potential to receive up to 75 percent federal funding for Pre-Engineering & Design and up to 65 percent for construction costs. If everything goes as planned with no delays, the earliest a project from the Feasibility Study could move to construction would be during the 2023-2024 fiscal year.

6.7 Findings and Recommendations

The capacity analysis for this DMP included identification of capacity-related problem areas of the drainage system. The analysis evaluated both conveyance and pump station capacity, with a focus on the critical conveyance network and Sandy Pump Station.

6.7.1 Capacity-Related Project Recommendations

Capacity-related problem areas are shown as "modeled flooding areas" in Figure 6, Appendix A, and listed below. The list of project recommendations related to capacity problems follow. Note that associated pipe size recommendations are included in the CIP descriptions included in Section 9.

- The low point along the Historic Columbia River Highway under the railroad tracks need drainage improvements to limit ponding.
- Piped section of Arata Creek from Historic Columbia River Highway under I-84 to the north side of I-84. This siphoned section of the system is undersized.
- Arata Creek along the south side of the railroad tracks (this is outside the SDIC and CoT boundary) south of Carl Diebold Lumber. The culvert under the railroad track at this location is undersized.
- NW Dunbar Avenue, various locations flood locally due to limited storm infrastructure.
- Pipe under Carl Diebold Lumber is undersized.
- Arata Creek south of NW Marine Drive to Carl Diebold Lumber. This includes open channel and several culverts.

- The two primary culverts conveying Arata Creek and Salmon Creek under the Troutdale Airport are undersized.
- The culvert under Sundial Road draining Arata Creek is undersized.
- The culvert under Rogers Circle conveying Arata Creek is undersized.
- The culverts and drainage at the intersection of NE Marine Drive and NW Sundial Road are undersized, plugged or not operating efficiently.
- The culvert under NE Marine Drive near Allwood Recyclers is undersized in some instances when the TRIP weir is closed.

Critical Culverts. The following culvert improvements have been identified with the Stakeholders. They are part of the critical conveyance network though are undersized and cause flooding. These culverts are included in the potential project evaluation discussed in Section 8:

- Culverts along Arata Creek that cross two driveways and NE Marine Drive. These culverts back-up water into the open channel and cause flooding upstream and along NE Marine Drive.
- Infrastructure and pipes/culverts draining the Historic Columbia River Highway at the railroad underpass lacks adequate capacity.
- Arata Creek culverts at Sundial Road and Rogers Circle. As capacity is increased upstream of these culverts, additional flows will result and these culverts will need to be upsized to accommodate.

Pump Station. The following pump station capacity upgrades are included in the pump station capacity evaluation described in Section 6.4,

- Sandy Pump Station has a new and recently serviced pumps. The station has capacity for the existing land use conditions up to the 100-year event but can provide capacity only up to the 5-year event for future full build out conditions. Additional capacity is needed to address the increase in future flow.

6.7.2 Debris and Blockage Considerations

Debris accumulation and other blockages can restrict the flow of water through the system and reduce the capacity reported through this analysis. Two methods for reducing blockages include improving infrastructure (larger culverts or bridges) and ongoing operations and maintenance (physically removing blockages). In some cases, the operation and maintenance of the system is the most cost-effective method for minimizing blockages while in other cases where blockages are chronic, new, or improved infrastructure may be a better long-term solution.

Examples of debris accumulation or system blockages include the following:

- Culvert debris blockages can occur with and without proper inlet protection
- Beaver dams are often built in unusual locations that reduce flows, particularly during lower flow conditions
- Open channel debris blockages due to larger debris starting a chain reaction of debris gathering
- Debris build up on structures of all kinds
- Debris build up on the intake structures of the pump station

The impacts resulting from blockages are mostly negative to varying degrees. The beaver dam blockages can have a significant impact on pump station cycling, which causes additional wear and increased deterioration of the pumping components. Regular clearing of the drainage system may be needed to maintain clear conveyance systems, and during larger events, staff may be required to work through the night to maintain blockage free conveyance systems. Working to clear debris during the night has inherent risks and is generally not an ideal standard for maintaining a clear conveyance system.

The Stakeholders should consider opportunities to improve debris removal systems, both at the pump station and at culverts throughout the service area.

This DMP recommends the Stakeholders install passive debris barriers (see example in Figure 6-3) at culverts in the critical conveyance network and at other key problem areas that would allow debris to collect without impeding the flow of water and allow the safe removal of debris from the drainage system contingent on staff availability.

Refer to Section 9 for program descriptions.

Figure 6-3. Example of passive debris barrier at large culvert

Section 7

Water Quality Retrofit Assessment

As part of this Drainage Master Plan (DMP), an assessment and identification of stormwater quality (WQ) treatment opportunity areas was conducted for the City of Troutdale (CoT) within any areas that fall under their National Pollutant Discharge Elimination System (NPDES) MS4 permit. SDIC has not been issued a NPDES permit, as such, no water quality evaluation was completed.

7.1 Objectives

The CoT's current NPDES MS4 Phase II General Permit outlines stormwater requirements to reduce the discharge of pollutants to waters of the state to the maximum extent practical, to protect water quality, and satisfy the appropriate water quality requirement of the Clean Water Act. A water quality retrofit program is an ongoing practice to move the City towards reducing pollutant loading and is part of meeting Phase II requirements. SDIC does not have a Phase II permit or other mandates for water quality.

Three strategies were identified for water quality opportunity area development: regional water quality facilities, green streets, and additional underground injection controls (UICs). Regional water quality facilities and green streets were identified as a strategy due to the availability of vacant land, limited public stormwater conveyance system, and limited infiltration capacity of soils and high seasonal groundwater in the northern part of the study area. Additional UICs were identified as a strategy due to their previous use in the CoT and the presence of suitable soils in the southern portion of the study area.

7.2 Methodology

Water quality opportunity areas were initially identified through of a review of information from CoT and other publicly available GIS data including aerial photos, existing vacant areas, publicly owned lands, wetlands, outdoor recreation areas, existing and future condition land uses, storm system layout, and topography, and areas that have been designated for future stormwater treatment. The CoT's current CIP was also reviewed.

The following steps were conducted to identify the initial opportunity areas for water quality retrofits.

Step 1 **Identify vacant lands.** A review of vacant lands was conducted to identify parcels where space may be available for siting of a new regional water quality facility. Publicly owned vacant lands were prioritized, and wetland areas were removed from consideration.

Step 2 **Review existing CIP.** The City's 2016 CIP was reviewed to identify potential opportunities to couple water quality projects with other planned capital improvements.

Step 3 **Review land use.** Outdoor recreation and conservation areas were avoided, and high pollution generating land uses such as industrial facilities were prioritized for installation of water quality facilities. Residential streets, streets with relatively light use, and streets with existing road upgrade CIPs were prioritized for green street installations. Installation of regional facilities in areas adjacent to the Troutdale Airport was avoided due to concerns over attracting wildlife to controlled airspace.

Step 4 **Review stormwater drainage patterns.** Review of stormwater conveyance infrastructure and topography was conducted to identify drainage patterns to determine the most effective locations for water quality facilities.

Step 5 **Review future stormwater treatment areas.** The CoT has designated certain areas for stormwater treatment under future development. These areas were prioritized to anticipate future stormwater treatment projects.

7.3 Water Quality Retrofit Assessment Results

This section presents the results of the water quality retrofit assessment, including a preliminary identification of water quality opportunity areas and selection of 10 water quality retrofit opportunity areas. This assessment only identifies potential locations and types of WQ treatment systems. These will require further CIP development if pursued in the future. The identified potential water quality locations have been developed independent of capacity and flood mitigation CIPs. Water quality should be considered as part of all capital improvement projects where feasible.

7.3.1 Rogers Circle Area

The area, which is an area of particular interest to the CoT, surrounding NW Rogers Circle to the west of NW Sundial Road was also considered for water quality retrofits. As discussed with CoT staff this area does not contain significant public land and is largely composed of industrial development. However, it does contain areas identified for stormwater treatment when additional development occurs. Therefore, while specific water quality opportunity areas have not been identified at this time, opportunities for stormwater treatment, in addition to that required by the city, should be considered for all new development and for any roadway improvement projects in the area.

7.3.2 Initial Identification of Water Quality Opportunity Areas

Using the methodology described in Section 7.2, an initial water quality opportunity list was developed and reviewed with CoT staff. Some refinement of potential areas was then based on CoT feedback to finalize the locations. See Figure 8, Appendix A, for a map of potential locations. In addition, previously identified capacity, erosion, flooding, and infrastructure problem areas have been identified and should be evaluated during the design phase for the potential to integrate water quality enhancement.

Table 7-1 summarizes the identified water quality opportunity areas, the associated project description, and rational behind their identification. The opportunity areas identified below are locations with *potential* for water quality enhancement projects, and each may or may not be viable for varying reasons. This list is not intended to establish a firm plan for construction of the facilities described, but rather to provide a starting point for evaluating potential future water quality retrofit projects. Figure 8, Appendix A, identifies the location on a map of each proposed location listed in Table 7-1.

Table 7-1. Water Quality CIP Opportunity Areas

ID	Proposed Project Description	Project Rational	CoT Existing CIP (2007)
1a	Green street facilities in existing ROW in the neighborhood north of SW Cherry Park Road between SW Sturges Ln and SW Napoleon Pl.	There is limited WQ treatment in the neighborhood catchment area. Drainage is curb and gutter flow in the area with steeper terrain than most of the rest of the study area. There is potential for a programmatic approach with transportation improvements.	None
1b	Water quality facility in area zoned 'open space' near the southern portion of the Edgefield golf course	There is limited WQ treatment in the neighborhood catchment area. Drainage is curb and gutter flow in the area with steeper terrain than most of the rest of the study area. There is potential for a facility or several to provide treatment for this area that is underserved for water quality.	None
2	Regional facility in the area zoned Open Space on the southern edge of Edgefield golf course.	There is limited WQ treatment upstream of this area, and the zoning designation as Open Space offers a unique opportunity for the CoT to obtain land for the construction of a vegetated water quality facility that could integrate with the golf course.	None
3	Green street facilities in existing ROW along SW Halsey St west of Edgefield Meadows Ave.	There is limited WQ treatment in the area. There is an opportunity to treat stormwater collected from the Edgefield development and several vacant parcels north of SW Halsey and conveyed by the existing piped system along SW Halsey.	None
4	Regional facility in northeast corner of vacant land near the Columbia River Highway railroad crossing	There is limited WQ treatment in this area. The area has been identified for future stormwater treatment as it is developed, and also as a potential flooding problem area under future flows, including in existing CIP SD-N25. A regional facility could provide treatment and detention support during and after phased development.	SD-N25
5	Regional facility on vacant land SW of Chevron at NW Frontage Rd. and NW Culpepper Dr.	There is limited WQ treatment in this area. The area has been identified for future stormwater treatment as it is developed and will receive flows from planned Columbia River Hwy bypass CIP SD-N25. A regional facility could provide treatment and detention support during and after development.	SD-N25
6	Regional facility on vacant land along North Arata Creek west of NW Dunbar Ave.	There is limited WQ treatment in area, with two existing stormwater CIPs nearby. The area has been identified for future stormwater treatment as it is developed.	SD-N24, SD-N16
7	Treatment swale to replace existing drainage ditch west of main airport building off of S Entrance Rd.	There is limited WQ treatment in area, and an opportunity to modify an existing drainage ditch to treat runoff from adjacent airport impervious areas. A swale is proposed rather than a larger regional facility with standing water to limit wildlife attraction next to the controlled airspace. This facility would only serve runoff from the airport and should be constructed and maintained by the airport.	None
8	Treatment swale in ROW along NE Marine Dr near intersection with NW Dunbar Ave.	There is limited WQ treatment in area. There is an opportunity to add a treatment swale to the scope of planned CIP SD-N26, which is planned to connect the two north-south drainage systems. The street appears to have a wide ROW.	SD-N26
9	Green street facilities along NW Dunbar Ave.	There is limited WQ treatment in area. Dunbar is unimproved, is located in an area that has been identified for WQ treatment and has existing road upgrade CIP.	ST-045

The primary regulatory driver for water quality improvements is the CoT's NPDES MS4 permit. The SDIC is not subject to a NPDES permit and therefore has no regulatory water quality driver. Because of this and the understanding CIPs outlined in Section 9 are the primary subject of this plan, the water quality potential CIPs have remained separate.

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Section 8

Project and Program Development

Section 8 of the Drainage Master Plan (DMP) documents the process to compile information from many data sources and the technical analyses described in Sections 4 through 6 to develop project and program recommendations. The process included capacity and condition-related evaluations, problem area compilation, and a comprehensive project strategy workshop, attended by Stakeholder staff, that focused on selecting capital projects and programs to be included in this DMP.

8.1 Problem Area Compilation

The DMP development process included a substantial effort to compile and document locations of known problems. The resulting problem area map is included in Figure 6, Appendix A, and the complete problem area table is included in Appendix D. Drainage related problem areas were identified through the system evaluations and input from Stakeholder staff which included condition issues identified at the pump station, condition issues in the conveyance system, modeled flooding locations, suspected problems reported by property owners, flooding or debris accumulation problems reported by Stakeholder staff, and locations where the operations staff spend unequal time addressing repeated maintenance issues.

8.1.1 Problem Area Sources

The Brown and Caldwell (BC) project team used a variety of data sources to identify potential problem areas across the study area. Sources used to populate the problem area database are listed below.

- Meetings with SDIC and CoT engineering, operations, maintenance, and administrative staff. The problem areas identified in the DMP were sourced over time, during the entire curation of this DMP. During the project kick-off meeting, BC provided District staff with a problem areas survey to identify existing known issues. The results of this survey and follow-up discussions became the start of the problem list.
- Site visits by project staff, both with and without accompanying Stakeholder staff over the duration of the project. This allowed for the identification and follow up discussions regarding the nature of reported problems and often led to additional problem area identification.
- Impromptu calls and meetings with Stakeholder staff led to additional identification of problem areas. Operations staff provided long-term institutional knowledge about operations.
- Pump Station Condition Assessment described in Section 4.
- Conveyance System Condition Assessment described in Section 5.
- Capacity assessment for both the conveyance network and pump stations, described in Section 6.

8.1.2 Problem Area Documentation

The problem areas identified and documented through this DMP process were compiled into a GIS shapefile to include the location, problem type, problem description, and source of the problem identification. Problem areas were plotted for each reported incidence. In some cases, problems locations were adjacent or overlapping because multiple sources reported the same problem location, or one location had multiple problem types.

The drainage-related problem areas identified through this DMP process are included in Figure 6, Appendix A. The mapped problem areas are sorted by problem type, including:

- **Capacity**–problem areas that are thought to be the result of under capacity infrastructure.
- **Infrastructure**–locations of failing conveyance infrastructure or areas where there is not an adequate drainage system to manage local runoff.
- **Flooding**–reported flooding locations (modeled flooding locations were also included on the problem area map, designated differently from the locations where staff or property owners reported flooding).
- **Erosion**–reported erosion of open channels and ditches.

A detailed list of the problem areas with descriptions is included in Appendix D.

Beaver dams are an issue across the study area (See example in Figure 8-1). Beaver dams are transient in nature and are not identified as a problem area in either Appendix D or Appendix A.

Additionally, sedimentation is known to occur over time throughout the study area. Sedimentation is a long, slow process and as such, no areas are highlighted currently as problems–rather it is an ongoing process that requires attention.

Figure 8-1. Beaver deceivers are used to discourage beavers from building in problem areas.

8.1.3 Risk Tool Analysis

As part of previous DMP studies, the project team worked with MCDD staff to develop a Risk Tool in 2018 to compare the relative risk between drainage system elements. The Risk Tool provides composite scoring of the likelihood of failure and consequence of failure of all pipes, culverts, and pump stations. The process to develop the risk tool is documented in a technical memorandum titled *Drainage Master Plan Risk Tool*, (BC May 6, 2019). The Risk Tool was developed in a manner that will allow contributing data to be updated and re-analyze relative risk as conditions change over time.

The Risk Tool considers both risk of failure (the likelihood that a given system component will not meet the desired level of service) and consequence of failure (the impacts of failure of a given system component) to establish a composite score for each drainage element.

For this DMP, the Risk Tool was not used or included in the scope. The results and data from this study may be used as input to the tool where SDIC staff can develop risk, risk of failure and consequence of failure for the infrastructure within the SDIC study area.

8.2 Project Investigations

Following the problem area compilation, the project team worked to investigate potential solutions and possible capital projects. Some of these investigations included modeling, while others required no modeling. The investigations listed below include engineering investigations and those that required modeling of alternative projects.

The project investigations described in Sections 8.2.1 through 8.2.5 where completed to evaluate potential project feasibility, benefits, impacts, and costs.

When the project investigations required hydraulic modeling, the model runs were completed using the future land use scenario from the 2019 XP-SWMM model, documented in *SDIC and North Troutdale Hydrologic and Hydraulic Model Update (*BC 2020). No additional data collection or survey was completed as part of these project investigations.

The primary goal of investigating potential projects was to help clarify which problem areas or project opportunity areas required inclusion on the capital project list. Those projects deemed necessary and feasible were moved to the capital project list for conceptual project design and cost estimating. Those that did not provide significant improvements or achieve the desired outcomes were not included as recommendations in this DMP.

8.2.1 Arata Creek at I-84 north to the railroad tracks

Objective. The system evaluation provided insight to the most upstream infrastructure within the Arata Creek drainage system. The siphon that conveys flows under I-84 is under capacity and does not allow the peak of the larger storms to downstream. The culvert immediately downstream of the siphon that conveys flows under the railroad tracks is also under capacity and limits the peak flow downstream.

Approach. Using the hydrologic and hydraulic model the project team was able to increase the size of the siphon and culvert at the railroad tracks to understand how the infrastructure is impacting the downstream system.

Findings. Based on the model updated for this study and upsizing the pipes to allow unrestricted flow the peak flow would increase by approximately 50 cubic feet per second if appropriately sized. Upsizing of Arata Creek at these locations will not be included on the project list. This information does inform potential future upgrades that may be needed should these two locations be improved.

8.2.2 Arata Creek from railroad tracks north to NE Marine Drive

Objective. Current infrastructure is inadequate to convey the current design storm event and flooding occurs along NE Marine Drive frequently. Understanding why and where the flooding is occurring is important to developing a solution to limit or remove flooding from the area.

Approach. Utilizing the hydrologic and hydraulic model, the four culverts in question were upsized to reduce the water surface elevation during the design event. The culverts at the downstream end at NE Marine Drive were upsized first to ensure the ninety-degree bend and potential for debris collection did not propagate an elevated water surface upstream to the other culverts and locations where flooding is experienced. The other culverts were then upsized as need to ensure the entire reach of Arata Creek would remain in its channel.

Findings. The culverts and channel require upsizing to provide additional capacity under current conditions with the upstream infrastructure unchanged. If the upstream infrastructure at I-84 or the railroad are improved the upsizing of these culverts will require additional evaluation. Full details of the culvert sizing is provided in Appendix E. The infrastructure along this stretch of Arata Creek require upsizing and led to moving onto the project list.

8.2.3 Arata Creek from NE Marine Drive north to Rogers Circle

Objective. Sections 8.2.2 and 8.2.1 outline the infrastructure along Arata Creek upstream of NW Sundial Road and NW Rogers Circle and the need to upsize to reduce flooding and provide appropriate system capacity. Once upsized the downstream infrastructure will experience greater and increase peak flow. As a result, upsizing of culverts at NW Sundial and NW Rogers Circle requires investigation.

Approach. Utilizing the model with all upstream capital improvements completed the culverts at NW Sundial and NW Rogers Circle were sized for the 25-year design event and tested for the 100-year event during existing and future conditions.

Findings. The culverts at NW Sundial Road and NW Rogers Circle will need to be upsized to manage the increased flows resulting from future upstream improvements. Full details of the culvert sizing is provided in Appendix E. The infrastructure along this stretch of Arata Creek require upsizing and led to moving onto the project list.

8.2.4 Blue Lake Flood Storage Analysis

Refer to Section 6.5.2 for discussion of the Blue Lake evaluation. This evaluation did not result in a project moving onto the project list. However, this evaluation will help inform the Stakeholders when determining if the levee culverts should be replaced or removed.

8.2.5 TRIP Weir Evaluation

Refer to Section 6.5.3 for discussion of the TRIP Weir evaluation. This evaluation did not result in a project moving onto the project list.

8.3 Project Strategy Workshop

In January 2020, the project team held a Project Strategy Workshop with Stakeholder staff from engineering, planning, operations, policy, and other groups. The goal of the workshop was to examine problem areas identified in the study area and select the projects that should be further developed as recommended projects. The workshop focused primarily on capital projects, but also addressed programs and operational activities that should be included in the DMP. The resulting list of project and program recommendations is provided in the Action Plan outlined in Section 9.

The workshop was organized to discuss potential projects throughout the study area which includes projects in the CoT, SDIC, and the area where jurisdictions overlap. The potential project list, summarized in Table 8-1, was assembled by the consultant team. The list is based on the problem area table included in Appendix D, results of technical analyses, and research throughout the DMP process. Pump station projects included considerations regarding capacity and the condition of mechanical, electrical, structural, and site/access components. Conveyance system projects included considerations regarding the capacity and condition of pipes, culverts, and open channels.

The potential projects were identified with the following goals in mind:

- Systematically investigate the current condition, along with existing and future projected capacity of the conveyance network and pump station.
- Evaluate alternative solutions to address drainage problem areas.
- Identify capital investments to address internal drainage issues and present conceptual project solutions to be considered in the stakeholder's Capital Improvement Plan process.
- Recommend operations and maintenance adjustments to reduce risk of failure of the pump station and conveyance features.

These five elements, pulled from the above goals, provided some focus to identification of projects:

- Protect safety of the public and District Staff
- Provide operational and emergency access
- Keep flooding levels below critical elevations
- Replace aging or failing infrastructure and pump station components
- Water quality treatment

Identification of potential projects did not include considerations regarding stream restoration, or privately-owned drainage systems, as those are not within the scope of this study.

A summary of the discussions and decisions made regarding each potential project are included in Table 8-1. The resulting list of recommended projects is included in the Action Plan in Section 9. Some potential projects were removed from the list because Stakeholder operations staff had already addressed the higher priority needs based on the previously prepared Pump Station Condition Assessment (Parametrix 2016 2020). In some cases, potential projects were combined, split, or deferred to another agency.

Table 8-1. Project Summary from January 2020 Project Strategy Workshop

Potential Project	Project List Action	Notes and Comments
Sandy pump station maintenance improvements	Include	• Wet well substructure repair and/or station replacement • Install new automated trash rack(s) • Provide variable frequency drives on existing pumps • Install a third pump • Provide backup power
Sandy pump station maintenance and operation improvements	Include	• Future re-test of pump performance (~3-5 years) • Replace flap gate on gravity outfall pipe. • Replace corrugated metal pipe section upstream of flap gate at outfall. • Replace isolation gates at gravity discharge influent structure. • Slipline/CIPP gravity outfall pipes (80-100 years old).
Sandy pump station capacity and redundancy improvements	Include	Capacity increase/replace entire pump station
Blue Lake outfall	Remove	Multnomah County is the owner and is planning to replace.
Gate tower replacement	Remove	Need to look at cost to decommission vs. rehabilitation
Decommission levee culverts and build a new pump station in MCDD	Remove	The effort would likely be shared in some capacity with MCDD and would need to be coordinated with the gate tower project.

Potential Project	Project List Action	Notes and Comments
Double culverts under Marine Dr. replacement (C-2)	Include	Known to be in poor condition but data to support condition and replacement is not available. These are owned by Multnomah County, so cooperation and coordination needed.
Salmon Creek culvert under Port of Portland runway (F-6)	Remove	Owned by the Port of Portland and currently under design for replacement.
Salmon Creek open channel erosion (E-1)	Remove	There are many locations throughout the study area that have erosion concerns so a program to address this would better suit a solution than a specific project.
Arata Creek at Rogers Cir. culvert replacement (F-7)	Remove	The channel was cleaned and graded years ago and is now somewhat filled in with vegetation growth. This is likely better addressed through management or a program to address sediment.
Arata Creek Culvert at Sundial Rd.	Remove	This is thought to be a nuisance flooding issue and not due to the culvert being under capacity. Ownership is unknown and may need to be discussed
Arata Creek Culvert at Marine Dr. (I-1)	Include	Needed but may not be a high priority. This project may be grouped with E-3.
Arata Creek Culverts at driveways along Marine Dr. (E-3)	Include	Replacement will alleviate flooding of the adjacent properties and roadway. Likely should be coordinated with I-1.
Arata Creek Dunbar Ave. (F-12)	Include	No comments. Dunbar has no stormwater infrastructure and is an area with localized nuisance flooding.
Arata Creek South of SDIC and west of Troutdale in Wood Village	Remove	The system is at capacity but not within the scope of this study.
Arata Creek at railroad crossing of Historic Columbia River Highway	Include	A consistent problem area for the city and a known capacity issue. Identified as a problem area in the previous master plan.
SD-N26 Marine Dr. culvert bypass	Remove	Project identified in previous master plan but does not specifically address a known or modeled problem.
Arata Creek siphon under I-84 (C4)	Remove	Modeled capacity issue but owned by ODOT and not showing significant flooding.

Table 8-1. Project Summary from January 2020 Project Strategy Workshop

Prior to and following the project strategy workshop, the potential project list was compared to a list of recommended CIPs identified in the City of Troutdale's *North Troutdale Stormwater Master Plan* (OTAK 2007). Project needs from the 2007 Plan that align with current capacity problems per the capacity evaluation conducted for this DMP and are part of the critical conveyance network or important to the CoT are included in the recommended Action Plan outlined in Section 9. The 2007 project needs were reviewed to inform the problem area table, and then again once the updated project list was determined.

8.4 Program Development

Results from the project strategy workshop identified the need for Stakeholder programs to address maintenance and operational issues at multiple locations. The program needs identified during the workshop included:

- Debris barrier program to install debris barriers on the culverts in the critical conveyance network to reduce flow blockages and allow for easier removal of debris/vegetation from open channels (see Figure 8-2).
- Detention/retention study to evaluate the current flow control exemption given to developments within the drainage district and determine whether that exemption is appropriate or should be replaced with a specific design standard or fee in lieu program.

These programs are outlined in more detail in Section 9, along with other operational programs that were identified through the Pump Station and Conveyance System Condition assessments in Sections 4 and 5.

Figure 8-2. The debris barrier program would install or replace debris barriers across the District.

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Section 9

Stakeholder Drainage Action Plan

The Stakeholder Drainage Action Plan is a detailed action plan for projects, programs, and further areas of study to operate the internal drainage system and efficiently move surface water through the study area managed by the Stakeholders. Costs are rising, flows are increasing, and the drainage system is deteriorating with age and use. The Stakeholders need to be proactive in maintaining and replacing aging infrastructure, including the pump station and the pipe and culvert conveyance network. As a result of these needs, it is likely that the Stakeholders will need to plan for additional funding to manage the drainage system. The Stakeholders also need to plan for emergency response and system redundancy as the region has increased uncertainty over climate and seismic events.

9.1 Drainage Master Plan Recommendations

This DMP considers an integrated approach to managing the conveyance and pump station systems throughout the study area. The recommendations provide a long-term strategy to manage the storage and movement of water during large storm events. Based on the technical analysis and risk evaluation, it is recommended that the Stakeholders take the following actions:

- Replace failing or undersized conveyance infrastructure in the critical conveyance network and key locations in the City of Troutdale's (CoT) infrastructure.
- Plan for significant structural repairs to or replacement of the Sandy Pump Station.
- Plan for increased capacity and redundancy at the Sandy Pump Station.
- Address mechanical deficiencies and install monitoring equipment to allow the SDIC to improve pump station operations.
- Improve debris management (debris barriers and trash rakes).
- Update plan for emergency service and increase resiliency by installing a transfer switch to connect to standby power sources, such as portable or permanent generators.
- Install equipment and implement inspection programs to track and monitor the condition of the critical conveyance network and pump station to identify (and rehabilitate) deteriorating systems and infrastructure.
- Pursue appropriate legal agreements (e.g., easements) to provide access to critical conveyance network to allow for effective maintenance and operation of the drainage system.
- Formalize operations, maintenance, and infrastructure replacement coordination between SDIC and the CoT.

Specific project and program recommendations are outlined in the following sections.

9.2 Recommended Capital Projects and Studies

Capital projects are those that require design by experts and major capital investment to complete construction. A total of nine capital projects were developed that will enable the Stakeholders to operate an internal drainage system that efficiently moves surface water through the study area and provides flood protection during peak storm events. Additionally, two studies (CIP #4a and CIP #10) are included in Table 9-1 that will fund additional evaluation efforts to inform improvements.

Table 9-1 summarizes the recommended capital projects. Maps showing the locations of these projects are included in Figure 3, Appendix A. Detailed project descriptions with design and construction notes are included in Appendix E.

Table 9-1. Drainage Master Plan, Recommended Capital Projects

Time Frame (years)	CIP Number	CIP ID (Problem area ID)	Project	Location	Preliminary Cost Estimate
1-5	1	C-1A	Sandy Pump Station (Structural/Operational)	Sandy Pump Station	$182,000
1-5	2	C-1B	Sandy Pump Station (Outfall Pipes/ Infrastructure)	Sandy Pump Station	$904,000
5-10	3	C-1C	Sandy Pump Station (Capacity)	Sandy Pump Station	$13,200,000
1-5	4a	C-2A	Condition Assessment: Salmon Creek Culverts	Marine Dr. and 223rd St NE	$15,000
10-20[a]	4b	C-2B	Remove and Replace: Salmon Creek Culverts	Marine Dr. and 223rd St NE	$4,039,000
5-10	5	I-1	Arata Creek Culverts (Knapheide/Airport)	Arata Creek at 2500 Marine Dr and west of Troutdale Airport Runway	$687,000
5-10	6	E-3	Arata Creek Culverts and Bank Stabilization	NE Marine Dr west of NW Dunbar Ave	$2,329,000
1-5	7	F-9	Historic Columbia River Highway	Underpass of railroad west of SW Edgefield Ct	$1,331,000
10-20	8a	I-2A	Gate Tower Decommission	Gate tower, culvert through levee	$1,866,000
10-20	8b	I-2B	Gate Tower and Culvert Replacement	Gate tower, culvert through levee	$2,754,000
5-10	9	C-7	Arata Creek Culverts (Sundial Rd/Rogers Cir)	Arata Creek at Sundial Rd and Rogers Cir	$1,450,000
1-5	10	F-12	Dunbar Avenue Feasibility Study	Dunbar Avenue neighborhood	$50,000

a. *Timing dependents somewhat on completion of CIP 4a and results of condition assessment.*

The recommended capital projects presented in this DMP are conceptual, representing an approximately 10 percent level of design. The concepts were developed based on field investigation, technical assessments discussed in this plan, modeling of alternatives, and discussions with Stakeholder staff. For the pump station, the concepts include capacity upgrades for future flows, as well as the structural, mechanical, electrical, communications, and valve and piping improvements identified through the pump station condition assessment in Section 3. The concepts for conveyance system projects include considerations of the location and impacts, traffic concerns and erosion/restoration near open channels.

Project concepts will require refinement during project pre-design. In some cases, a more extensive study may be required to refine the preferred solution or to evaluate the impact of project phasing. Those associated studies have been included as a line item in the project cost estimates. Following adoption of this DMP, the Stakeholders will need to plan for the implementation and phasing of recommended projects. Some projects identified in Table 9-1 may require coordination between the Stakeholders with regard to planning for implementation and phasing, and some projects may require coordination with other partner agencies.

Project costs were developed based on standard unit costs from RS Means and recent construction bids in the Portland Metro area. The costs generally represent prices as of 2019 and include a market factor multiplier of 10 percent to adjust for rapidly increasing construction costs in the region. These planning level cost estimates include a 40 percent estimating contingency. The total estimated project cost shown in Table 9-1 includes multipliers for engineering and permitting and construction administration that may fall in separate fiscal years from the major capital construction cost. Detailed costs breakdowns for each project, including cost multiplier assumptions are included in Appendix E.

9.3 Recommended Programs

In addition to the capital projects, 13 programmatic recommendations were identified through development of this DMP. These are the operational actions recommended for implementation by the Stakeholders to track the condition of the conveyance system, perform preventative maintenance on the pump station, prepare for emergencies, plan for future replacements before systems reach failure conditions, and formalize agreements and coordination between the Stakeholders.

Many of the recommendations are for ongoing programs that the Stakeholders should implement immediately. This includes CCTV inspections, pump station testing and monitoring, and pump station maintenance. Other programs, such as the debris barrier program and portable generator acquisition program, may take more time to implement. Table 9-2 summarizes the programs that are recommended; detailed program descriptions and cost estimates are included in Appendix F. The program cost estimates include both the total cost of the program, as well as the annual cost for a long-term program

Table 9-2. Recommended Programs

Program ID	Program Name	Total Cost	Timeline	Annual Cost
1	Open Channel Sediment Control Program	$50,000	5 years	$10,000
2[a]	SDIC-CCTV Inspection, Condition Assessment, and Asset Management Program	$286,000	5 years	$82,200
3[b]	Troutdale-CCTV Inspection, Condition Assessment, and Asset Management Program	$543,000	5 years	$133,600
4	Flow Control Requirements Evaluation	$10,000	NA	NA
5	Pump Station Testing and Monitoring	$4,800[c]	--[d]	$4,800
6	Pump Station Maintenance Program	$8,100[c]	--[d]	$8,100
7	Pump Station Structural Program	$10,000[c]	--[d]	$10,000
8	District Wide Debris Barrier Program	$1,195,000	10 years	$119,500
9	Portable Generator Acquisition Program	$427,000	10 years	$42,700
10	Water Quality Retrofit Program	$50,000[c]	--[d]	$50,000
11[e]	Operations and Maintenance Collaboration	--[f]	--[d]	--[f]
12[e]	Design Review and Permitting Coordination	--[f]	--[d]	--[f]
13[e]	System Reinvestment and Rehabilitation Program	--[f]	per year	--[f]

a. *Costs specific to SDIC and infrastructure. Annual cost includes $25,000 per year for 3rd party evaluation.*
b. *Costs specific to CoT and infrastructure. Annual cost includes $25,000 per year for 3rd party evaluation.*
c. *Annual cost.*
d. *Ongoing cost per year (average).*
e. *Costs for programs are assumed to be part of normal operating costs.*
f. *Cost to be developed.*

The programs presented in this DMP have been developed in coordination with the Stakeholders. Costs and program details have been developed to describe the need and potential cost. The program concepts were developed based on field investigation, system evaluation discussed in this plan, modeling of alternatives, and discussions with Stakeholder staff. For the pump station, the programs include a framework to enhance the structural elements, regular testing and monitoring, and a formalized maintenance program. Costs represent anticipated level of effort based on existing knowledge and applicable 2019-unit costs. Some programs, such as the water quality retrofit program, pump station structural program, flow control evaluation, and open channel sediment control program, have associated costs that were vetted by the Stakeholders.

9.4 Additional Recommendations

An important next step for the Stakeholders is to establish a plan for funding projects. Current funding may support some or portions of the programs listed in Table 9-2.

The Stakeholders are heavily reliant on partner agencies (Multnomah County, ODOT, Port of Portland) and property owners for management of the conveyance infrastructure. Many of the projects proposed in this DMP will require joint attention to fund and construct the required upgrades. MCDD is working, on behalf of SDIC, to establish formal agreements with partner agencies and landowners, related to conveyance system maintenance and rehabilitation responsibility.

The Stakeholders may also consider a mitigation strategy to offset the cost incurred as development expands across the basin and in upstream contributing areas. Increased flows from developing areas impact the conveyance and pump station infrastructure. Each of these changes has an incremental impact on the Sandy Pump Station, but the sum of all potential development is likely to require pump station and conveyance system upgrades. It is challenging to identify a “tipping point” project that is solely responsible for a pump station improvement, so the incremental impacts and resulting costs should be distributed among all who develop in the drainage area. The SDIC must continue development review activities to evaluate any new drainage infrastructure and investigate a mitigation strategy to recoup the costs associated with impacts that accumulate from development over time.

Formalizing the maintenance, operations, and infrastructure improvement agreements between the stakeholders and partner agencies will be a key factor to implement programs and projects outlined in this DMP.

Section 10

Limitations

This document was prepared for the Sandy Drainage Improvement Company (SDIC) and the City of Troutdale in accordance with professional standards at the time the services were performed and in accordance with the contract between the SDIC and Brown and Caldwell dated May 15, 2019. This document is governed by the specific Scope of Work authorized by the SDIC; 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 the District and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

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Section 11

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https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?or8634

Appendices

A: Figures

B: Photograph Log

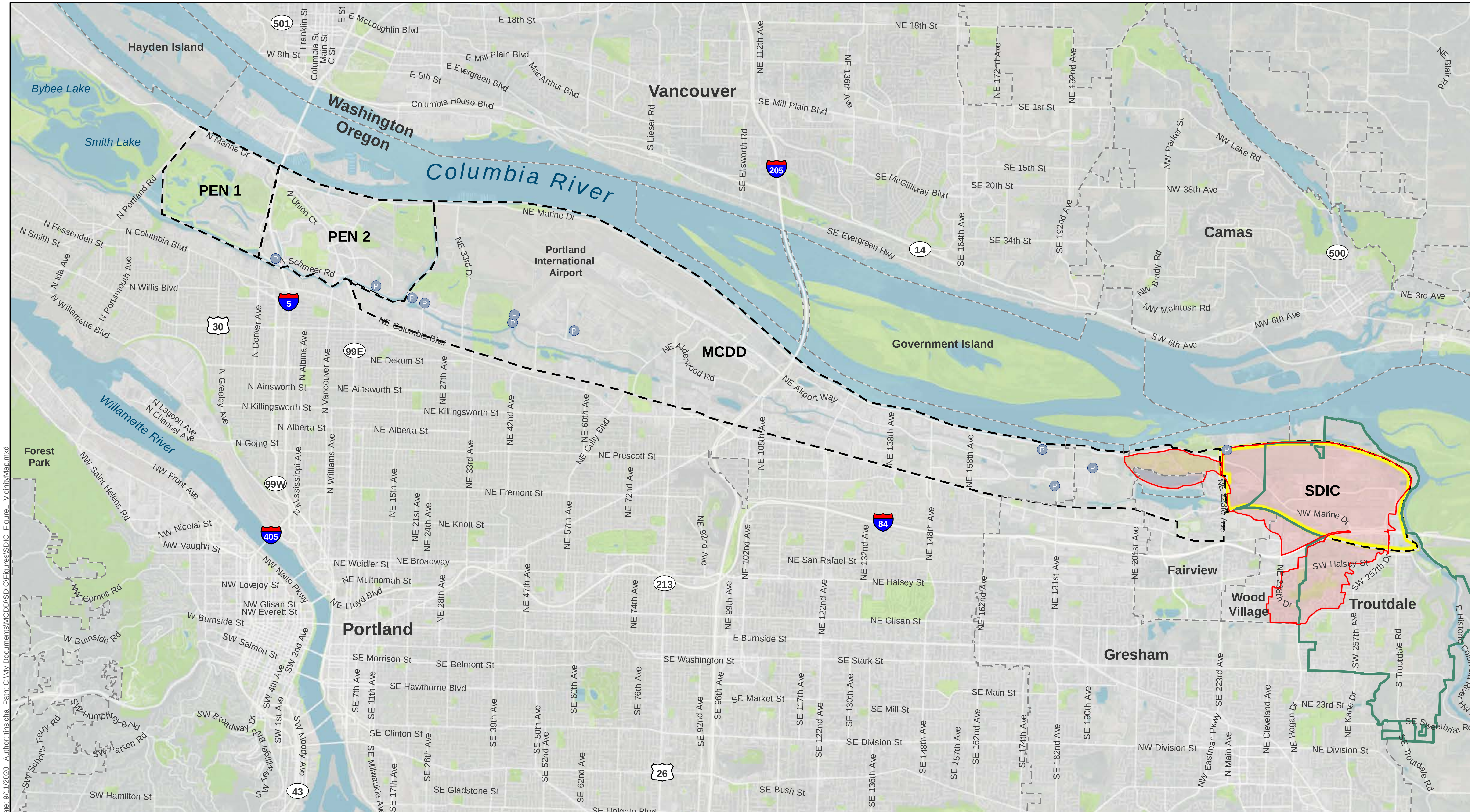
C: Model Results Tables

D: Problem Area Database/Table

E: Recommended Projects

F: Recommended Programs

Appendix A: Figures

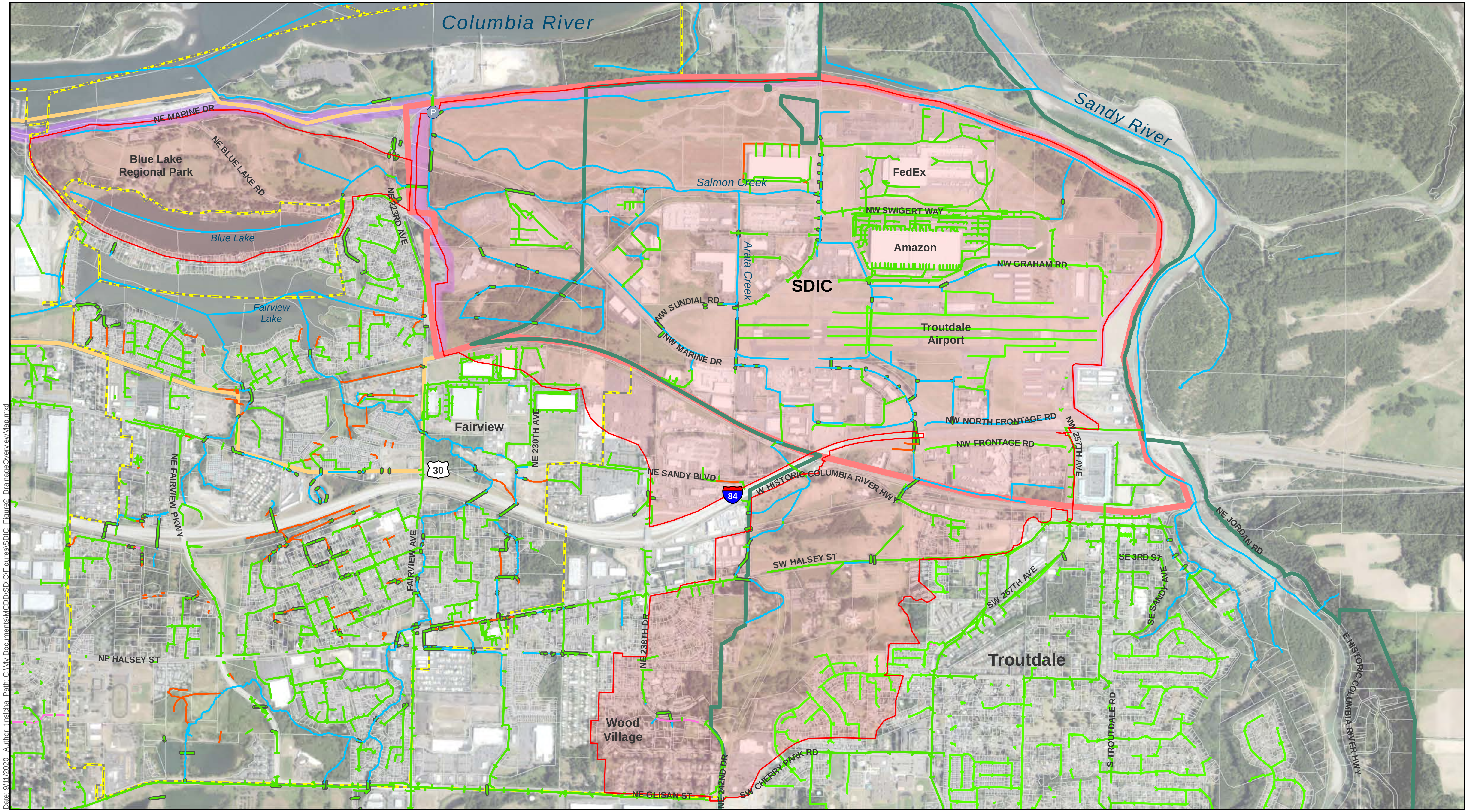


Source: Parametrix, Brown and Caldwell, MCDD, City of Portland, © Mapbox, © OpenStreetMap

Pump Station
SDIC Boundary
Study/Watershed Area
District Boundary
Troutdale City Limit
Other City Limit

0 0.5 1 2 Miles

Figure 1
Vicinity Map



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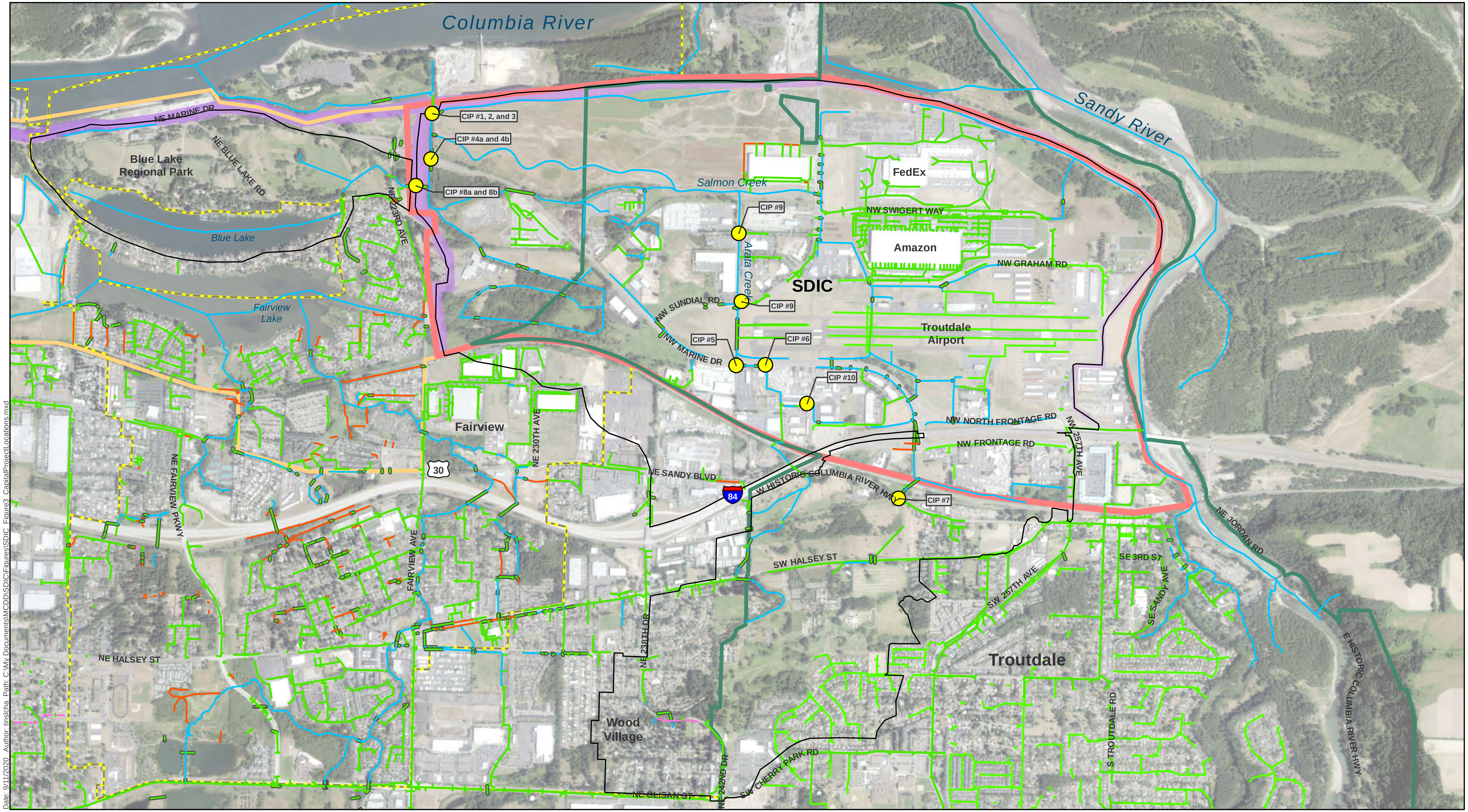
Parametrix

Source: Parametrix, Brown and Caldwell, MCDD, City of Portland, City of Troutdale, RLIS, © Mapbox, © OpenStreetMap

0 500 1,000 2,000 Feet

- SDIC Boundary
- Study/Watershed Area
- Adjacent District Boundary
- Troutdale City Limit
- Adjacent City Limit
- Pump Station
- Levee
- Tax Lot
- Open Channel
- Stormwater Pipe
- Culvert
- Swale/Bioswale
- Drain/French Drain
- Inlet Leader
- Vault

Figure 2
Drainage Overview Map



Parametrix

Source: Parametrix, Brown and Caldwell, MCDD, City of Portland, City of Troutdale, RLIS, © Mapbox, © OpenStreetMap

N

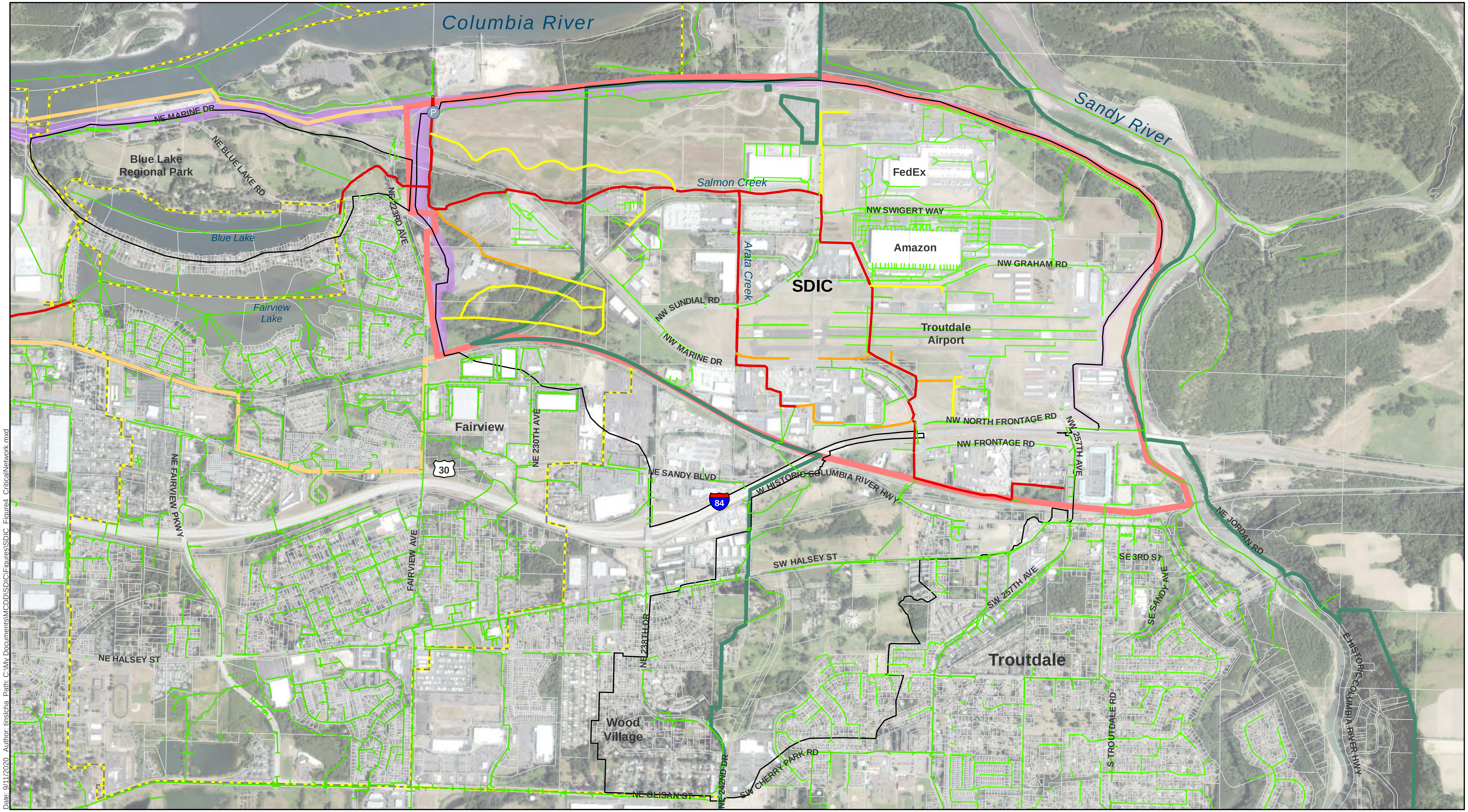
0 500 1,000 2,000 Feet

- SDIC Boundary
- Study/Watershed Area
- Adjacent District Boundary
- Troutdale City Limit
- Adjacent City Limit
- Pump Station
- Capital Improvement Location
- Levee
- Open Channel
- Stormwater Pipe
- Culvert
- Swale/Bioswale
- Drain/French Drain
- Inlet Leader
- Vault

Figure 3

Capital Improvement Locations

SDIC and North Troutdale Drainage Master Plan



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Parametrix

Source: Parametrix, Brown and Caldwell, MCDD, City of Portland, City of Troutdale, RLIS, © Mapbox, © OpenStreetMap

0 500 1,000 2,000 Feet

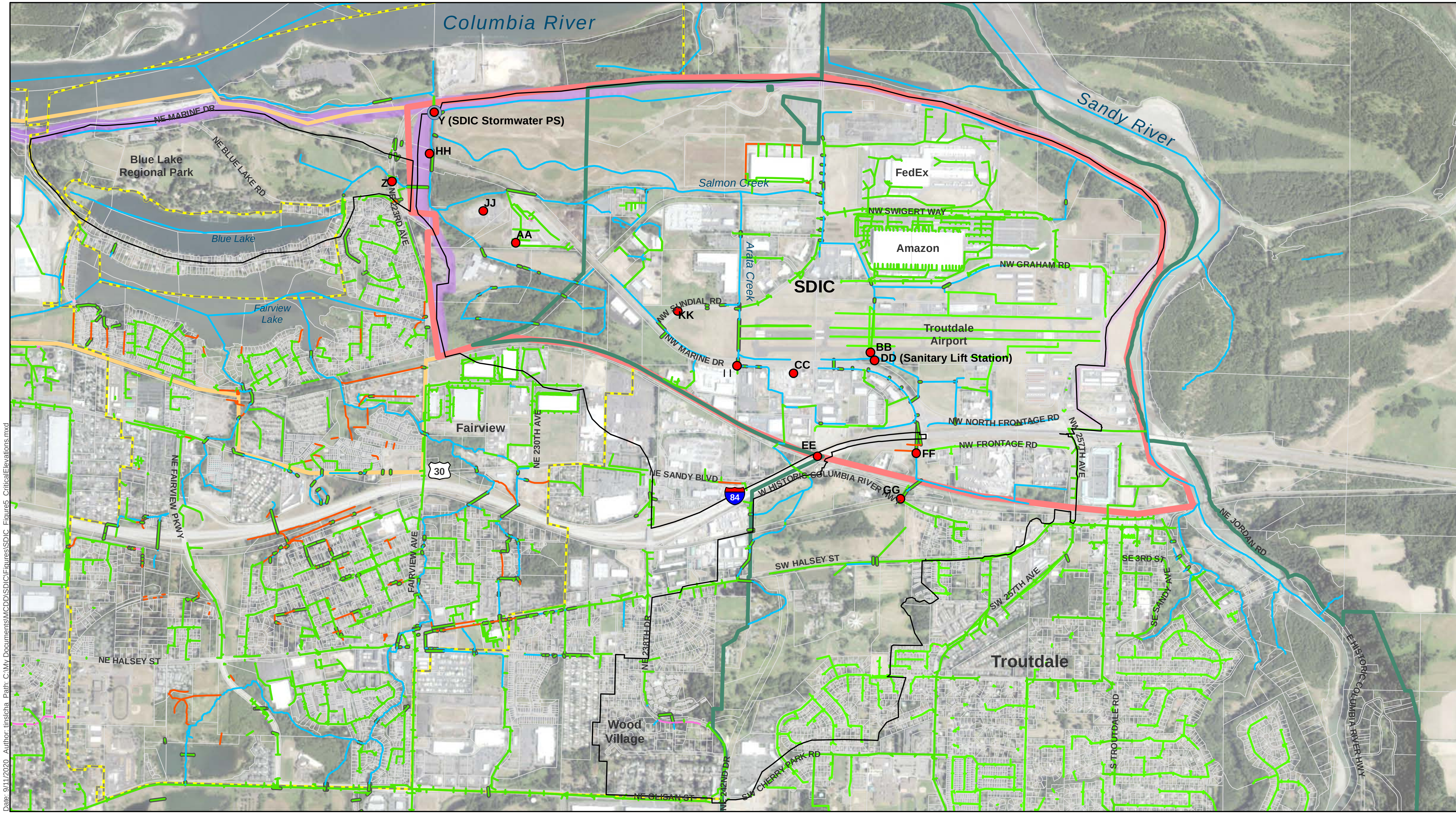
SDIC Boundary
Study/Watershed Area
Adjacent District Boundary
Troutdale City Limit
Adjacent City Limit

Pump Station
Levee
Tax Lot

Conveyance Criticality Level
High
Medium
Low
None

Figure 4
Critical Network Map

SDIC and North Troutdale Drainage Master Plan



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Parametrix

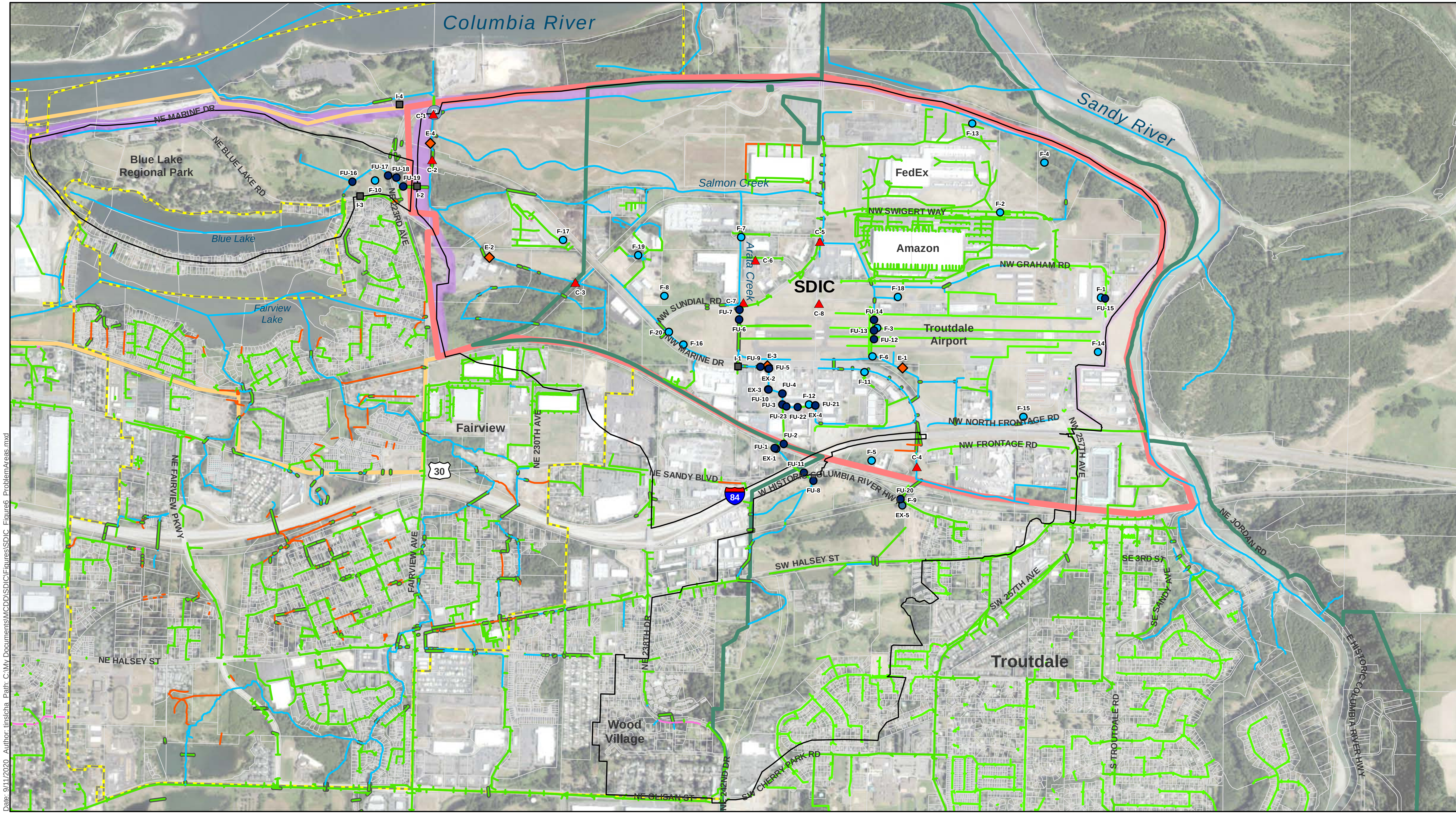
Source: Parametrix, Brown and Caldwell, MCDD, City of Portland, City of Troutdale, RLIS, © Mapbox, © OpenStreetMap

0 500 1,000 2,000 Feet

SDIC Boundary
Study/Watershed Area
Adjacent District Boundary
Troutdale City Limit
Adjacent City Limit
Pump Station
Reference Elevation
Levee
Tax Lot
Open Channel
Stormwater Pipe
Culvert
Swale/Bioswale
Drain/French Drain
Inlet Leader
Vault

Figure 5
Critical Elevations

SDIC and North Troutdale Drainage Master Plan



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Parametrix

Source: Parametrix, Brown and Caldwell, MCDD, City of Portland, City of Troutdale, RLIS, © Mapbox, © OpenStreetMap

0 500 1,000 2,000 Feet

Problem Areas

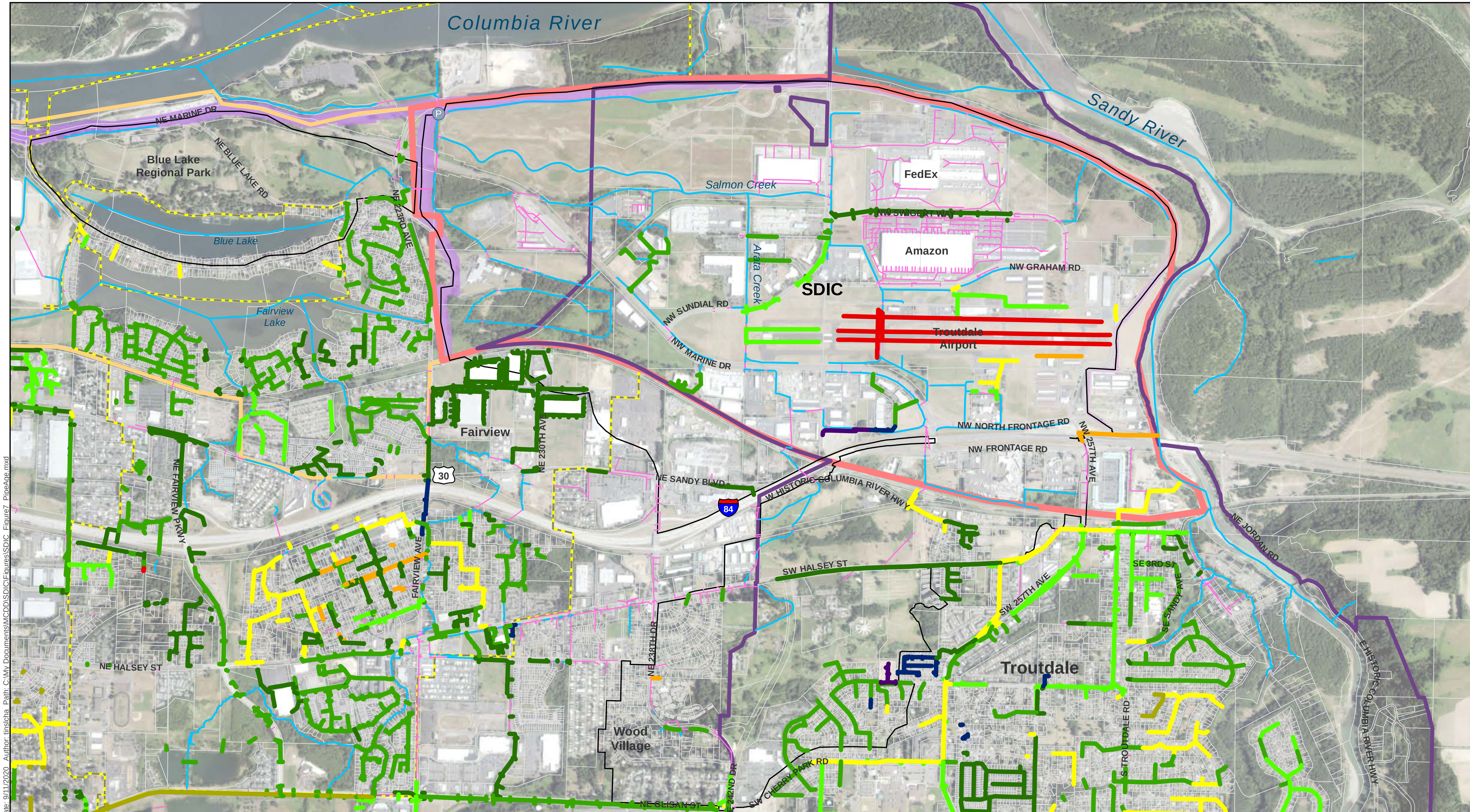
- Capacity
- Erosion
- Flooding
- Infrastructure
- Existing Modeled Flooding
- Future Modeled Flooding

- SDIC Boundary
- Study/Watershed Area
- Adjacent District Boundary
- Troutdale City Limit
- Adjacent City Limit
- Tax Lot

- Pump Station
- Levee
- Open Channel
- Stormwater Pipe

- Culvert
- Swale/Bioswale
- Drain/French Drain
- Inlet Leader
- Vault

Figure 6
Problem Areas



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Parametrix

Source: Parametrix, Brown and Caldwell, MCDD, City of Portland, City of Troutdale, RLIS,
© Mapbox, © OpenStreetMap

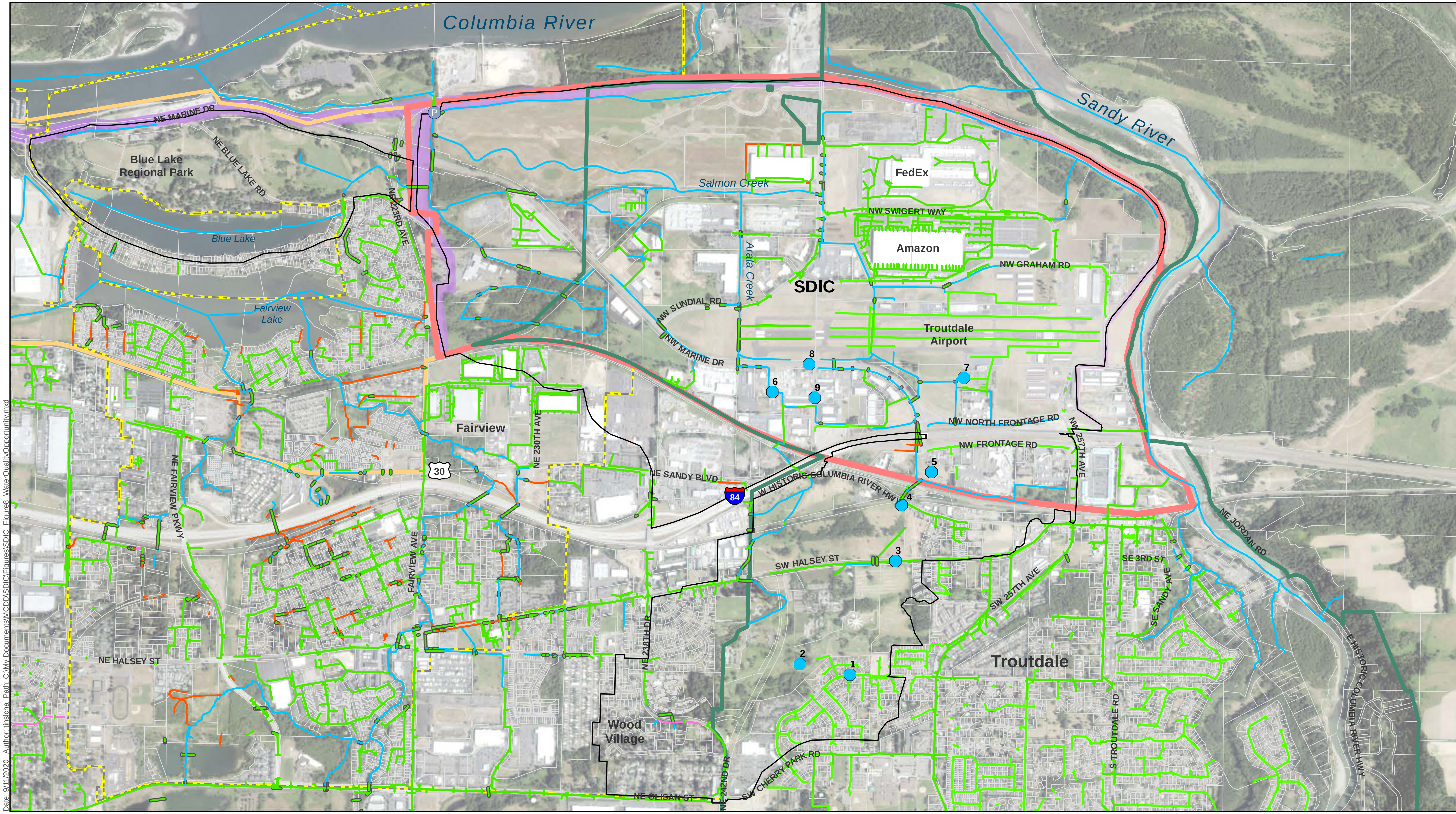
0 500 1,000 2,000 Feet

- Pump Station
- SDIC Boundary
- Study/Watershed Area
- Adjacent District Boundary
- Troutdale City Limit
- City Limit
- Levee
- Tax Lot

Pipe Install Date

- 1940s
- 1950s
- 1960s
- 1970s
- 1980s
- 1990s
- 2000s
- 2010s
- 2020s
- Unknown Install Date
- Open Channel

Figure 7
Pipe Age



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Parametrix

Source: Parametrix, Brown and Caldwell, MCDD, City of Portland, City of Troutdale, RLIS, © Mapbox, © OpenStreetMap

0 500 1,000 2,000 Feet

SDIC Boundary
Study/Watershed Area
Adjacent District Boundary
Troutdale City Limit
Adjacent City Limit
Tax Lot

Pump Station
Water Quality Opportunity Location
Levee
Open Channel
Stormwater Pipe

Culvert
Swale/Bioswale
Drain/French Drain
Inlet Leader
Vault

Figure 8

Water Quality Opportunities

SDIC and North Troutdale Drainage Master Plan

Appendix B: Photograph Log

Appendix B

Field Observation Photo Log

Photographs and descriptions of the field investigation (by site) are provided on the following pages. Site location numbers correspond to problem area numbers in the Problem Area Matrix, Appendix D.

Problem Area: #15 and #16
Waterbody: Arata Creek

Figure 1. Filename: 20190618_140344.jpg - Arata Creek, along Marine Drive, looking west.

Figure 2. Filename: ArcGISApp_1560891829862.jpg - Erosion at driveway to Twelve Mile Disposal Services (2430 NW marine Dr.)

Figure 3. Filename: ArcGISApp_1560891601488.jpg - Arata Creek, North-to-West bend at Marine Dr – bank erosion.

Figure 4. Filename: ArcGISApp_1560892038682.jpg - Arata creek culvert entrance, south side of Marine Drive. Debris and partially crushed CMP.

Figure 5. Filename: 20190618_140654.jpg - Stretch of Arata Creek, south of Marine Drive, in front of Knapheide Truck Equipment Center (2500 NW Marine Dr.).

Problem Area: #9
Waterbody: Arata Creek – Roger's Circle culverts

Figure 6. Filename: IMG_3654.jpg - Arata Creek at Roger's Circle, double culverts, also Toyo Tanso process water discharge point.

Figure 7. Filename: ArcGISApp_1560892702709.jpg - Toyo Tanso discharge point. Appeared to be clear water from 6- or 8" diameter pipe.

Figure 8. Filename: ArcGISApp_1560892745887.jpg - close up of Arata Creek culvert at Roger's Circle entrance (south side) – some vegetation, looked to be in good shape.

Problem Area: near #10, #11, and #23
Waterbody: Arata Creek/Salmon Creek/ West Sundial Wetlands

Figure 9. Filename: ArcGISApp_1560893492147.jpg - Lift gate separating Arata/Salmon creek (seen here, foreground) and Sundial wetlands (behind gate, drain to SDIC pump station).

Figure 10. Filename: 20190618_143124.jpg - View of Salmon Creek from lift gate, facing East.

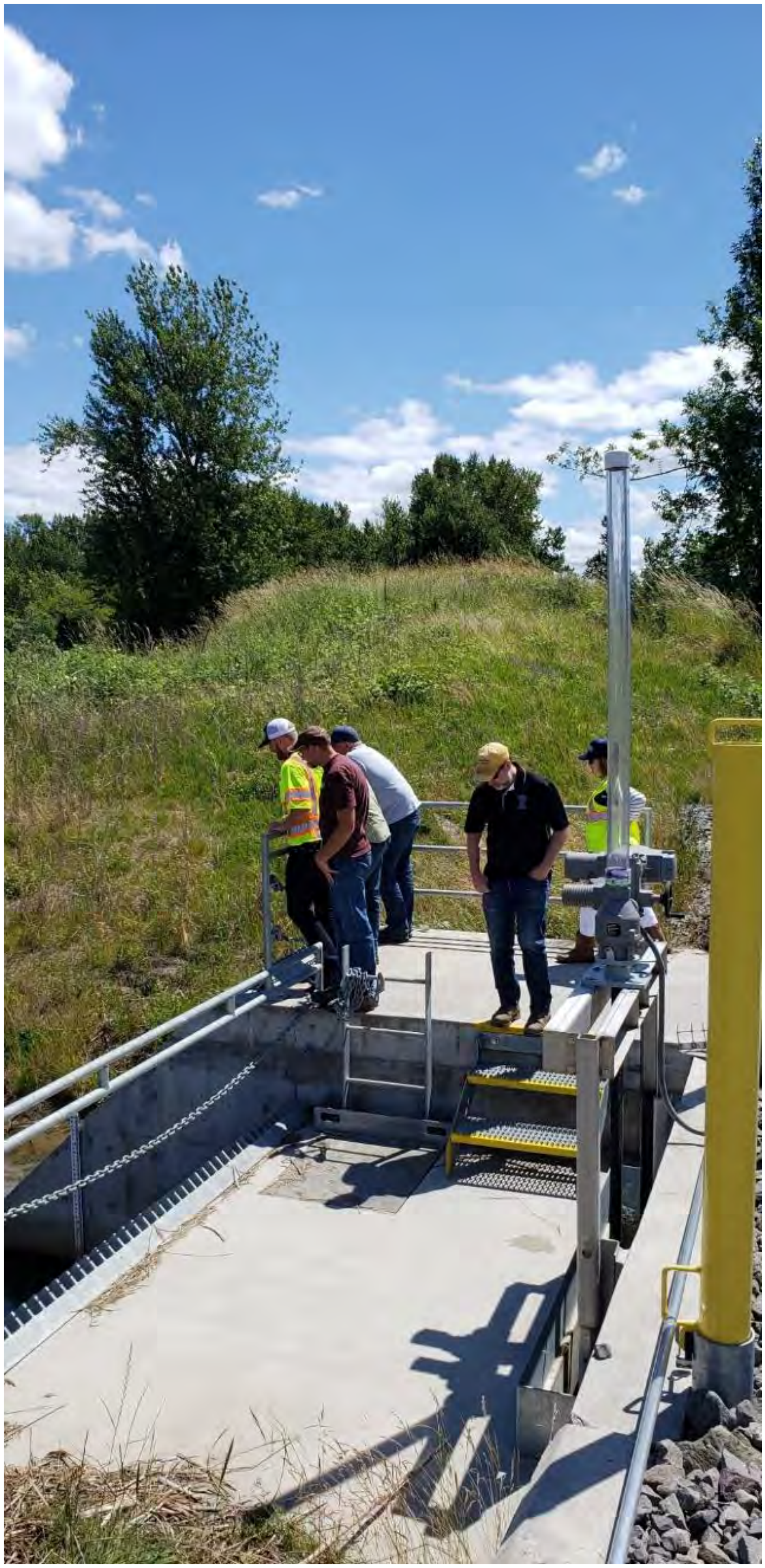


Figure 11. Filename: 20190618_143131.jpg - View of top of lift gate, facing South.

Figure 12. Filename: ArcGISApp_1560893759800.jpg - Taken from lift gate, facing south; View of Arata/Salmon Creek Culverts under Marine Drive.

Problem Area: No associated problem, Field Note #13, East of Problem area #'s 10, 11, and 23
Waterbody: Arata Creek/Salmon Creek

Figure 13. Filename: 20190618_144555.jpg - Point where Arata/Salmon creek flow splits; Either continues west (top of figure, right side) and heads under Marine Dr, or splits off and goes to lift gate (bottom right of image).

Figure 14. Filename: ArcGISApp_1560894434638.jpg - Zoom in on split in flow point. Flow either continues (top left of image) or when if flow high enough can split off and go directly to lift gate (right side of image).

Problem Area: #13
Waterbody: Blue Lake

Figure 15. Filename: 20190618_150304.jpg - Small ponded area, just north of Blue Lake Rd. Sluice gate / overflow weir separates Blue Lake and SDIC.

Figure 16. Filename: ArcGISApp_1560895410744.jpg - shot from behind sluice gate /overflow weir. Gate currently closed.

Figure 17. Filename: ArcGISApp_1560895448480.jpg - Zoom-in on gate/weir.

Problem Area: #3
Waterbody: Airport Drainage ditch

Figure 18. Filename: ArcGISApp_1560891004757.jpg - Airport culvert entrance, south side of runway.

Figure 19. Filename: ArcGISApp_1560891093552.jpg - Zoom-in on culver entrance. CPP slightly crushed or elliptical shape. Some sediment build-up and vegetation growth.

Problem Area: #14
Waterbody: North Troutdale / SDIC / Airport Drainage ditch

Figure 20. Filename: ArcGISApp_1560896281402.jpg - Drainage ditch south of Frontage Rd. Three beaver deceivers installed, heavy vegetation. View facing North.

Figure 21. Filename: ArcGISApp_1560896370130.jpg - Drainage ditch south of Frontage road, view facing South.

Appendix C: Model Results Tables

Table C-1. Existing Hydraulic Model Parameters and Results										
Link ID	Length (ft)	Shape	Diameter/ Height (ft)	Slope (%)	Node Name		Existing Max Flow (cfs)			
					US	DS	5 yr	10 yr	25 yr	100 yr
S32	480.0	Natural	0.0	0.1	S-32	S-31	19.7	24.1	26.2	29.9
Hotel Weir.1	NA	NA	NA	NA	S-31	S-29	0.0	0.0	0.0	0.0
Pipe	48.6	Circular	3.0	1.5	S-31	S-29	20.0	24.5	26.6	30.2
S24	710.0	Circular	2.5	0.2	S-24	S-23	19.7	20.2	20.2	20.3
AirportW1.1	NA	NA	NA	NA	S-24	A-09	0.7	14.2	20.1	35.9
S21	176.0	Natural	0.0	0.0	S-21	S-20.1	22.6	24.1	25.4	30.8
S18	523.0	Natural	0.0	0.0	S-18	S-17	27.8	31.5	34.7	48.4
S12	100.0	Rectangular	7.0	0.2	S-12	S-11	43.0	57.2	67.4	99.8
S10	803.3	Natural	0.0	0.0	S-10	S-09	104.7	141.4	169.5	239.5
S8	1082.0	Natural	0.0	0.1	S-08	S-07	62.6	69.7	72.2	76.5
S7	900.0	Natural	0.0	0.1	S-07	S-06	62.3	68.4	70.8	74.5
S6	462.0	Circular	5.0	0.1	S-06	S-05	62.2	67.8	70.3	73.4
MarineDr-W	346.0	Circular	6.0	-0.1	S-03	S-02	35.0	36.4	37.4	40.2
MarineDr-E	346.0	Circular	6.0	-0.1	S-03	S-02	34.8	36.4	37.4	40.1
S2	260.0	Natural	0.0	0.1	S-02	S-01	68.7	71.3	72.7	76.7
SandyPS_1	NA	NA	NA	NA	PS	OUT	39.8	39.8	39.8	40.4
SandyPS_2	NA	NA	NA	NA	PS	OUT	31.9	31.9	31.9	32.5
A22	86.0	Circular	4.0	0.8	A48	A-21	62.8	81.7	92.2	107.4
A21	129.0	Natural	0.0	6.6	A-21	A-20	62.8	81.7	92.2	107.4
A20	657.0	Circular	4.0	1.4	A-20	A-19	62.7	81.7	91.4	100.0
A19	190.0	Natural	0.0	-0.3	A-19	A-18	63.3	82.3	92.3	102.6
A18	246.0	Natural	0.0	0.3	A-18	A-17	61.3	77.5	88.4	99.6
A16	157.0	Natural	0.0	0.4	A-16	A-15	58.4	74.7	82.9	95.5
Marine1	117.0	Circular	4.0	-0.4	A-11	A-10	24.6	31.8	35.6	41.3
Marine2	118.0	Circular	4.0	-0.1	A-11	A-10	34.1	43.3	47.7	54.5
A10	143.0	Natural	0.0	1.3	A-10	A-09	58.7	75.0	83.3	95.8
AirportW2	NA	NA	NA	NA	A-09	A-08	0.0	0.0	0.0	49.9
airport-e	520.0	Circular	4.0	0.1	A-09	A-08	29.4	37.7	47.8	49.5
airport-w	520.0	Circular	4.0	0.1	A-09	A-08	29.7	37.8	47.8	49.5
A8	164.0	Natural	0.0	0.0	A-08	A-07	59.6	77.4	98.2	134.3
sundial-e	103.0	Circular	4.0	-0.7	A-07	A-06	26.2	36.1	47.3	66.9
sundial-w	100.0	Circular	4.0	-0.8	A-07	A-06	34.6	43.3	53.4	71.4
A6	795.0	Natural	0.0	0.3	A-06	A-05	60.8	79.4	100.6	138.3
A2	43.0	Natural	0.0	0.1	A-02	A-01	64.3	84.8	106.2	147.2
A1	184.0	Natural	0.0	0.7	A-01	S-10	64.3	84.7	106.2	147.3
A24	112.0	Circular	4.0	0.3	A-24	A-23.3	28.3	41.7	51.4	72.6
S33	120.0	Circular	2.1	5.4	S-33	S-32	17.0	19.7	20.8	22.8
S25	520.0	Natural	0.0	0.1	S-25	S-24	20.3	33.2	38.8	53.2
S20	90.0	Rectangular	4.0	1.0	S-20	S-19	26.4	29.6	32.7	46.1
S19	665.0	Natural	0.0	0.1	S-19	S-18	27.6	31.2	34.4	49.0

Table C-1. Existing Hydraulic Model Parameters and Results										
Link ID	Length (ft)	Shape	Diameter/ Height (ft)	Slope (%)	Node Name		Existing Max Flow (cfs)			
					US	DS	5 yr	10 yr	25 yr	100 yr
S15	172.0	Natural	0.0	0.1	S-15	S-14	28.3	32.1	35.5	49.2
S11	1280.9	Natural	0.0	0.0	S-11	S-10	43.4	57.3	66.4	98.5
S26	125.0	Natural	0.0	0.1	S-26	S-25	19.5	25.6	29.1	36.1
S5	1024.0	Natural	0.0	0.1	S-05	S-04	61.5	66.0	67.7	68.6
S4	500.0	Natural	0.0	0.1	S-04	Node233	66.7	71.5	73.9	78.2
S1	300.0	Natural	0.0	0.1	S-01	PS	67.5	68.6	69.0	79.6
S-08a_Culvert	27.7	Circular	2.0	1.6	S-08a	S-08	0.0	0.3	1.2	2.7
S-08a_overtop	27.2	Trapezoidal	0.5	8.5	S-08a	S-08	0.0	0.0	0.0	0.0
A3	500.0	Natural	0.0	0.1	A-03	A-02	64.4	84.8	106.2	147.2
Rogers-e	82.0	Circular	5.0	0.6	A-04	A-03	31.1	40.7	51.3	70.8
Rogers-w	85.0	Circular	5.0	0.5	A-04	A-03	30.4	40.1	50.9	70.4
A15	60.0	Circular	4.0	-0.2	A-15	A-14	58.3	74.5	82.7	94.8
A14	170.0	Natural	0.0	0.0	A-14	A-13	58.3	74.4	82.5	94.8
A13	60.0	Circular	4.0	0.2	A-13	A-12	58.2	74.4	82.5	94.8
A12	88.0	Natural	0.0	0.9	A-12	A-11	58.2	74.4	82.5	94.8
A17	347.0	Natural	0.0	0.1	A-17	A-16	57.7	73.9	83.5	95.9
A23	410.0	Trapezoidal	2.5	0.5	A-23	A48	28.9	42.8	54.9	61.8
S-29_OD1	715.0	Trapezoidal	2.0	0.2	S-29	OD1	0.0	0.0	0.0	0.0
Link301	108.0	Circular	3.0	0.2	S-29	36E	20.1	24.6	26.7	30.4
S27	162.0	Circular	4.0	0.4	S-27	S-26	20.2	25.6	29.1	36.1
S28a	724.0	Natural	0.0	0.4	S-28a	S-28	0.8	0.9	1.0	1.5
S25a	336.0	Natural	0.0	0.3	S-25a	S-25	7.0	11.4	15.0	20.5
perim-e	45.0	Circular	3.0	0.0	S-22	S-21	6.4	6.8	7.2	8.7
perimr-m	45.0	Circular	3.0	0.5	S-22	S-21	8.8	9.2	9.6	10.8
perimr-w	45.0	Circular	3.0	0.2	S-22	S-21	6.7	7.1	7.4	9.0
S23	149.0	Natural	0.0	0.2	S-23	S-22	21.8	23.2	24.2	28.5
S17	286.0	Natural	0.0	0.2	S-17	S-15	28.3	32.1	35.5	49.4
S14	92.0	Rectangular	6.7	0.5	S-14	S-13	28.5	32.4	35.9	49.9
S13	266.0	Natural	0.0	0.3	S-13	S-12	37.9	49.7	57.5	82.4
A5	290.0	Natural	0.0	0.2	A-05	A-04	61.6	80.8	102.2	141.1
S28	347.0	Natural	0.0	0.2	S-28	S-27	19.9	24.5	27.8	34.0
6 ft Pipe	29.0	Circular	6.0	0.0	SPLIT-01	S-01	0.0	0.0	0.0	0.0
Rectangular Culvert	36.0	Rectangular	5.5	0.0	SPLIT-01	Node374	0.2	0.2	0.1	0.1
Weir_WEST_01	NA	NA	NA	NA	SPLIT-01	Node374	0.0	0.0	0.0	0.0
S20.1	90.0	Natural	0.0	0.2	S-20.1	S-20	22.6	24.1	25.4	30.8
S8b	300.0	Natural	0.0	0.5	S-08b	S-08a	0.0	0.3	1.2	2.7
A23.1	13.0	Circular	4.0	0.5	A-23.1	A-23	28.3	41.7	51.5	59.0
SS01	950.0	Natural	0.0	0.1	SS-01	S-04	12.5	12.5	12.5	19.2
A23.2	216.0	Circular	2.5	0.2	A-23.2	A-23.1	28.3	41.7	51.5	59.0
A23.3	37.0	Circular	2.5	2.1	A-23.3	A-23.2	28.3	41.7	51.4	59.0

Table C-1. Existing Hydraulic Model Parameters and Results										
Link ID	Length (ft)	Shape	Diameter/ Height (ft)	Slope (%)	Node Name		Existing Max Flow (cfs)			
					US	DS	5 yr	10 yr	25 yr	100 yr
SS02	150.0	Circular	4.0	1.4	SS-02	SS-01	6.1	9.0	11.0	17.2
SS03	562.0	Natural	0.0	0.2	SS-03	SS-02	6.1	9.0	11.0	17.2
372.1-N	90.0	Special	3.0	0.1	SS-04	SS-03	4.5	6.4	7.4	10.9
372.2-S	90.0	Circular	3.0	0.5	SS-04	SS-03	1.6	2.9	3.9	6.7
SS05	13.0	Natural	0.0	1.3	SS-05	SS-04	6.1	9.0	11.1	17.5
SS06	124.5	Special	4.0	0.7	SS-06	SS-05	6.1	9.0	11.1	17.4
SS07	147.0	Natural	0.0	0.3	SS-07	SS-06	5.3	7.7	9.3	14.1
SS08	24.6	Special	3.3	-0.7	SS-08	SS-07	5.3	7.7	9.3	14.1
SS09	624.0	Natural	0.0	0.2	SS-09	SS-08	5.3	7.7	9.3	14.1
SS10	61.7	Circular	3.0	1.1	SS-10	SS-09	5.3	7.7	9.3	14.2
SS11	344.0	Natural	0.0	0.3	SS-11	SS-10	5.3	7.7	9.3	14.2
SS12	20.9	Circular	3.0	1.6	SS-12	SS-11	5.3	7.7	9.3	14.2
SS13a	161.0	Natural	0.0	-0.8	SS-13a	SS-12	5.3	7.7	9.3	14.2
13b N Culv	55.0	Circular	4.0	-2.4	SS-13b	SS-13a	1.1	1.5	2.1	3.6
13b S Culv	68.4	Circular	2.0	-1.1	SS-13b	SS-13a	0.0	0.0	0.0	0.0
13c N Culv	50.2	Circular	1.2	0.5	SS-13c	SS-13b	0.0	0.0	0.3	1.0
13c S Culv	40.0	Circular	1.3	-3.3	SS-13c	SS-13b	0.0	0.0	0.0	0.3
SS14	250.0	Natural	0.0	4.0	SS-14	SS-13a	10.4	13.0	14.5	18.7
SS15	98.0	Circular	3.0	6.2	SS-15R	SS-14	10.5	13.1	14.7	18.8
SUN5	95.0	Circular	2.5	0.3	SUN-5	SUN-4	1.2	1.8	2.4	4.6
SUN4	154.0	Circular	3.5	0.2	SUN-4	SUN-3	10.4	12.7	14.3	19.5
SUN3	467.0	Natural	0.0	0.2	SUN-3	SUN-2	10.3	12.7	14.6	21.1
SUN2	100.0	Circular	3.5	0.2	SUN-2	SUN-1	10.3	12.7	14.5	21.0
SUN1	100.0	Natural	0.0	0.2	SUN-1	S-12	10.3	12.6	14.5	21.0
SW1	755.0	Circular	5.5	0.3	SW-01	S-13	16.6	23.0	27.0	40.4
SW2	765.0	Circular	5.0	0.3	SW-02	SW-01	12.9	17.7	20.8	29.4
SW3	645.0	Circular	4.5	0.3	SW-03	SW-02	12.8	17.4	20.3	28.6
SW4	991.0	Circular	4.0	0.2	SW-04	SW-03	7.3	9.9	11.5	16.3
FED05	143.0	Circular	2.5	0.4	FED-05	FED-04	4.2	6.4	7.7	11.6
FED04	122.0	Circular	2.5	0.4	FED-04	FED-03	4.2	6.4	7.7	11.6
FED03	133.0	Circular	3.5	0.4	FED-03	FED-02	4.2	6.4	7.7	11.6
FED02	151.0	Circular	3.5	0.4	FED-02	FED-01	4.2	6.4	7.7	11.6
FED01	51.0	Circular	3.5	0.4	FED-01	FED-0.2	4.2	6.4	7.7	11.6
FED14	140.0	Special	1.9	0.2	FED-14	FED-13	10.6	12.9	14.2	17.8
FED13	140.0	Special	2.0	0.2	FED-13	FED-12	10.6	12.9	14.2	17.8
FED12	213.0	Special	2.0	0.2	FED-12	FED-11	10.6	12.9	14.2	17.8
FED11	165.0	Special	2.0	0.2	FED-11	FED-10	10.6	12.8	14.2	17.8
FED10	155.0	Special	2.0	0.2	FED-10	FED-09	10.6	12.8	14.2	17.8
FED09	236.0	Special	2.0	0.3	FED-09	FED-08	10.5	12.8	14.2	17.8
FED08	258.0	Special	2.6	0.2	FED-08	FED-07	10.5	12.8	14.2	17.8

Table C-1. Existing Hydraulic Model Parameters and Results										
Link ID	Length (ft)	Shape	Diameter/ Height (ft)	Slope (%)	Node Name		Existing Max Flow (cfs)			
					US	DS	5 yr	10 yr	25 yr	100 yr
FED07	262.0	Special	3.0	0.2	FED-07	FED-06.2	10.5	12.8	14.2	17.8
FED06	60.0	Circular	4.0	0.2	FED-06	SW-03	10.5	12.8	14.1	17.7
FED15	25.0	Circular	3.5	0.6	FED-15	SUN-4	10.4	12.6	14.0	17.5
FED16	361.0	Circular	3.5	0.3	FED-16	FED-15	10.4	12.6	14.0	17.6
FED17	238.0	Circular	3.5	0.3	FED-17	FED-16	10.4	12.7	14.0	17.6
FED18	35.0	Circular	3.5	0.2	FED-18	FED-17	10.4	12.7	14.0	17.6
FED19	261.0	Circular	3.5	0.2	FED-19	FED-18	10.4	12.7	14.0	17.6
FED20	200.0	Circular	3.5	0.2	FED-20	FED-19	10.4	12.7	14.0	17.6
FED21	200.0	Circular	3.5	0.2	FED-21	FED-20	10.4	12.7	14.0	17.6
FED22	200.0	Circular	3.5	0.2	FED-22	FED-21	10.4	12.7	14.0	17.7
FED23	192.0	Circular	3.5	0.2	FED-23	FED-22	10.4	12.7	14.1	17.7
FED24	201.0	Circular	3.0	0.2	FED-24	FED-23	10.4	12.7	14.1	17.7
FED25	199.0	Circular	3.0	0.2	FED-25	FED-24	10.5	12.7	14.1	17.7
FED26	304.0	Circular	2.5	0.2	FED-26	FED-25	10.5	12.7	14.1	17.7
FED0.2	35.0	Circular	3.5	0.3	FED-0.2	FED-0.1	4.2	6.4	7.7	11.6
FED0.1	100.0	Circular	3.5	0.4	FED-0.1	SW-01	4.2	6.4	7.7	11.6
FED06.2	35.0	Circular	4.0	0.1	FED-06.2	FED-06.1	10.5	12.8	14.2	17.8
FED06.1	200.0	Circular	4.0	0.2	FED-06.1	FED-06	10.5	12.8	14.1	17.8
S23.3	151.0	Circular	1.3	0.2	S-23.3	S-23.2	0.5	0.8	1.0	2.0
S23.2	174.0	Circular	1.5	0.2	S-23.2	S-23.1	1.0	1.6	2.2	4.0
S23.1	160.0	Circular	1.6	0.2	S-23.1	S-23	2.1	3.3	4.5	8.2
S09	369.7	Natural	0.0	0.0	S-09	SPLIT-07	104.5	141.4	170.1	240.7
SGR13	177.0	Circular	2.5	0.3	SGR-13	SGR-12	2.0	3.5	4.4	7.4
SGR14	255.0	Circular	2.0	0.3	SGR-14	SGR-13	1.1	1.9	2.4	4.0
SGR15	536.0	Circular	1.5	0.4	SGR-15	SGR-14	1.1	1.9	2.4	4.1
SPLIT07A	455.3	Natural	0.0	0.3	SPLIT-07	S-08	63.2	71.6	74.6	78.9
SPLIT07B	1055.2	Natural	0.0	0.0	SPLIT-07	SPLIT-06	33.7	67.7	97.9	168.4
NGR01	52.0	Circular	3.0	0.3	NGR-01	S-19	0.9	1.3	1.8	3.5
NGR02	57.0	Circular	3.0	0.5	NGR-02	NGR-01	0.9	1.3	1.8	3.5
NGR03	271.0	Circular	3.0	0.3	NGR-03	NGR-02	0.9	1.3	1.8	3.5
NGR04	201.0	Circular	3.0	0.3	NGR-04	NGR-03	0.9	1.3	1.8	3.5
NGR05	126.0	Circular	3.0	0.3	NGR-05	NGR-04	0.9	1.3	1.8	3.5
NGR06	50.0	Circular	3.0	0.3	NGR-06	NGR-05	0.8	1.1	1.6	3.1
NGR07	300.0	Circular	3.0	0.3	NGR-07	NGR-06	0.8	1.1	1.6	3.1
NGR08	177.0	Circular	3.0	0.3	NGR-08	NGR-07	0.8	1.1	1.6	3.1
NGR09	58.0	Circular	3.0	0.3	NGR-09	NGR-08	0.8	1.1	1.6	3.1
NGR10	285.0	Circular	3.0	0.3	NGR-10	NGR-09	0.8	1.1	1.6	3.1
NGR11	300.0	Circular	2.0	0.3	NGR-11	NGR-10	0.3	0.4	0.5	1.1
NGR12	187.0	Circular	2.0	0.3	NGR-12	NGR-11	0.2	0.4	0.5	0.9
SGR01	50.0	Trapezoidal	4.0	1.3	SGR-01	S-20	3.9	6.3	8.7	15.5

Table C-1. Existing Hydraulic Model Parameters and Results										
Link ID	Length (ft)	Shape	Diameter/ Height (ft)	Slope (%)	Node Name		Existing Max Flow (cfs)			
					US	DS	5 yr	10 yr	25 yr	100 yr
SGR02	408.8	Trapezoidal	4.0	0.3	SGR-02	SGR-01	3.9	6.3	8.7	15.6
SGR03	726.9	Trapezoidal	4.0	0.5	SGR-03	SGR-02	3.9	6.4	8.7	15.5
SGR04A	90.0	Special	3.8	0.3	SGR-04	SGR-03	1.9	3.2	4.4	7.8
SGR04B	90.0	Special	3.8	0.3	SGR-04	SGR-03	1.9	3.2	4.4	7.8
SGR05	341.0	Trapezoidal	3.0	0.2	SGR-05	SGR-04	2.5	4.3	5.8	10.0
SGR06	719.0	Trapezoidal	3.0	0.0	SGR-06	SGR-05	2.5	4.3	5.8	10.0
SGR07	203.0	Circular	4.0	0.3	SGR-07	SGR-06	2.6	4.7	6.1	10.3
SGR08	200.0	Circular	4.0	0.3	SGR-08	SGR-07	2.6	4.7	6.2	10.3
SGR09	250.0	Circular	4.0	0.3	SGR-09	SGR-08	2.6	4.7	6.2	10.3
SGR10	127.0	Circular	4.0	0.3	SGR-10	SGR-09	2.6	4.7	6.2	10.3
SGR11	255.0	Circular	3.0	0.3	SGR-11	SGR-10	2.3	4.1	5.3	8.9
SGR12	209.0	Circular	3.0	0.3	SGR-12	SGR-11	2.0	3.5	4.4	7.4
SWS01	103.0	Circular	3.0	0.3	SWS-01	SGR-10	0.4	0.6	0.9	1.7
SWS02	258.0	Circular	3.0	0.3	SWS-02	SWS-01	0.4	0.6	0.9	1.7
SWS03	64.0	Circular	3.0	0.3	SWS-03	SWS-02	0.4	0.6	0.9	1.7
SWS04	167.0	Circular	2.5	0.3	SWS-04	SWS-03	0.4	0.6	0.9	1.7
SW06	35.0	Circular	3.5	0.3	SW-06	SW-05	6.7	8.8	10.2	13.9
SW08	95.0	Circular	2.5	0.3	SW-08	SW-07	6.4	8.3	9.4	12.6
SW09	206.0	Circular	2.5	0.3	SW-09	SW-08	6.4	8.3	9.4	12.6
SW10	153.0	Circular	2.5	0.3	SW-10	SW-09	6.4	8.3	9.4	12.6
SW07	225.0	Circular	3.5	0.3	SW-07	SW-06	6.7	8.8	10.2	13.9
SW05	36.0	Circular	3.5	0.3	SW-05	SW-04	7.3	9.9	11.5	16.3
SW11	97.0	Circular	2.5	0.3	SW-11	SW-10	6.4	8.3	9.4	12.6
SPLIT06	714.5	Natural	0.0	0.0	SPLIT-06	SPLIT-05	29.5	65.9	94.6	170.8
SPLIT05	466.0	Natural	0.0	0.0	SPLIT-05	SPLIT-04	28.5	64.0	91.7	167.4
SPLIT04	849.8	Natural	0.0	0.0	SPLIT-04	SPLIT-03	27.5	48.3	69.6	126.9
SPLIT03	1062.9	Natural	0.0	0.0	SPLIT-03	SPLIT-02	16.3	19.6	29.2	52.8
SPLIT02	378.3	Natural	0.0	0.0	SPLIT-02	SPLIT-01	5.8	6.2	6.3	6.3
DD-ON2	329.0	Circular	1.5	0.1	DD	ON2	0.7	1.1	1.5	2.2
DD-MD1	80.0	Trapezoidal	0.2	-1.1	DD	MD1	0.0	0.0	0.0	0.0
LL-MM	265.0	Circular	2.0	0.2	LL	MM	0.9	1.9	2.7	4.7
HH-JJ	10.0	Trapezoidal	2.0	0.0	HH	JJ	1.0	1.2	1.2	1.5
E18-MD3	51.0	Circular	1.5	3.0	E18	MD3	1.0	1.6	1.9	3.0
II-JJ	10.0	Trapezoidal	3.0	18.8	II	JJ	0.0	0.0	0.0	0.0
II-E18	504.0	Trapezoidal	3.0	0.3	II	E18	0.0	0.0	0.0	0.0
JJ-D-1	75.0	Circular	3.0	1.1	JJ	D-1	1.4	1.9	2.2	3.0
D-1_S-25a	640.0	Trapezoidal	3.0	0.4	D-1	S-25a	1.5	1.8	2.1	2.9
D-2_S-25a	1190.0	Trapezoidal	3.0	0.4	D-2	S-25a	2.1	3.6	4.8	8.4
NN-D2	68.0	Circular	2.0	-0.3	NN	D-2	2.1	3.8	5.1	8.7
MM-NN	11.0	Circular	2.0	3.6	MM	NN	2.1	3.8	5.1	8.7

Table C-1. Existing Hydraulic Model Parameters and Results										
Link ID	Length (ft)	Shape	Diameter/ Height (ft)	Slope (%)	Node Name		Existing Max Flow (cfs)			
					US	DS	5 yr	10 yr	25 yr	100 yr
MM-JJ	527.0	Trapezoidal	2.0	0.6	MM	JJ	0.0	0.0	0.0	0.0
24-2_S-28a	400.0	Circular	2.0	0.5	24-2	S-28a	0.1	0.2	0.3	0.6
24-1_S-28a	283.0	Circular	2.0	0.1	24-1	S-28a	0.4	0.6	0.8	1.4
AA-BB	60.0	Circular	1.5	-0.8	AA	BB	0.0	0.0	0.0	0.0
EE-ON1	287.2	Circular	1.5	0.4	EE	ON1	0.0	0.0	0.0	0.2
FF-GG	60.0	Circular	2.0	0.4	FF	GG	1.0	1.2	1.2	1.4
BB-DD	73.0	Circular	1.5	-0.8	BB	DD	0.5	0.9	1.1	1.6
BB-CC	110.0	Circular	1.5	-0.6	BB	CC	0.1	0.1	0.1	0.2
CC-EE	73.0	Circular	1.5	-1.1	CC	EE	0.0	0.0	0.0	0.2
GG-HH	288.0	Circular	2.0	0.5	GG	HH	1.0	1.1	1.2	1.4
KK-LL	80.0	Circular	2.0	0.4	KK	LL	0.3	1.0	1.5	2.8
KK-FF	511.0	Circular	1.0	0.0	KK	FF	1.0	1.2	1.2	1.4
OO-PP	324.0	Circular	1.5	0.4	OO	PP	0.7	1.0	1.3	2.2
OO-KK	409.0	Circular	2.0	0.5	OO	KK	0.9	1.6	2.0	3.1
PP-MM	353.0	Circular	2.0	0.3	PP	MM	0.7	1.0	1.3	2.1
T1-RD1	120.0	Circular	2.0	0.0	T1	RD1	0.1	0.2	0.2	0.4
RD1-RD2	525.0	Natural	0.0	0.4	RD1	RD2	0.7	1.3	1.6	2.7
RD2-S-32	1134.0	Natural	0.0	0.2	RD2	S-32	3.1	5.1	6.4	10.7
T3-RD2	187.0	Circular	1.5	10.7	T3	RD2	1.1	1.7	2.2	3.9
T2-RD1	150.0	Circular	2.0	14.7	T2	RD1	0.1	0.2	0.3	0.4
ON1-ON2	117.8	Trapezoidal	3.0	1.0	ON1	ON2	0.0	0.0	0.0	0.1
MD1-MD2	182.0	Circular	2.5	0.3	MD1	MD2	0.1	0.2	0.2	0.3
MD2-MD3	152.0	Circular	2.5	0.5	MD2	MD3	0.1	0.2	0.2	0.3
MD3-36N	84.0	Circular	3.0	0.1	MD3	36N	1.1	1.7	2.1	3.2
E15	33.0	Circular	1.3	0.9	OD1	24-2	0.0	0.0	0.0	0.0
GI	NA	NA	NA	NA	OD1	24-2	0.0	0.0	0.0	0.0
OD2-24-1	100.0	Trapezoidal	2.0	0.0	OD2	24-1	0.0	0.0	0.0	0.0
OD1_OD2	100.0	Trapezoidal	2.0	0.4	OD2	OD1	0.0	0.0	0.0	0.0
ON2-E18	135.0	Trapezoidal	1.0	0.0	ON2	E18	0.7	1.1	1.3	2.1
WA-01_A-8	1650.0	Circular	2.0	0.5	WA-01	A-08	1.6	2.2	2.9	5.6
Z9	135.0	Circular	1.0	47.6	20-A	A30.1	0.8	1.3	1.8	3.4
L150	490.0	Circular	1.0	5.4	22-A	24-A	0.0	0.0	0.0	0.0
Z11	136.8	Circular	1.8	22.9	24-A	A30.1	0.5	0.8	1.0	1.8
Z12	82.4	Circular	2.0	0.3	25-A	26-A	0.0	0.0	0.0	0.0
L148	158.0	Circular	2.0	0.9	26-A	31-A	0.0	0.0	0.0	0.0
L147	380.0	Circular	2.0	0.7	31-A	60-A	0.0	0.0	0.0	0.0
L151	224.0	Circular	2.0	11.8	60-A	A30.1	1.1	1.7	2.1	3.4
Z22	151.0	Circular	2.0	0.4	36-A	38-A	0.0	0.0	0.0	0.0
Z23	138.0	Circular	2.0	1.7	38-A	39-A	0.0	0.0	0.0	0.0
X5	492.0	Natural	0.8	27.8	C5R	A30.1	0.7	1.1	1.4	2.3

Table C-1. Existing Hydraulic Model Parameters and Results										
Link ID	Length (ft)	Shape	Diameter/ Height (ft)	Slope (%)	Node Name		Existing Max Flow (cfs)			
					US	DS	5 yr	10 yr	25 yr	100 yr
X7	336.6	Natural	2.3	3.0	C6	C12	0.0	0.0	0.0	0.0
X12	141.7	Natural	1.5	2.5	C12	C13	0.0	0.0	0.0	0.0
Z29	150.0	Natural	1.5	1.9	A29	A29.1	0.0	0.0	0.0	0.0
L143	570.2	Natural	10.8	0.6	A31R	A33	22.4	31.9	37.8	58.6
292.1	240.0	Circular	3.0	1.4	A33	A34	23.0	26.2	27.7	32.5
RoadZ33	100.0	Trapezoidal	2.0	0.0	A33	A34	0.0	8.1	12.9	31.3
777.1	10.0	Circular	3.0	5.0	D5	A34	1.8	2.8	3.5	6.2
OFLOW D5	10.0	Trapezoidal	0.5	66.0	D5	A34	0.0	0.0	0.0	0.0
Z35	265.0	Natural	2.5	17.4	A35	A-24	25.4	38.3	45.5	72.6
W4	412.7	Circular	1.5	5.3	49-A	D5	1.0	1.6	2.0	3.5
W3	145.0	Circular	2.0	0.7	50-A	51-A	0.0	0.0	0.0	0.0
W2	171.0	Circular	2.0	1.9	51-A	D2	0.0	0.0	0.0	0.0
Y31	200.0	Circular	2.0	10.1	41-A	A30.1	0.5	0.8	1.0	1.8
Y33	85.4	Circular	2.0	1.9	42-A	44-A	0.0	0.0	0.0	0.0
Z24	127.2	Circular	2.0	0.7	39-A	40-A	0.0	0.0	0.0	0.0
L145	396.0	Circular	2.0	0.4	40-A	43-A	0.0	0.0	0.0	0.0
Z27	717.0	Circular	2.0	2.5	44-A	A30.1	0.8	1.2	1.6	2.6
Z42	50.0	Rectangular	3.0	0.0	A42-A41R	A43R	3.5	4.9	5.7	8.2
Z43	1700.0	Natural	3.0	0.7	A43R	A-24	3.3	4.7	5.6	8.0
Z28	25.0	Circular	2.5	0.6	45-A	46-A	0.0	0.0	0.0	0.0
W1.3	206.0	Circular	2.0	1.1	D2	D3	0.0	0.0	0.0	0.0
W1.2	101.0	Circular	2.0	4.1	D3	D4	0.0	0.0	0.0	0.0
L144	108.0	Circular	2.0	1.1	43-A	44-A	0.0	0.0	0.0	0.0
Chrry	NA	NA	NA	NA	Cherry-PkR	N151	6.6	8.4	9.5	12.2
L154	1600.0	Natural	3.0	5.4	N145R	A30.2R	8.2	10.9	12.5	17.0
L158	435.0	Natural	1.0	2.5	N149	N150	0.0	0.0	0.0	0.0
L159	183.0	Circular	1.5	11.8	N150	A30.1	1.1	1.7	2.3	4.3
L153	1400.0	Natural	3.0	9.1	N151	A30.2R	6.6	8.4	9.5	12.2
Bypass	17.0	Rectangular	5.4	0.6	46-A	47-A	0.0	0.0	0.0	0.0
Filter	NA	NA	NA	NA	46-A	47-A	0.0	0.0	0.0	0.0
Z28.2	90.0	Circular	2.5	0.6	47-A	A29	0.0	0.0	0.0	0.0
W5	581.0	Circular	1.5	3.8	D1	D5	0.8	1.3	1.6	2.8
W1.1	72.0	Circular	2.0	4.0	D4	D5	0.0	0.0	0.0	0.0
294.1	72.0	Circular	3.0	5.6	A34	A35	24.7	37.1	44.0	70.1
RoadZ34	60.0	Trapezoidal	3.0	0.0	A34	A35	0.0	0.0	0.0	0.0
Z30.3	690.3	Natural	6.0	1.7	A30.2R	A31R	22.5	32.0	37.9	59.0
Z30.2	65.0	Special	5.8	1.5	A30.1	A30.2R	4.4	7.2	9.3	17.6
Z29.2	180.0	Natural	1.5	0.9	A29.2	A29.3	0.0	0.0	0.0	0.0
Z29.1	63.0	Natural	2.7	1.8	A29.1	A29.2	0.0	0.0	0.0	0.0
X14	437.6	Natural	1.5	2.5	C14	A29	0.0	0.0	0.0	0.0

Table C-1. Existing Hydraulic Model Parameters and Results										
Link ID	Length (ft)	Shape	Diameter/ Height (ft)	Slope (%)	Node Name		Existing Max Flow (cfs)			
					US	DS	5 yr	10 yr	25 yr	100 yr
X13	110.0	Natural	3.4	2.4	C13	C14	0.0	0.0	0.0	0.0
Z29.3	180.0	Natural	2.0	1.1	A29.3	A29.4	0.0	0.0	0.0	0.0
Z29.4	149.8	Natural	1.5	3.3	A29.4	A30.1	0.0	0.0	0.0	0.0
36N-S-28	60.0	Circular	4.0	0.2	36N	S-28	21.0	25.9	28.3	32.9
S29	357.0	Circular	3.0	0.2	36E	36N	20.1	24.7	26.8	30.5
Link333	267.0	Circular	3.0	1.0	WA-03	Node369	0.6	1.0	1.2	2.1
Link332	420.0	Circular	3.0	2.7	WA-04	WA-03	0.3	0.4	0.5	0.7
Link330	892.0	Trapezoidal	3.0	1.2	WA-06	WA-14	3.4	4.8	5.7	8.2
Link331	476.0	Trapezoidal	3.0	3.3	WA-02	WA-14	12.9	18.6	22.3	32.5
WA-12-1	30.0	Trapezoidal	3.0	3.3	WA-12	WA-12.1	13.3	15.7	17.0	20.7
WA-11-1	30.0	Trapezoidal	3.0	3.3	WA-11	WA-12.1	11.9	14.8	16.6	21.4
WA-13-1	30.0	Trapezoidal	3.0	2.2	WA-13	WA-13.1	1.6	2.1	2.4	3.2
Link304	230.0	Natural	0.0	0.2	Node233	S-03	70.0	74.1	76.5	83.0
Link323	67.0	Circular	5.0	0.5	BlueLakeN	Node352	8.0	11.9	14.4	21.4
Link307	200.9	Circular	3.0	0.3	BlueLake	Node349	2.8	4.1	4.8	6.7
Link308	55.5	Circular	3.0	1.0	Node349	Node350	2.8	4.1	4.8	6.7
Weir1-West	NA	NA	NA	NA	Node350	Node351	0.0	0.0	0.0	0.0
Weir1_East	NA	NA	NA	NA	Node350	Node351	0.0	0.0	0.0	0.0
weir top.1	NA	NA	NA	NA	Node350	Node351	0.0	0.0	0.0	0.0
24 inch	NA	NA	NA	NA	Node350	Node351	2.8	4.1	4.8	9.8
Link318	277.4	Natural	3.0	1.0	Node351	Node352	2.9	4.2	4.9	10.0
Link319	749.2	Natural	0.0	0.1	Node352	Node353	7.8	11.1	13.8	19.9
Link320	146.4	Circular	5.0	0.0	Node353	Node363	8.2	10.6	11.8	18.1
Link321	271.2	Natural	3.0	0.3	Node363	Node364	8.9	10.3	11.5	17.3
886.1	336.8	Circular	3.5	0.0	Node364	Node233	4.8	5.0	5.6	6.9
886.2	336.8	Circular	3.5	0.0	Node364	Node233	4.8	5.0	5.6	6.9
WA-12-2	2340.0	Trapezoidal	3.0	0.4	WA-12.1	A48	25.0	30.2	33.4	41.8
WA-13-2	585.0	Trapezoidal	3.0	3.8	WA-13.1	SS-15R	1.6	2.1	2.4	3.2
Link329	295.0	Circular	2.0	0.3	WA-14	S-33	16.1	18.4	19.2	20.7
Link334	1020.0	Trapezoidal	3.0	0.9	Node369	S-33	0.6	0.9	1.2	2.0
Link335	306.0	Circular	1.0	0.3	Node370	Node371	2.4	3.1	3.5	4.0
Link336	186.0	Trapezoidal	3.0	0.0	Node371	Node372	2.3	3.4	3.6	4.0
Link337	80.0	Circular	1.5	0.8	Node372	A-19	2.5	3.8	4.0	4.5
Link339	1320.0	Trapezoidal	3.0	0.5	WA-15	WA-02	10.9	15.7	18.8	27.4
Overstop Gate.1	NA	NA	NA	NA	Node374	S-01	0.0	0.0	0.0	0.0

Table C-1. Future Hydraulic Model Parameters and Results										
Link ID	Length (ft)	Shape	Diameter/ Height (ft)	Slope (%)	Node Name		Future Max Flow (cfs)			
					US	DS	5 yr	10 yr	25 yr	100 yr
S32	480.0	Natural	0.0	0.1	S-32	S-31	35.1	38.8	41.0	51.4
Hotel Weir.1	NA	NA	NA	NA	S-31	S-29	0.0	0.0	0.0	12.2
Pipe	48.6	Circular	3.0	1.5	S-31	S-29	36.3	40.2	42.5	45.6
S24	710.0	Circular	2.5	0.2	S-24	S-23	23.5	23.7	23.7	23.8
AirportW1.1	NA	NA	NA	NA	S-24	A-09	92.1	109.3	119.8	146.2
S21	176.0	Natural	0.0	0.0	S-21	S-20.1	51.5	53.6	54.4	55.7
S18	523.0	Natural	0.0	0.0	S-18	S-17	106.4	117.7	123.4	139.3
S12	100.0	Rectangular	7.0	0.2	S-12	S-11	195.8	224.5	240.4	284.9
S10	803.3	Natural	0.0	0.0	S-10	S-09	411.7	458.6	484.1	545.4
S8	1082.0	Natural	0.0	0.1	S-08	S-07	83.4	80.2	78.2	76.8
S7	900.0	Natural	0.0	0.1	S-07	S-06	85.3	83.9	82.4	78.8
S6	462.0	Circular	5.0	0.1	S-06	S-05	84.7	84.2	83.3	80.3
MarineDr-W	346.0	Circular	6.0	-0.1	S-03	S-02	42.5	42.5	42.2	42.0
MarineDr-E	346.0	Circular	6.0	-0.1	S-03	S-02	42.5	42.5	42.3	42.0
S2	260.0	Natural	0.0	0.1	S-02	S-01	80.6	80.0	80.0	80.0
SandyPS_1	NA	NA	NA	NA	PS	OUT	40.8	41.1	41.3	41.6
SandyPS_2	NA	NA	NA	NA	PS	OUT	33.0	33.3	33.5	33.9
A22	86.0	Circular	4.0	0.8	A48	A-21	99.1	105.0	107.9	115.2
A21	129.0	Natural	0.0	6.6	A-21	A-20	99.1	105.0	107.9	115.2
A20	657.0	Circular	4.0	1.4	A-20	A-19	96.2	98.1	99.0	100.4
A19	190.0	Natural	0.0	-0.3	A-19	A-18	101.2	103.0	104.7	107.5
A18	246.0	Natural	0.0	0.3	A-18	A-17	97.8	99.9	101.0	102.8
A16	157.0	Natural	0.0	0.4	A-16	A-15	93.4	97.5	99.2	102.4
Marine1	117.0	Circular	4.0	-0.4	A-11	A-10	40.5	42.7	43.5	45.1
Marine2	118.0	Circular	4.0	-0.1	A-11	A-10	53.2	55.9	56.9	59.0
A10	143.0	Natural	0.0	1.3	A-10	A-09	93.8	98.8	100.5	104.1
AirportW2	NA	NA	NA	NA	A-09	A-08	154.7	178.3	201.6	252.9
airport-e	520.0	Circular	4.0	0.1	A-09	A-08	48.3	48.4	48.4	48.6
airport-w	520.0	Circular	4.0	0.1	A-09	A-08	48.3	48.4	48.4	48.6
A8	164.0	Natural	0.0	0.0	A-08	A-07	179.3	192.1	195.0	201.0
sundial-e	103.0	Circular	4.0	-0.7	A-07	A-06	95.2	101.8	102.8	103.8
sundial-w	100.0	Circular	4.0	-0.8	A-07	A-06	96.0	103.8	104.7	105.6
A6	795.0	Natural	0.0	0.3	A-06	A-05	191.3	205.8	206.8	207.3
A2	43.0	Natural	0.0	0.1	A-02	A-01	213.7	231.2	237.2	249.2
A1	184.0	Natural	0.0	0.7	A-01	S-10	213.8	231.3	237.2	248.9
A24	112.0	Circular	4.0	0.3	A-24	A-23.3	84.5	91.5	94.3	98.6
S33	120.0	Circular	2.1	5.4	S-33	S-32	21.4	23.0	23.8	25.7
S25	520.0	Natural	0.0	0.1	S-25	S-24	104.3	119.9	128.7	151.4
S20	90.0	Rectangular	4.0	1.0	S-20	S-19	94.7	103.3	106.8	118.6
S19	665.0	Natural	0.0	0.1	S-19	S-18	108.6	120.0	125.3	140.8
S15	172.0	Natural	0.0	0.1	S-15	S-14	108.7	120.7	126.9	145.4
S11	1280.9	Natural	0.0	0.0	S-11	S-10	196.3	225.0	241.5	288.5

Table C-1. Future Hydraulic Model Parameters and Results

Link ID	Length (ft)	Shape	Diameter/ Height (ft)	Slope (%)	Node Name		Future Max Flow (cfs)			
					US	DS	5 yr	10 yr	25 yr	100 yr
S26	125.0	Natural	0.0	0.1	S-26	S-25	46.8	50.1	51.8	57.1
S5	1024.0	Natural	0.0	0.1	S-05	S-04	78.1	77.1	76.3	75.2
S4	500.0	Natural	0.0	0.1	S-04	Node233	106.0	107.2	105.9	105.7
S1	300.0	Natural	0.0	0.1	S-01	PS	79.3	74.4	75.9	72.7
S-08a_Culvert	27.7	Circular	2.0	1.6	S-08a	S-08	24.1	25.3	26.1	27.4
S-08a_overtop	27.2	Trapezoidal	0.5	8.5	S-08a	S-08	0.0	0.0	0.0	0.0
A3	500.0	Natural	0.0	0.1	A-03	A-02	213.6	231.1	237.2	250.0
Rogers-e	82.0	Circular	5.0	0.6	A-04	A-03	100.1	108.0	109.5	111.8
Rogers-w	85.0	Circular	5.0	0.5	A-04	A-03	99.9	107.8	109.3	111.6
A15	60.0	Circular	4.0	-0.2	A-15	A-14	92.3	96.8	98.6	102.3
A14	170.0	Natural	0.0	0.0	A-14	A-13	92.3	96.8	98.6	102.3
A13	60.0	Circular	4.0	0.2	A-13	A-12	92.3	96.8	98.6	102.3
A12	88.0	Natural	0.0	0.9	A-12	A-11	92.3	96.8	98.7	102.4
A17	347.0	Natural	0.0	0.1	A-17	A-16	92.7	96.3	97.8	100.4
A23	410.0	Trapezoidal	2.5	0.5	A-23	A48	63.7	64.1	64.6	64.7
S-29_OD1	715.0	Trapezoidal	2.0	0.2	S-29	OD1	0.8	3.3	5.0	14.5
Link301	108.0	Circular	3.0	0.2	S-29	36E	35.8	37.2	37.8	39.8
S27	162.0	Circular	4.0	0.4	S-27	S-26	46.7	50.0	51.7	57.0
S28a	724.0	Natural	0.0	0.4	S-28a	S-28	3.6	6.1	7.6	11.8
S25a	336.0	Natural	0.0	0.3	S-25a	S-25	54.0	65.3	71.7	88.6
perim-e	45.0	Circular	3.0	0.0	S-22	S-21	14.3	14.6	14.8	15.1
perimr-m	45.0	Circular	3.0	0.5	S-22	S-21	14.6	15.0	15.2	15.6
perimr-w	45.0	Circular	3.0	0.2	S-22	S-21	14.4	14.7	14.9	15.1
S23	149.0	Natural	0.0	0.2	S-23	S-22	43.1	43.9	44.4	45.3
S17	286.0	Natural	0.0	0.2	S-17	S-15	108.7	120.5	126.7	144.7
S14	92.0	Rectangular	6.7	0.5	S-14	S-13	111.5	124.1	130.6	150.0
S13	266.0	Natural	0.0	0.3	S-13	S-12	163.9	186.8	199.3	233.5
A5	290.0	Natural	0.0	0.2	A-05	A-04	200.0	215.5	218.7	223.2
S28	347.0	Natural	0.0	0.2	S-28	S-27	42.3	45.2	46.6	50.1
6 ft Pipe	29.0	Circular	6.0	0.0	SPLIT-01	S-01	0.0	0.0	0.0	0.0
Rectangular Culvert	36.0	Rectangular	5.5	0.0	SPLIT-01	Node374	0.0	2.1	30.4	108.1
Weir_WEST_01	NA	NA	NA	NA	SPLIT-01	Node374	0.0	0.0	0.8	36.3
S20.1	90.0	Natural	0.0	0.2	S-20.1	S-20	51.6	53.5	54.1	56.5
S8b	300.0	Natural	0.0	0.5	S-08b	S-08a	24.7	26.3	26.7	27.5
A23.1	13.0	Circular	4.0	0.5	A-23.1	A-23	60.5	61.9	62.5	63.7
SS01	950.0	Natural	0.0	0.1	SS-01	S-04	41.9	47.9	51.5	58.9
A23.2	216.0	Circular	2.5	0.2	A-23.2	A-23.1	60.5	61.9	62.5	63.7
A23.3	37.0	Circular	2.5	2.1	A-23.3	A-23.2	60.5	61.9	62.5	63.7
SS02	150.0	Circular	4.0	1.4	SS-02	SS-01	30.9	34.9	37.2	41.2
SS03	562.0	Natural	0.0	0.2	SS-03	SS-02	30.9	35.0	37.2	42.1
372.1-N	90.0	Special	3.0	0.1	SS-04	SS-03	18.6	21.2	22.6	25.8
372.2-S	90.0	Circular	3.0	0.5	SS-04	SS-03	12.3	14.3	15.0	17.2

Table C-1. Future Hydraulic Model Parameters and Results

Link ID	Length (ft)	Shape	Diameter/ Height (ft)	Slope (%)	Node Name		Future Max Flow (cfs)			
					US	DS	5 yr	10 yr	25 yr	100 yr
SS05	13.0	Natural	0.0	1.3	SS-05	SS-04	30.9	35.0	37.5	42.9
SS06	124.5	Special	4.0	0.7	SS-06	SS-05	30.9	35.3	37.8	43.1
SS07	147.0	Natural	0.0	0.3	SS-07	SS-06	22.7	25.2	26.5	30.1
SS08	24.6	Special	3.3	-0.7	SS-08	SS-07	22.7	25.2	26.5	30.1
SS09	624.0	Natural	0.0	0.2	SS-09	SS-08	22.6	25.1	26.5	30.1
SS10	61.7	Circular	3.0	1.1	SS-10	SS-09	22.6	25.1	26.5	30.1
SS11	344.0	Natural	0.0	0.3	SS-11	SS-10	22.6	25.1	26.5	30.1
SS12	20.9	Circular	3.0	1.6	SS-12	SS-11	22.6	25.1	26.5	30.1
SS13a	161.0	Natural	0.0	-0.8	SS-13a	SS-12	22.6	25.2	26.5	30.1
13b N Culv	55.0	Circular	4.0	-2.4	SS-13b	SS-13a	10.5	12.5	13.4	15.3
13b S Culv	68.4	Circular	2.0	-1.1	SS-13b	SS-13a	0.0	0.0	0.0	0.0
13c N Culv	50.2	Circular	1.2	0.5	SS-13c	SS-13b	2.0	2.3	2.4	2.6
13c S Culv	40.0	Circular	1.3	-3.3	SS-13c	SS-13b	1.2	2.0	2.5	3.5
SS14	250.0	Natural	0.0	4.0	SS-14	SS-13a	15.0	17.5	19.1	23.1
SS15	98.0	Circular	3.0	6.2	SS-15R	SS-14	15.0	17.6	19.1	23.2
SUN5	95.0	Circular	2.5	0.3	SUN-5	SUN-4	13.9	16.6	18.2	22.5
SUN4	154.0	Circular	3.5	0.2	SUN-4	SUN-3	25.3	30.1	32.9	40.3
SUN3	467.0	Natural	0.0	0.2	SUN-3	SUN-2	34.0	40.3	44.0	53.3
SUN2	100.0	Circular	3.5	0.2	SUN-2	SUN-1	33.7	39.8	43.4	52.4
SUN1	100.0	Natural	0.0	0.2	SUN-1	S-12	33.6	39.7	43.3	52.4
SW1	755.0	Circular	5.5	0.3	SW-01	S-13	63.6	75.0	81.7	98.8
SW2	765.0	Circular	5.0	0.3	SW-02	SW-01	47.4	55.9	60.8	72.9
SW3	645.0	Circular	4.5	0.3	SW-03	SW-02	44.4	52.6	57.4	68.8
SW4	991.0	Circular	4.0	0.2	SW-04	SW-03	25.9	30.8	33.8	41.6
FED05	143.0	Circular	2.5	0.4	FED-05	FED-04	16.3	19.1	20.7	25.1
FED04	122.0	Circular	2.5	0.4	FED-04	FED-03	16.3	19.1	20.7	25.1
FED03	133.0	Circular	3.5	0.4	FED-03	FED-02	16.3	19.1	20.7	25.1
FED02	151.0	Circular	3.5	0.4	FED-02	FED-01	16.3	19.1	20.7	25.1
FED01	51.0	Circular	3.5	0.4	FED-01	FED-0.2	16.3	19.1	20.7	25.1
FED14	140.0	Special	1.9	0.2	FED-14	FED-13	13.0	15.2	16.5	19.0
FED13	140.0	Special	2.0	0.2	FED-13	FED-12	13.0	15.2	16.5	19.0
FED12	213.0	Special	2.0	0.2	FED-12	FED-11	13.0	15.2	16.5	19.0
FED11	165.0	Special	2.0	0.2	FED-11	FED-10	13.0	15.2	16.5	19.0
FED10	155.0	Special	2.0	0.2	FED-10	FED-09	13.0	15.2	16.5	19.0
FED09	236.0	Special	2.0	0.3	FED-09	FED-08	13.0	15.2	16.5	19.0
FED08	258.0	Special	2.6	0.2	FED-08	FED-07	13.0	15.2	16.5	19.0
FED07	262.0	Special	3.0	0.2	FED-07	FED-06.2	13.0	15.2	16.5	19.0
FED06	60.0	Circular	4.0	0.2	FED-06	SW-03	13.0	15.1	16.5	19.2
FED15	25.0	Circular	3.5	0.6	FED-15	SUN-4	11.7	13.9	15.2	18.5
FED16	361.0	Circular	3.5	0.3	FED-16	FED-15	11.8	14.0	15.3	18.7
FED17	238.0	Circular	3.5	0.3	FED-17	FED-16	11.9	14.1	15.5	18.9
FED18	35.0	Circular	3.5	0.2	FED-18	FED-17	11.9	14.2	15.5	19.1

Table C-1. Future Hydraulic Model Parameters and Results										
Link ID	Length (ft)	Shape	Diameter/ Height (ft)	Slope (%)	Node Name		Future Max Flow (cfs)			
					US	DS	5 yr	10 yr	25 yr	100 yr
FED19	261.0	Circular	3.5	0.2	FED-19	FED-18	11.9	14.2	15.5	19.1
FED20	200.0	Circular	3.5	0.2	FED-20	FED-19	11.9	14.2	15.5	19.1
FED21	200.0	Circular	3.5	0.2	FED-21	FED-20	11.9	14.2	15.5	19.1
FED22	200.0	Circular	3.5	0.2	FED-22	FED-21	11.9	14.2	15.5	19.1
FED23	192.0	Circular	3.5	0.2	FED-23	FED-22	12.0	14.2	15.5	19.1
FED24	201.0	Circular	3.0	0.2	FED-24	FED-23	12.0	14.2	15.5	19.1
FED25	199.0	Circular	3.0	0.2	FED-25	FED-24	12.0	14.2	15.6	19.1
FED26	304.0	Circular	2.5	0.2	FED-26	FED-25	12.0	14.2	15.6	19.1
FED0.2	35.0	Circular	3.5	0.3	FED-0.2	FED-0.1	16.3	19.0	20.7	25.1
FED0.1	100.0	Circular	3.5	0.4	FED-0.1	SW-01	16.2	19.0	20.6	25.0
FED06.2	35.0	Circular	4.0	0.1	FED-06.2	FED-06.1	13.0	15.2	16.5	19.0
FED06.1	200.0	Circular	4.0	0.2	FED-06.1	FED-06	13.0	15.2	16.5	19.1
S23.3	151.0	Circular	1.3	0.2	S-23.3	S-23.2	7.3	7.8	8.0	8.3
S23.2	174.0	Circular	1.5	0.2	S-23.2	S-23.1	10.1	11.2	11.5	12.0
S23.1	160.0	Circular	1.6	0.2	S-23.1	S-23	19.5	20.0	20.3	21.2
S09	369.7	Natural	0.0	0.0	S-09	SPLIT-07	419.9	469.0	495.9	561.1
SGR13	177.0	Circular	2.5	0.3	SGR-13	SGR-12	12.9	14.4	15.3	17.6
SGR14	255.0	Circular	2.0	0.3	SGR-14	SGR-13	5.2	5.3	5.4	5.6
SGR15	536.0	Circular	1.5	0.4	SGR-15	SGR-14	5.2	5.3	5.4	5.6
SPLIT07A	455.3	Natural	0.0	0.3	SPLIT-07	S-08	69.4	66.6	66.2	66.4
SPLIT07B	1055.2	Natural	0.0	0.0	SPLIT-07	SPLIT-06	359.3	416.6	444.5	516.9
NGR01	52.0	Circular	3.0	0.3	NGR-01	S-19	14.3	16.8	18.3	22.1
NGR02	57.0	Circular	3.0	0.5	NGR-02	NGR-01	14.4	16.8	18.3	22.1
NGR03	271.0	Circular	3.0	0.3	NGR-03	NGR-02	14.5	16.9	18.4	22.2
NGR04	201.0	Circular	3.0	0.3	NGR-04	NGR-03	14.6	17.1	18.6	22.3
NGR05	126.0	Circular	3.0	0.3	NGR-05	NGR-04	14.7	17.2	18.7	22.5
NGR06	50.0	Circular	3.0	0.3	NGR-06	NGR-05	12.7	14.9	16.2	19.5
NGR07	300.0	Circular	3.0	0.3	NGR-07	NGR-06	12.7	14.9	16.2	19.6
NGR08	177.0	Circular	3.0	0.3	NGR-08	NGR-07	12.7	14.9	16.2	19.6
NGR09	58.0	Circular	3.0	0.3	NGR-09	NGR-08	12.7	14.9	16.2	19.6
NGR10	285.0	Circular	3.0	0.3	NGR-10	NGR-09	12.7	14.9	16.2	19.6
NGR11	300.0	Circular	2.0	0.3	NGR-11	NGR-10	4.5	5.3	5.8	7.0
NGR12	187.0	Circular	2.0	0.3	NGR-12	NGR-11	3.9	4.6	5.0	6.1
SGR01	50.0	Trapezoidal	4.0	1.3	SGR-01	S-20	44.2	51.0	54.6	64.9
SGR02	408.8	Trapezoidal	4.0	0.3	SGR-02	SGR-01	44.9	52.0	55.7	66.1
SGR03	726.9	Trapezoidal	4.0	0.5	SGR-03	SGR-02	44.9	52.0	56.2	67.4
SGR04A	90.0	Special	3.8	0.3	SGR-04	SGR-03	22.5	26.0	28.1	33.7
SGR04B	90.0	Special	3.8	0.3	SGR-04	SGR-03	22.5	26.0	28.1	33.7
SGR05	341.0	Trapezoidal	3.0	0.2	SGR-05	SGR-04	25.4	29.1	31.3	37.2
SGR06	719.0	Trapezoidal	3.0	0.0	SGR-06	SGR-05	25.3	29.0	31.2	37.0
SGR07	203.0	Circular	4.0	0.3	SGR-07	SGR-06	25.6	29.3	31.5	37.3
SGR08	200.0	Circular	4.0	0.3	SGR-08	SGR-07	25.6	29.3	31.5	37.3

Table C-1. Future Hydraulic Model Parameters and Results

Link ID	Length (ft)	Shape	Diameter/ Height (ft)	Slope (%)	Node Name		Future Max Flow (cfs)			
					US	DS	5 yr	10 yr	25 yr	100 yr
SGR09	250.0	Circular	4.0	0.3	SGR-09	SGR-08	25.6	29.3	31.5	37.3
SGR10	127.0	Circular	4.0	0.3	SGR-10	SGR-09	25.6	29.3	31.5	37.3
SGR11	255.0	Circular	3.0	0.3	SGR-11	SGR-10	19.0	21.5	23.0	27.0
SGR12	209.0	Circular	3.0	0.3	SGR-12	SGR-11	12.9	14.4	15.3	17.6
SWS01	103.0	Circular	3.0	0.3	SWS-01	SGR-10	6.7	7.8	8.5	10.3
SWS02	258.0	Circular	3.0	0.3	SWS-02	SWS-01	6.7	7.8	8.5	10.3
SWS03	64.0	Circular	3.0	0.3	SWS-03	SWS-02	6.7	7.8	8.5	10.3
SWS04	167.0	Circular	2.5	0.3	SWS-04	SWS-03	6.7	7.9	8.5	10.4
SW06	35.0	Circular	3.5	0.3	SW-06	SW-05	15.7	18.7	20.5	25.3
SW08	95.0	Circular	2.5	0.3	SW-08	SW-07	11.7	14.1	15.5	19.3
SW09	206.0	Circular	2.5	0.3	SW-09	SW-08	11.7	14.0	15.4	19.2
SW10	153.0	Circular	2.5	0.3	SW-10	SW-09	11.7	14.0	15.4	19.2
SW07	225.0	Circular	3.5	0.3	SW-07	SW-06	15.7	18.7	20.5	25.3
SW05	36.0	Circular	3.5	0.3	SW-05	SW-04	26.0	30.9	33.8	41.7
SW11	97.0	Circular	2.5	0.3	SW-11	SW-10	11.7	14.0	15.4	19.1
SPLIT06	714.5	Natural	0.0	0.0	SPLIT-06	SPLIT-05	373.9	439.0	470.5	548.1
SPLIT05	466.0	Natural	0.0	0.0	SPLIT-05	SPLIT-04	359.5	412.7	437.8	490.1
SPLIT04	849.8	Natural	0.0	0.0	SPLIT-04	SPLIT-03	271.9	306.0	321.2	346.0
SPLIT03	1062.9	Natural	0.0	0.0	SPLIT-03	SPLIT-02	104.8	119.0	122.8	142.3
SPLIT02	378.3	Natural	0.0	0.0	SPLIT-02	SPLIT-01	0.0	0.0	30.8	142.5
DD-ON2	329.0	Circular	1.5	0.1	DD	ON2	2.7	2.9	2.9	3.3
DD-MD1	80.0	Trapezoidal	0.2	-1.1	DD	MD1	0.0	0.0	0.0	0.0
LL-MM	265.0	Circular	2.0	0.2	LL	MM	7.4	8.8	9.6	11.6
HH-JJ	10.0	Trapezoidal	2.0	0.0	HH	JJ	2.5	3.0	3.2	4.1
E18-MD3	51.0	Circular	1.5	3.0	E18	MD3	3.8	3.8	3.8	3.8
II-JJ	10.0	Trapezoidal	3.0	18.8	II	JJ	2.2	4.0	5.1	8.3
II-E18	504.0	Trapezoidal	3.0	0.3	II	E18	-2.2	-4.1	-5.1	-8.1
JJ-D-1	75.0	Circular	3.0	1.1	JJ	D-1	7.1	11.6	14.3	21.6
D-1_S-25a	640.0	Trapezoidal	3.0	0.4	D-1	S-25a	7.1	11.5	14.2	21.4
D-2_S-25a	1190.0	Trapezoidal	3.0	0.4	D-2	S-25a	14.4	15.6	16.0	16.7
NN-D2	68.0	Circular	2.0	-0.3	NN	D-2	14.5	15.6	16.0	16.8
MM-NN	11.0	Circular	2.0	3.6	MM	NN	14.5	15.6	16.0	16.8
MM-JJ	527.0	Trapezoidal	2.0	0.6	MM	JJ	0.2	1.8	3.0	6.5
24-2_S-28a	400.0	Circular	2.0	0.5	24-2	S-28a	1.4	3.1	4.0	6.9
24-1_S-28a	283.0	Circular	2.0	0.1	24-1	S-28a	2.0	2.8	3.5	5.9
AA-BB	60.0	Circular	1.5	-0.8	AA	BB	0.0	0.0	0.0	0.0
EE-ON1	287.2	Circular	1.5	0.4	EE	ON1	1.8	2.3	2.5	3.1
FF-GG	60.0	Circular	2.0	0.4	FF	GG	2.6	2.9	3.1	3.6
BB-DD	73.0	Circular	1.5	-0.8	BB	DD	1.9	2.0	2.0	1.9
BB-CC	110.0	Circular	1.5	-0.6	BB	CC	1.8	2.3	2.5	3.1
CC-EE	73.0	Circular	1.5	-1.1	CC	EE	1.8	2.3	2.5	3.1
GG-HH	288.0	Circular	2.0	0.5	GG	HH	2.6	2.9	3.1	3.6

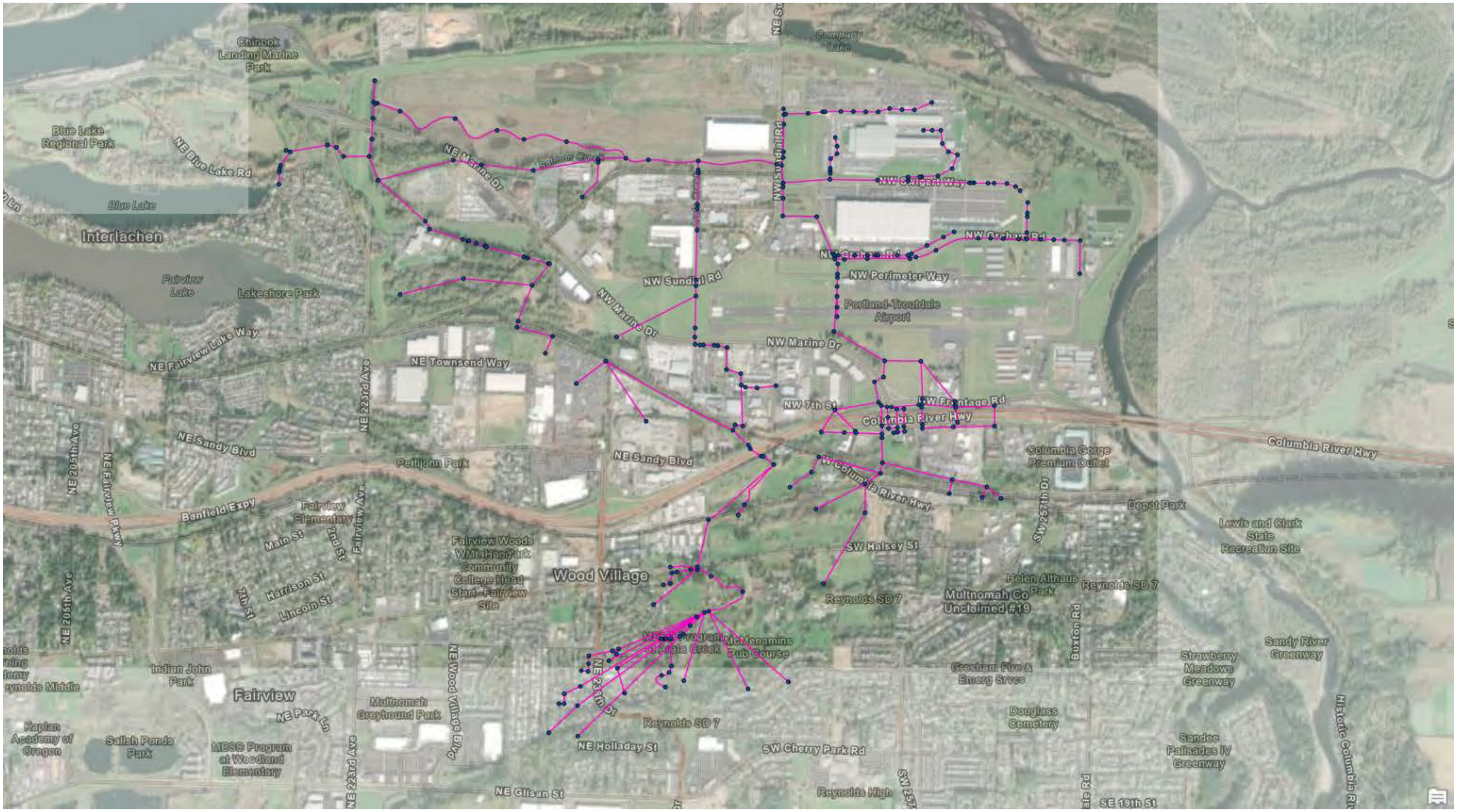
Table C-1. Future Hydraulic Model Parameters and Results										
Link ID	Length (ft)	Shape	Diameter/ Height (ft)	Slope (%)	Node Name		Future Max Flow (cfs)			
					US	DS	5 yr	10 yr	25 yr	100 yr
KK-LL	80.0	Circular	2.0	0.4	KK	LL	4.3	5.1	5.6	7.0
KK-FF	511.0	Circular	1.0	0.0	KK	FF	2.6	2.9	3.1	3.6
OO-PP	324.0	Circular	1.5	0.4	OO	PP	3.8	4.5	4.9	5.8
OO-KK	409.0	Circular	2.0	0.5	OO	KK	5.1	5.9	6.4	8.5
PP-MM	353.0	Circular	2.0	0.3	PP	MM	3.8	4.5	4.9	5.8
T1-RD1	120.0	Circular	2.0	0.0	T1	RD1	0.9	1.0	1.1	1.3
RD1-RD2	525.0	Natural	0.0	0.4	RD1	RD2	7.9	9.0	9.4	10.2
RD2-S-32	1134.0	Natural	0.0	0.2	RD2	S-32	24.7	27.2	28.1	29.0
T3-RD2	187.0	Circular	1.5	10.7	T3	RD2	8.4	9.8	10.7	13.1
T2-RD1	150.0	Circular	2.0	14.7	T2	RD1	0.8	1.0	1.1	1.3
ON1-ON2	117.8	Trapezoidal	3.0	1.0	ON1	ON2	1.7	2.2	2.4	3.0
MD1-MD2	182.0	Circular	2.5	0.3	MD1	MD2	0.5	0.6	0.7	0.8
MD2-MD3	152.0	Circular	2.5	0.5	MD2	MD3	0.5	0.6	0.6	0.8
MD3-36N	84.0	Circular	3.0	0.1	MD3	36N	4.1	4.0	4.3	4.4
E15	33.0	Circular	1.3	0.9	OD1	24-2	0.4	1.4	1.9	3.6
GI	NA	NA	NA	NA	OD1	24-2	-0.7	1.2	1.4	2.2
OD2-24-1	100.0	Trapezoidal	2.0	0.0	OD2	24-1	0.0	0.8	1.6	8.8
OD1_OD2	100.0	Trapezoidal	2.0	0.4	OD2	OD1	0.0	-0.8	-1.6	-8.9
ON2-E18	135.0	Trapezoidal	1.0	0.0	ON2	E18	3.7	4.5	5.0	6.0
WA-01_A-8	1650.0	Circular	2.0	0.5	WA-01	A-08	13.2	13.4	13.4	13.3
Z9	135.0	Circular	1.0	47.6	20-A	A30.1	3.9	5.7	6.9	10.1
L150	490.0	Circular	1.0	5.4	22-A	24-A	0.0	0.0	0.0	0.0
Z11	136.8	Circular	1.8	22.9	24-A	A30.1	1.8	2.5	2.9	4.1
Z12	82.4	Circular	2.0	0.3	25-A	26-A	0.0	0.0	0.0	0.0
L148	158.0	Circular	2.0	0.9	26-A	31-A	0.0	0.0	0.0	0.0
L147	380.0	Circular	2.0	0.7	31-A	60-A	0.0	0.0	0.0	0.0
L151	224.0	Circular	2.0	11.8	60-A	A30.1	4.4	5.5	6.1	7.8
Z22	151.0	Circular	2.0	0.4	36-A	38-A	0.0	0.0	0.0	0.0
Z23	138.0	Circular	2.0	1.7	38-A	39-A	0.0	0.0	0.0	0.0
X5	492.0	Natural	0.8	27.8	C5R	A30.1	9.0	11.6	13.3	17.8
X7	336.6	Natural	2.3	3.0	C6	C12	0.0	0.0	0.0	0.0
X12	141.7	Natural	1.5	2.5	C12	C13	0.0	0.0	0.0	0.0
Z29	150.0	Natural	1.5	1.9	A29	A29.1	0.0	0.0	0.0	0.0
L143	570.2	Natural	10.8	0.6	A31R	A33	67.1	85.8	97.1	127.6
292.1	240.0	Circular	3.0	1.4	A33	A34	33.2	33.3	33.3	33.3
RoadZ33	100.0	Trapezoidal	2.0	0.0	A33	A34	37.0	64.6	83.3	116.4
777.1	10.0	Circular	3.0	5.0	D5	A34	8.1	10.4	12.0	15.6
OFLOW D5	10.0	Trapezoidal	0.5	66.0	D5	A34	0.0	0.0	0.0	0.0
Z35	265.0	Natural	2.5	17.4	A35	A-24	82.9	105.6	118.7	156.8
W4	412.7	Circular	1.5	5.3	49-A	D5	4.1	5.3	6.0	7.9
W3	145.0	Circular	2.0	0.7	50-A	51-A	0.0	0.0	0.0	0.0
W2	171.0	Circular	2.0	1.9	51-A	D2	0.0	0.0	0.0	0.0

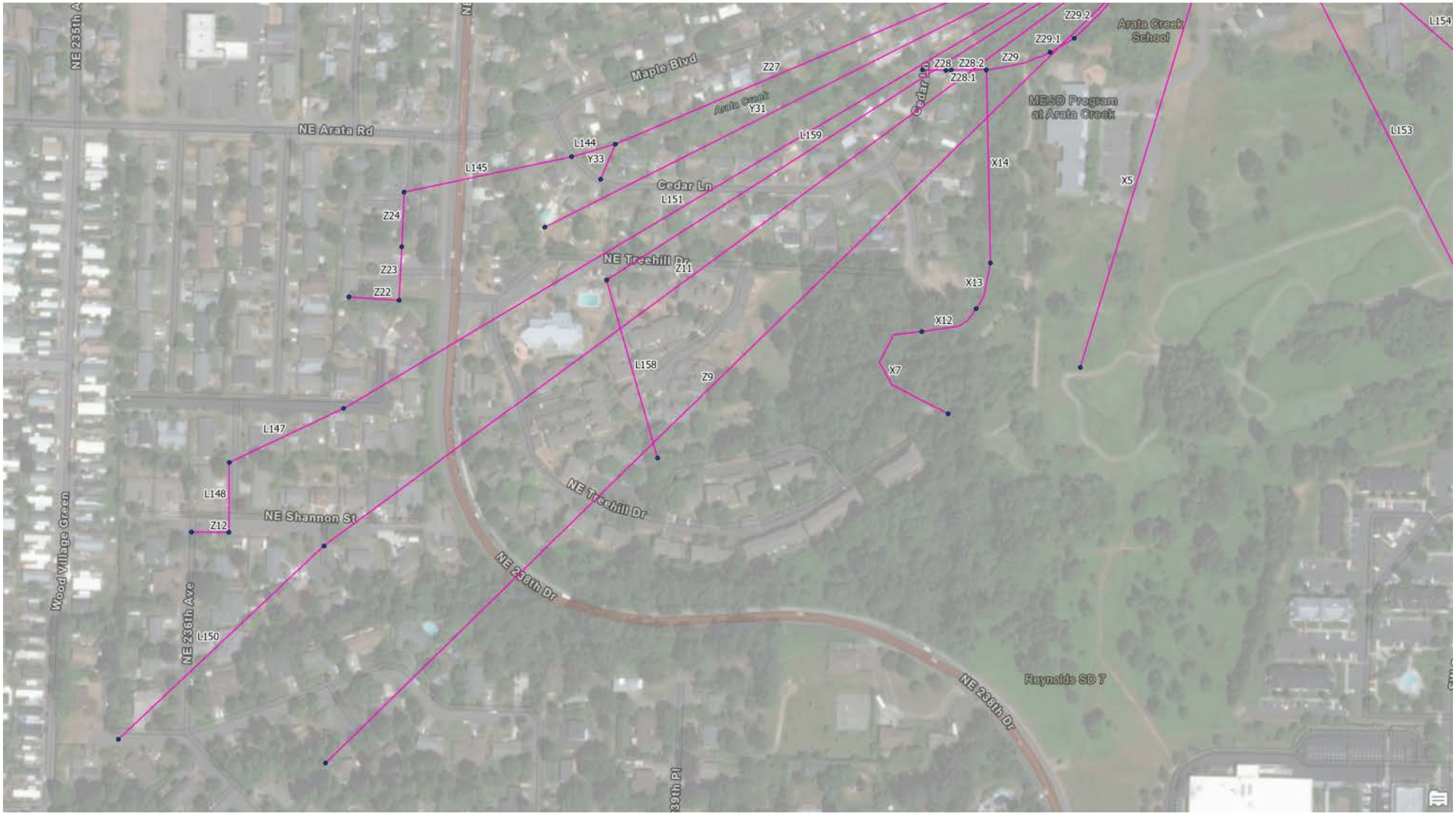
Table C-1. Future Hydraulic Model Parameters and Results

Link ID	Length (ft)	Shape	Diameter/ Height (ft)	Slope (%)	Node Name		Future Max Flow (cfs)			
					US	DS	5 yr	10 yr	25 yr	100 yr
Y31	200.0	Circular	2.0	10.1	41-A	A30.1	2.9	3.6	4.1	5.2
Y33	85.4	Circular	2.0	1.9	42-A	44-A	0.0	0.0	0.0	0.0
Z24	127.2	Circular	2.0	0.7	39-A	40-A	0.0	0.0	0.0	0.0
L145	396.0	Circular	2.0	0.4	40-A	43-A	0.0	0.0	0.0	0.0
Z27	717.0	Circular	2.0	2.5	44-A	A30.1	2.6	3.3	3.8	5.0
Z42	50.0	Rectangular	3.0	0.0	A42-A41R	A43R	9.6	11.1	12.0	14.6
Z43	1700.0	Natural	3.0	0.7	A43R	A-24	11.4	13.0	13.8	14.4
Z28	25.0	Circular	2.5	0.6	45-A	46-A	0.0	0.0	0.0	0.0
W1.3	206.0	Circular	2.0	1.1	D2	D3	0.0	0.0	0.0	0.0
W1.2	101.0	Circular	2.0	4.1	D3	D4	0.0	0.0	0.0	0.0
L144	108.0	Circular	2.0	1.1	43-A	44-A	0.0	0.0	0.0	0.0
Chrry	NA	NA	NA	NA	Cherry-PkR	N151	11.2	12.8	13.6	14.9
L154	1600.0	Natural	3.0	5.4	N145R	A30.2R	13.2	16.2	17.9	22.7
L158	435.0	Natural	1.0	2.5	N149	N150	0.0	0.0	0.0	0.0
L159	183.0	Circular	1.5	11.8	N150	A30.1	5.8	8.1	9.6	13.7
L153	1400.0	Natural	3.0	9.1	N151	A30.2R	11.2	12.8	13.6	14.9
Bypass	17.0	Rectangular	5.4	0.6	46-A	47-A	0.0	0.0	0.0	0.0
Filter	NA	NA	NA	NA	46-A	47-A	0.0	0.0	0.0	0.0
Z28.2	90.0	Circular	2.5	0.6	47-A	A29	0.0	0.0	0.0	0.0
W5	581.0	Circular	1.5	3.8	D1	D5	4.0	5.1	5.8	7.6
W1.1	72.0	Circular	2.0	4.0	D4	D5	0.0	0.0	0.0	0.0
294.1	72.0	Circular	3.0	5.6	A34	A35	78.2	100.1	112.1	118.4
RoadZ34	60.0	Trapezoidal	3.0	0.0	A34	A35	0.0	0.0	0.8	31.0
Z30.3	690.3	Natural	6.0	1.7	A30.2R	A31R	67.3	86.1	97.5	128.0
Z30.2	65.0	Special	5.8	1.5	A30.1	A30.2R	29.7	39.7	45.8	62.8
Z29.2	180.0	Natural	1.5	0.9	A29.2	A29.3	0.0	0.0	0.0	0.0
Z29.1	63.0	Natural	2.7	1.8	A29.1	A29.2	0.0	0.0	0.0	0.0
X14	437.6	Natural	1.5	2.5	C14	A29	0.0	0.0	0.0	0.0
X13	110.0	Natural	3.4	2.4	C13	C14	0.0	0.0	0.0	0.0
Z29.3	180.0	Natural	2.0	1.1	A29.3	A29.4	0.0	0.0	0.0	0.0
Z29.4	149.8	Natural	1.5	3.3	A29.4	A30.1	0.0	0.0	0.0	0.0
36N-S-28	60.0	Circular	4.0	0.2	36N	S-28	38.3	38.9	39.0	39.9
S29	357.0	Circular	3.0	0.2	36E	36N	36.0	37.4	38.1	40.3
Link333	267.0	Circular	3.0	1.0	WA-03	Node369	4.2	4.9	5.3	6.5
Link332	420.0	Circular	3.0	2.7	WA-04	WA-03	0.7	0.9	0.9	1.1
Link330	892.0	Trapezoidal	3.0	1.2	WA-06	WA-14	9.7	11.4	12.4	15.1
Link331	476.0	Trapezoidal	3.0	3.3	WA-02	WA-14	5.8	6.9	7.5	9.3
WA-12-1	30.0	Trapezoidal	3.0	3.3	WA-12	WA-12.1	13.4	15.7	17.0	20.7
WA-11-1	30.0	Trapezoidal	3.0	3.3	WA-11	WA-12.1	17.0	19.9	21.6	26.3
WA-13-1	30.0	Trapezoidal	3.0	2.2	WA-13	WA-13.1	3.2	3.7	4.0	4.9
Link304	230.0	Natural	0.0	0.2	Node233	S-03	88.5	88.9	87.7	87.7
Link323	67.0	Circular	5.0	0.5	BlueLakeN	Node352	6.5	6.5	6.5	11.0

Table C-1. Future Hydraulic Model Parameters and Results										
Link ID	Length (ft)	Shape	Diameter/ Height (ft)	Slope (%)	Node Name		Future Max Flow (cfs)			
					US	DS	5 yr	10 yr	25 yr	100 yr
Link307	200.9	Circular	3.0	0.3	BlueLake	Node349	2.8	4.1	5.0	7.1
Link308	55.5	Circular	3.0	1.0	Node349	Node350	2.8	4.1	5.0	7.1
Weir1-West	NA	NA	NA	NA	Node350	Node351	0.0	0.0	0.0	0.0
Weir1_East	NA	NA	NA	NA	Node350	Node351	0.0	0.0	0.0	0.0
weir top.1	NA	NA	NA	NA	Node350	Node351	0.0	0.0	0.0	0.0
24 inch	NA	NA	NA	NA	Node350	Node351	2.9	7.4	7.9	9.7
Link318	277.4	Natural	3.0	1.0	Node351	Node352	2.6	7.6	7.5	9.1
Link319	749.2	Natural	0.0	0.1	Node352	Node353	8.0	10.7	11.8	14.0
Link320	146.4	Circular	5.0	0.0	Node353	Node363	11.6	11.2	12.0	14.0
Link321	271.2	Natural	3.0	0.3	Node363	Node364	12.9	12.5	12.0	14.0
886.1	336.8	Circular	3.5	0.0	Node364	Node233	6.9	6.8	6.0	7.0
886.2	336.8	Circular	3.5	0.0	Node364	Node233	6.9	6.8	6.0	7.0
WA-12-2	2340.0	Trapezoidal	3.0	0.4	WA-12.1	A48	30.1	35.4	38.5	46.8
WA-13-2	585.0	Trapezoidal	3.0	3.8	WA-13.1	SS-15R	3.2	3.7	4.0	4.9
Link329	295.0	Circular	2.0	0.3	WA-14	S-33	15.8	16.9	17.4	18.5
Link334	1020.0	Trapezoidal	3.0	0.9	Node369	S-33	4.2	4.9	5.3	6.5
Link335	306.0	Circular	1.0	0.3	Node370	Node371	4.3	4.4	4.5	4.7
Link336	186.0	Trapezoidal	3.0	0.0	Node371	Node372	4.6	4.6	4.7	6.4
Link337	80.0	Circular	1.5	0.8	Node372	A-19	5.5	5.4	5.5	8.6
Link339	1320.0	Trapezoidal	3.0	0.5	WA-15	WA-02	0.0	0.0	0.0	0.0
Overstop Gate.1	NA	NA	NA	NA	Node374	S-01	0.0	0.0	0.0	0.0

Model Reference Maps

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Arata Creek School
MESD Program at Arata Creek
Cedar Ln
NE Treehill Dr
NE Shannon St
NE 238th Dr
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Wood Village Green
Reynolds SD 7
Z29.2
Z29.1
Z29
Z28
Z28.2
Z28.1
Z27
Y31
L144
Y33
L145
L159
L151
Z24
Z23
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X5
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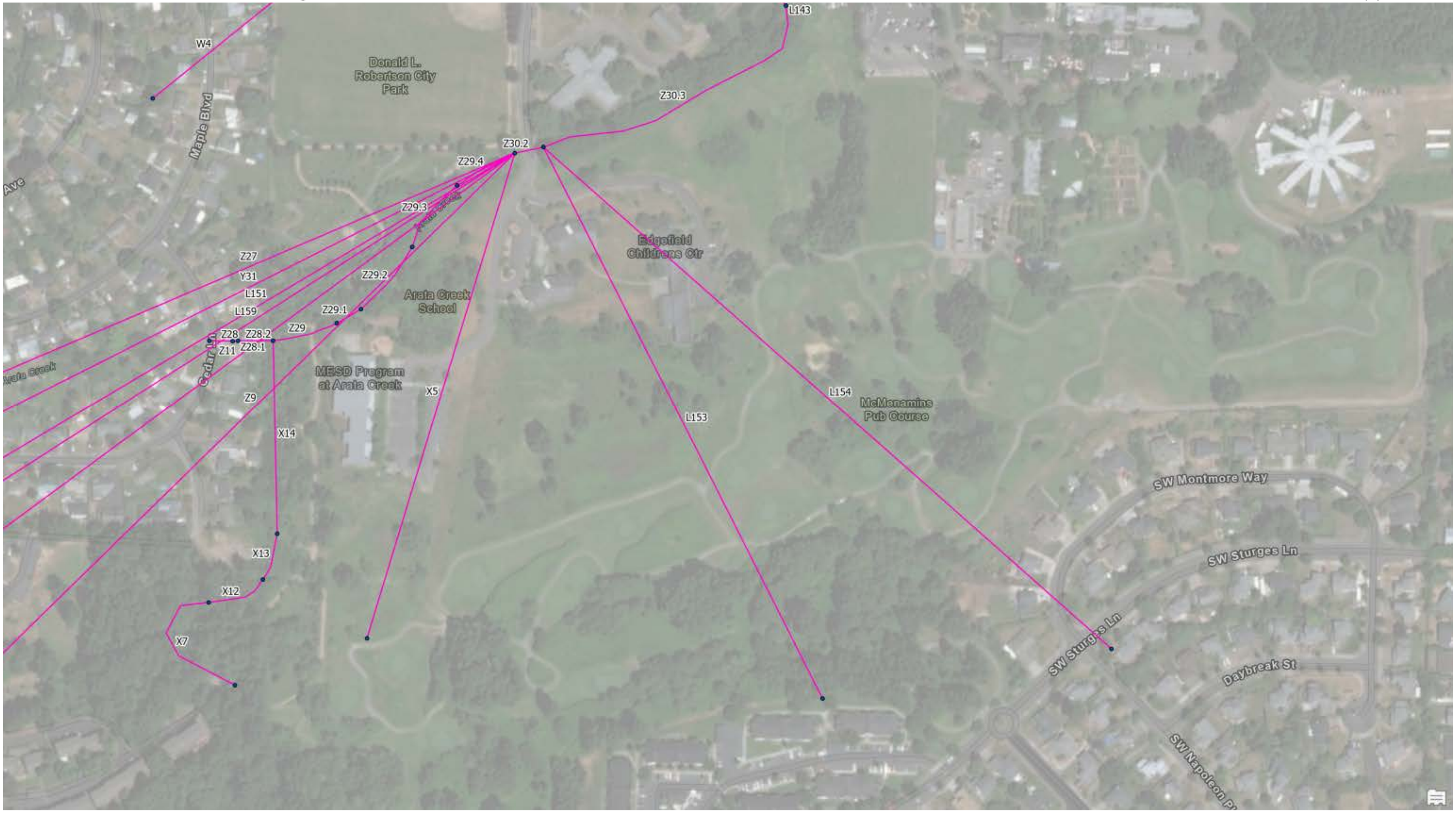
L153
L154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Z30.3
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Z27
Y31
Z29.2
L151
Arata Creek School
L159
Z29.1
Z28
Z28.2
Z29
Z11
Z28.1
Cedar Ln
Arata Creek
MESD Program at Arata Creek
X5
L154
McMenamins Pub Course
Z9
L153
X14
SW Montmore Way
X13
SW Sturges Ln
X12
SW Sturges Ln
X7
Daybreak St
SW Napoleon Pl


Banfield Expy
Banfield Expy
NE 238th Dr
NE 238th Dr
UP
UP
UP
UP
NE 244th Ave
Arata Creek
SW Halsey St
SW Halsey St
NE Halsey St
NE Halsey St
Elm Ave
Elm Ave
Birch Ave
Maple Blvd
Donald L. Robertson City Park
Z43
Z42
Z35
Z34
Z33
W5
W1.4
W1.1
W1.2
W1.3
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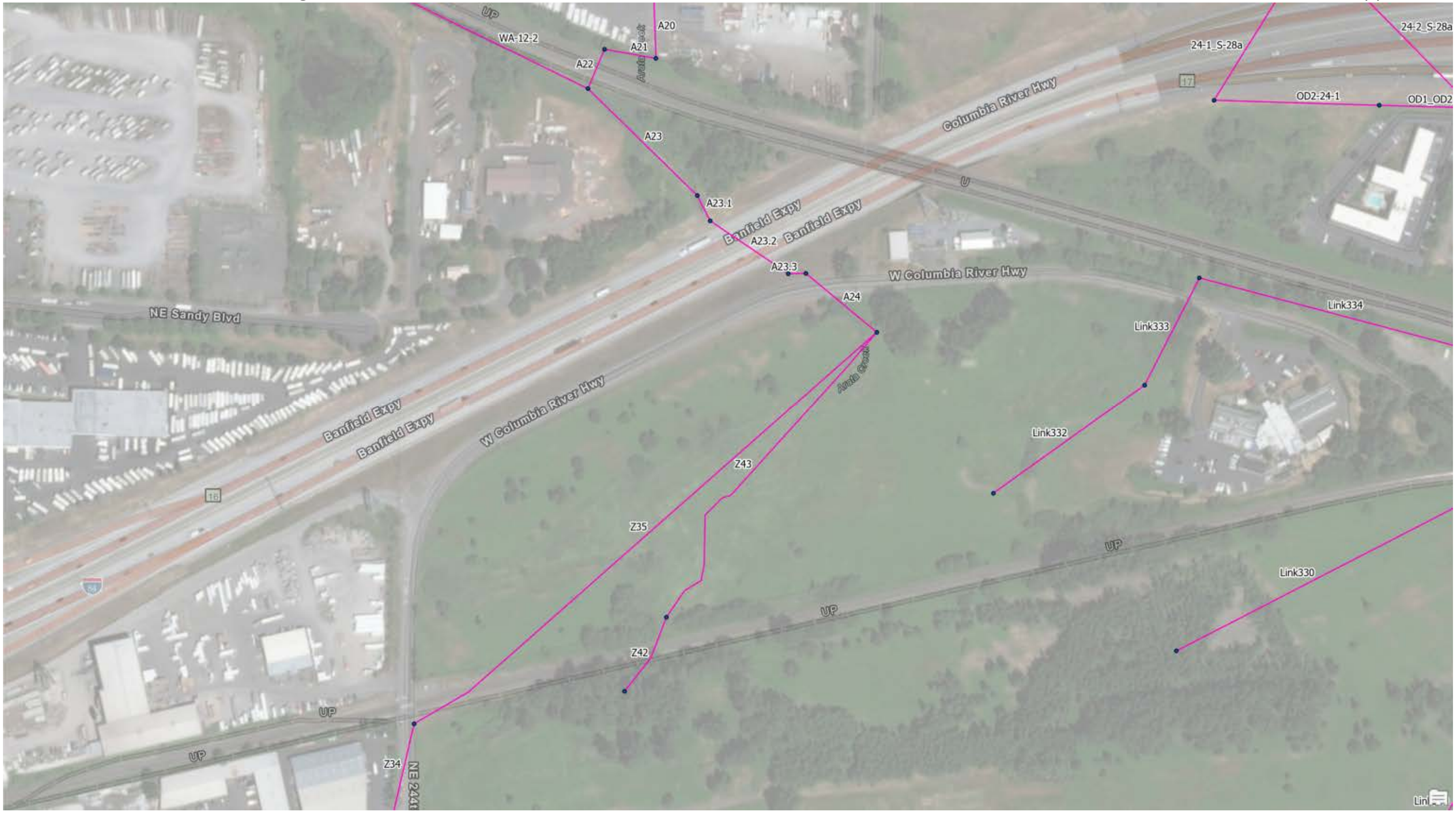
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24-1_S-28a
24-2_S-28a
OD2-24-1
OD1_OD2
Link334
Link333
Link332
Link330
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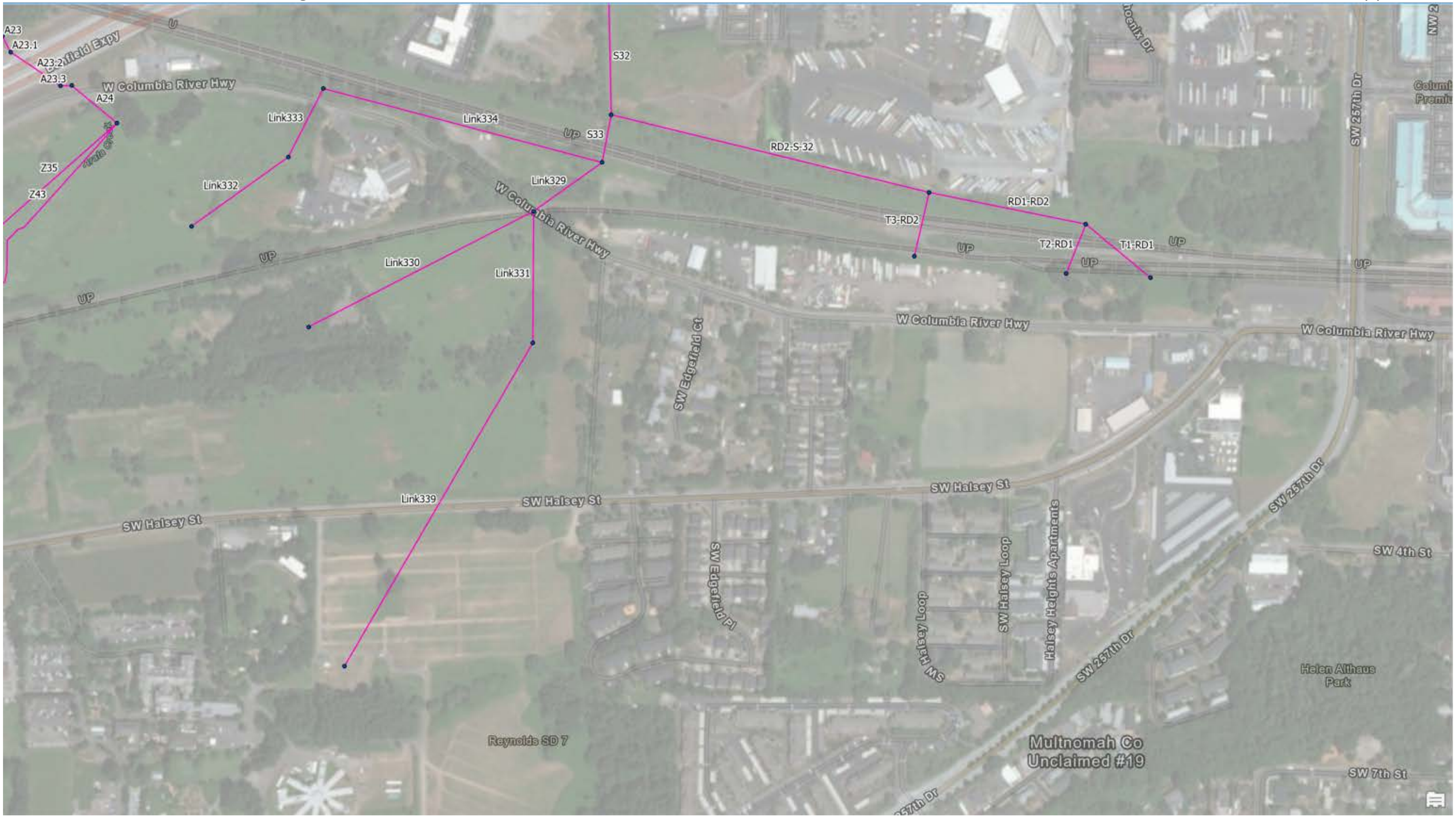
Banfield Expy
W Columbia River Hwy
NE Sandy Blvd
Arata Creek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Link332
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RD2-S-32
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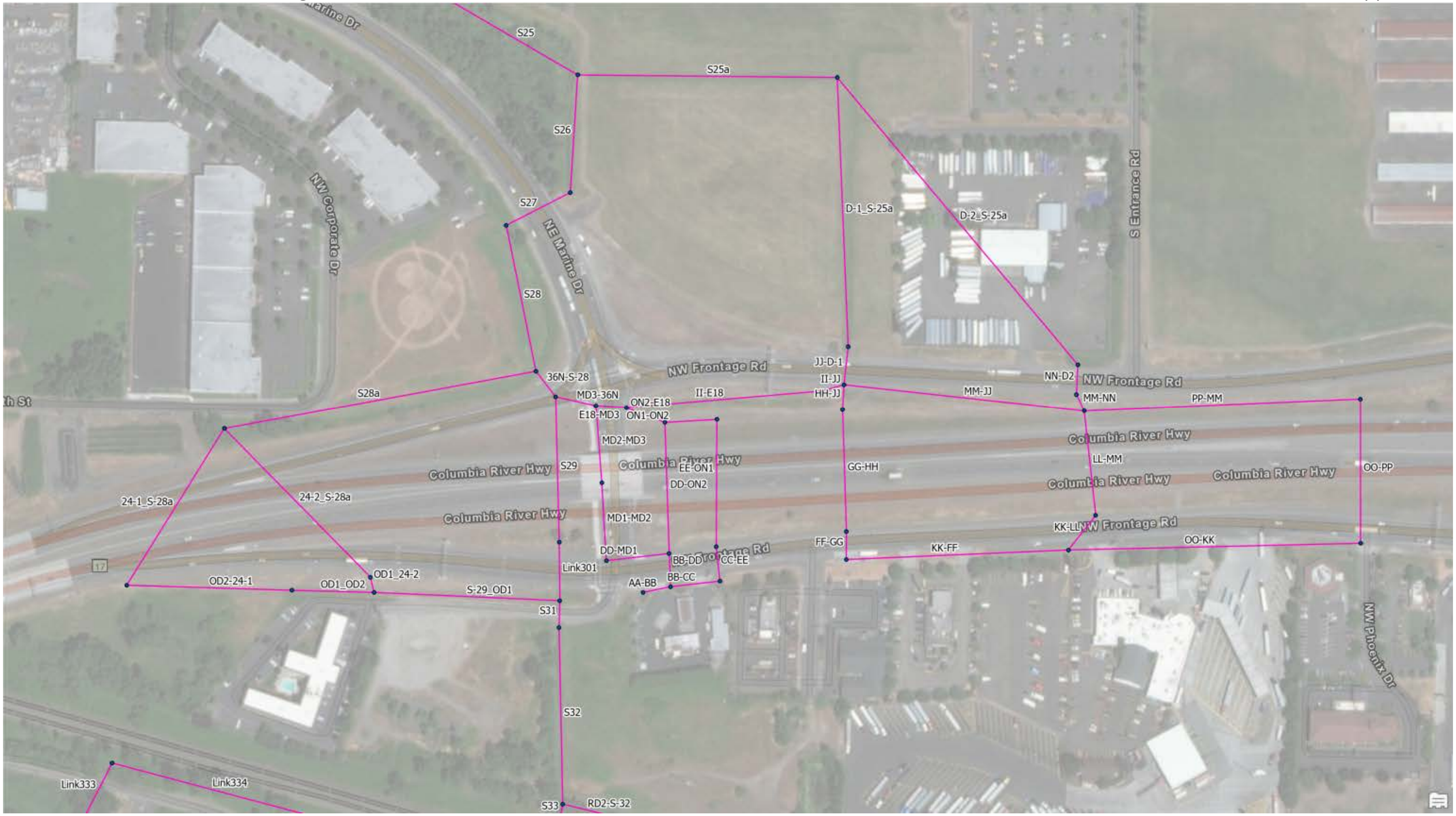
Link330
Link331
Link339
T3-RD2
RD1-RD2
T2-RD1
T1-RD1
W Columbia River Hwy
SW Halsey St
SW Edgefield Ct
SW Edgefield Pl
SW Halsey Loop
Halsey Heights Apartments
SW 257th Dr
SW 4th St
SW 7th St
Helen Althaus Park
Multnomah Co Unclaimed #19
Reynolds SD 7
UP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S26
S27
S28
S28a
36N-S-28
MD3-36N
E18-MD3
ON2-E18
ON1-ON2
II-E18
JJ-D-1
II-JJ
HH-JJ
D-1_S-25a
D-2_S-25a
NN-D2
MM-NN
MM-JJ
PP-MM
MD2-MD3
S29
EE-ON1
DD-ON2
GG-HH
LL-MM
OO-PP
24-1_S-28a
24-2_S-28a
MD1-MD2
KK-LL
DD-MD1
Link301
BB-DD
CC-EE
FF-GG
KK-FF
OO-KK
OD1_24-2
OD2-24-1
OD1_OD2
S-29_OD1
AA-BB
BB-CC
S31
S32
Link333
Link334
S33
RD2-S-32
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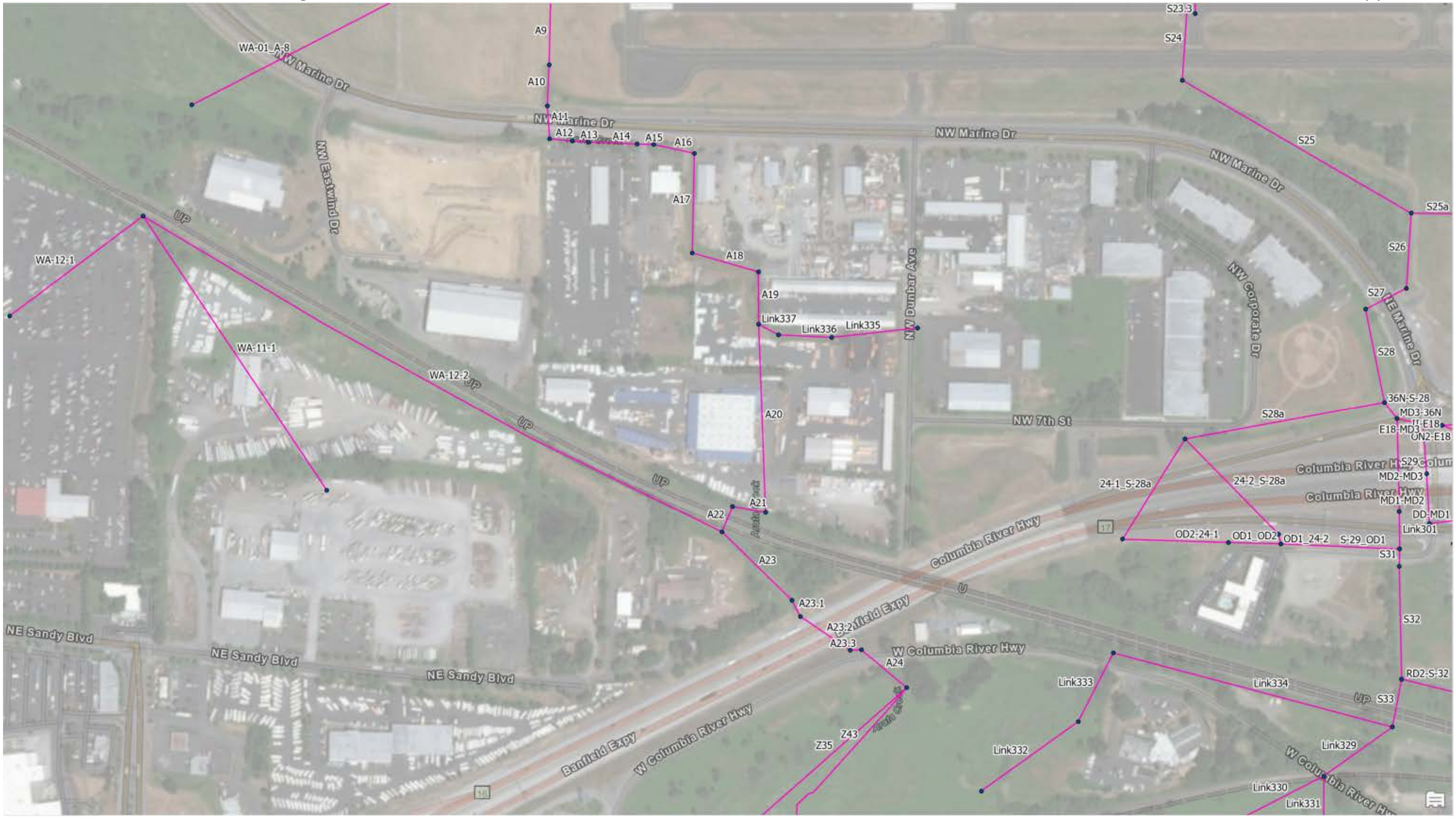
NW Corporate Dr
NW Frontage Rd
Columbia River Hwy
S Entrance Rd
NW Phoenix Dr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A10
A11
A12
A13
A14
A15
A16
A17
A18
A19
A20
A21
A22
A23
A23.1
A23.2
A23.3
A24
Link337
Link336
Link335
Link333
Link334
Link332
Link329
Link330
Link331
Link301
WA-12-1
WA-11-1
WA-12-2
NW Eastwind Dr
NW Dunbar Ave
NW 7th St
NW Corporate Dr
NE Marine Dr
NE Sandy Blvd
Columbia River Hwy
W Columbia River Hwy
Banfield Expy
S23.3
S24
S25
S25a
S26
S27
S28
S28a
36N-S-28
MD3-36N
E18-MD3
ON2-E18
S29
MD2-MD3
MD1-MD2
DD-MD1
24-1_S-28a
24-2_S-28a
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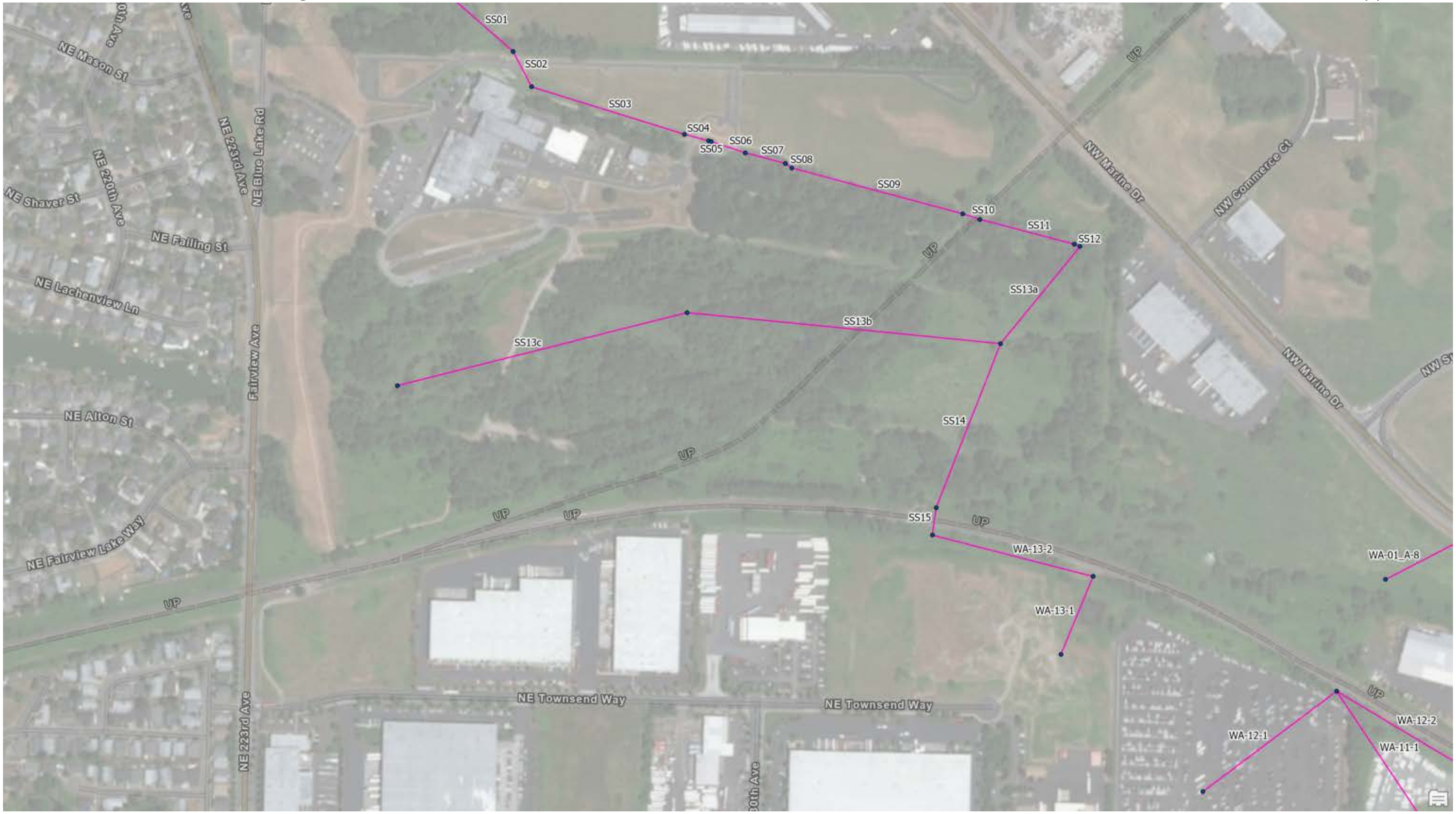
S33
Z35
Z43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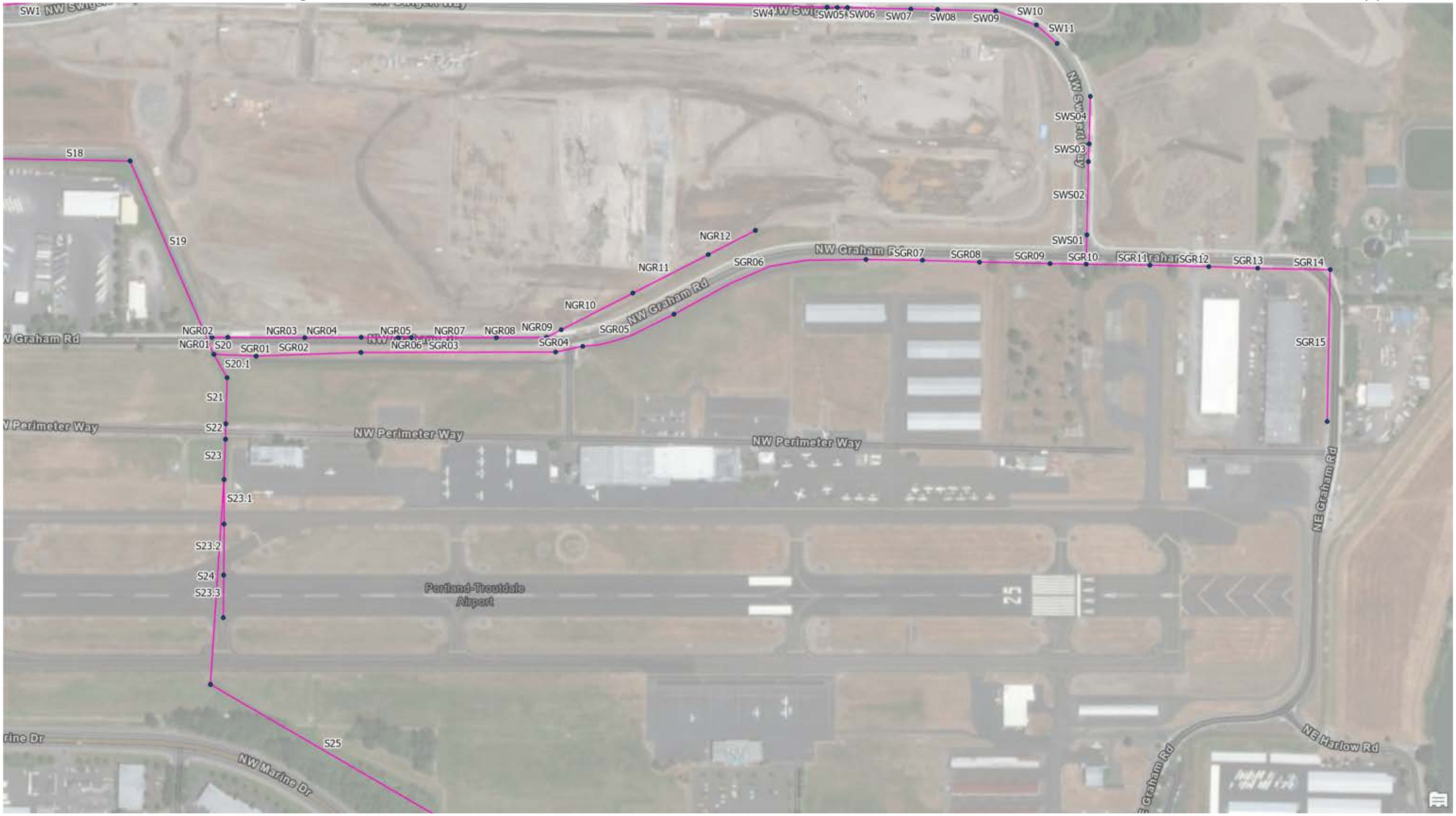
SS03
SS04
SS05
SS06
SS07
SS08
SS09
SS10
SS11
SS12
SS13a
SS13b
SS13c
SS14
SS15
WA-13-2
WA-13-1
WA-01_A-8
WA-12-1
WA-12-2
WA-11-1
NE Mason St
NE Shaver St
NE Failing St
NE Lachenview Ln
NE Alton St
NE Fairview Lake Way
NE 220th Ave
NE 223rd Ave
NE Blue Lake Rd
Fairview Ave
NE Townsend Way
NW Marine Dr
NW Commerce Ct
UP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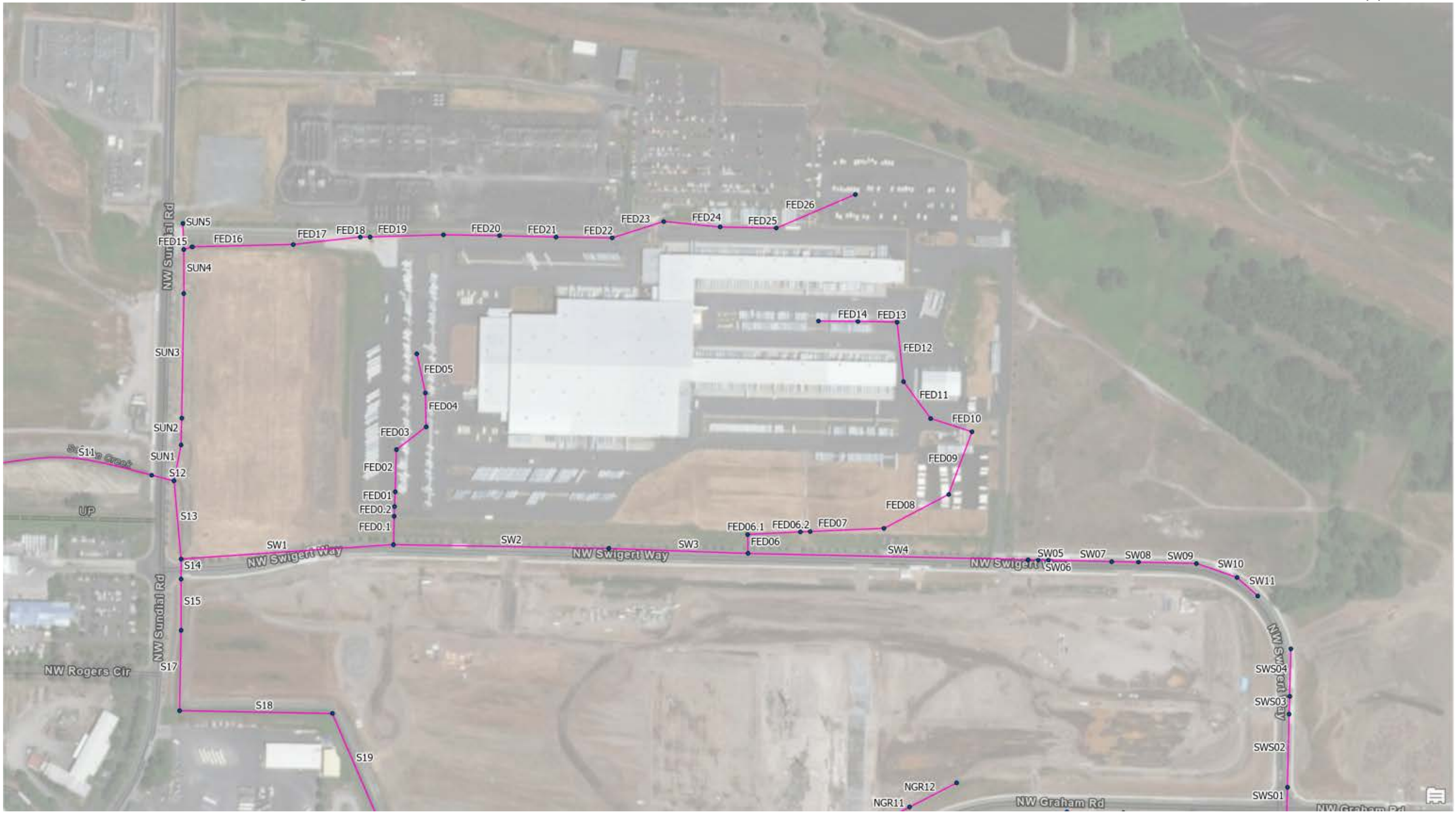
SW4 NW Swigert
SW05
SW06
SW07
SW08
SW09
SW10
SW11
NW Swigert Way
SWS04
SWS03
SWS02
SWS01
S18
S19
NGR12
NGR11
NGR10
NGR09
NGR08
NGR07
NGR06
NGR05
NGR04
NGR03
NGR02
NGR01
S20
S20.1
SGR01
SGR02
SGR03
SGR04
SGR05
SGR06
NW Graham Rd
SGR07
SGR08
SGR09
SGR10
SGR11
SGR12
SGR13
SGR14
SGR15
NE Graham Rd
S21
S22
S23
S23.1
S23.2
S24
S23.3
S25
NW Perimeter Way
Portland-Troutdale Airport
25
NW Marine Dr
NE Harlow Rd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NW Swigert Way
NW Rogers Cir
NW Graham Rd
UP
SUN1
SUN2
SUN3
SUN4
SUN5
FED0.1
FED0.2
FED01
FED02
FED03
FED04
FED05
FED06
FED06.1
FED06.2
FED07
FED08
FED09
FED10
FED11
FED12
FED13
FED14
FED15
FED16
FED17
FED18
FED19
FED20
FED21
FED22
FED23
FED24
FED25
FED26
S11
S12
S13
S14
S15
S17
S18
S19
SW1
SW2
SW3
SW4
SW05
SW06
SW07
SW08
SW09
SW10
SW11
SWS01
SWS02
SWS03
SWS04
NGR11
NGR12


A10
A11
Marine Dr
A12
A13
A14
A15
A16
A17
A18
A19
A20
A21
A22
A23
Link337
Link336
Link335
NW Marine Dr
NW Eastwind Dr
NW Dunbar Ave
NW 7th St
WA-12-2
WA-11-1
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Columbia River Hwy
S24
S25
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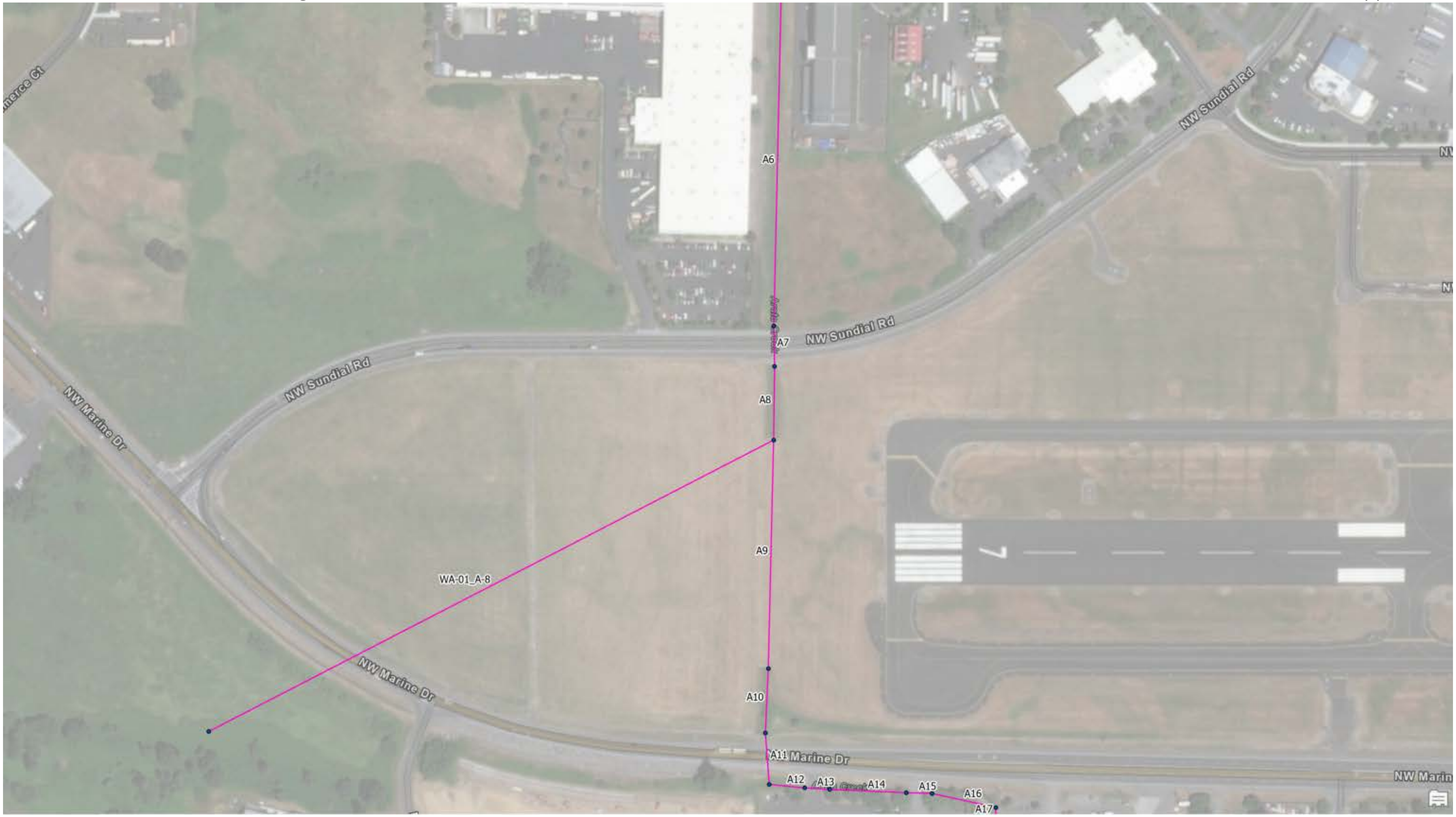
24-1_S-28a
OD2-24-1
17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WA-01_A-8
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A12
A13
A14
A15
A16
A17
NW Marin


SPLIT04
SPLIT05
SPLIT06
SPLIT07B
SPLIT07A
S6
S7
S8
S8a
S8b
S09
S10
S11
A1
A2
A3
A4
A5
A6
UP
Salmon Creek
NE Marine Dr
NW Marine Dr
NW Commerce Ct
NW Rogers Cir
NW Graham Cir
NW Sundial Rd
SS03
SS04
SS05
SS06
SS07
SS08
SS09
SS10
SS11
SS12
SS13a


NE Marine Dr
NE Marine Dr
NE Marine Dr
NE Marine Dr
NE Marine Dr
NE Marine Dr
S1
6 ft
Pipe
Concrete
Channel
SPLIT02
S2
S3
SPLIT03
SPLIT04
SPLIT05
NE 223rd Ave
Link320
Link319
Link323
Link321
Link322
Link304
Link318
Link308
Link307
NE Blue Lake Rd
NE Blue Lake Rd
S4
S5
S6
S7
Salmon Creek
SS01
SS02
SS03
NE 218th Ave
NE 220th Ave
NE 223rd Ave
NE Blue Lake Rd
NE Mason St

Appendix D: Problem Area Database/Table

SDIC and City of Troutdale Problem Area Matrix

ID	Type_ID	Location	Source	Problem Category	Notes	Site Visit (6/18/19)
1	F-1	Graham Road	Pre-site visit meeting	Critical Mains or primary trunk lines - not a problem	Travis Hultin (Troutdale) identified this as a high priority line for Troutdale.	Did not visit.
2	F-2	Swigert Drive	Pre-site visit meeting	Critical Mains or primary trunk lines - not a problem	Travis Hultin (Troutdale) identified this as a high priority line for Troutdale.	Did not visit.
3	F-3	Airport Culvert	Site visit	Flooding/Clogging	Culvert frequently gets clogged, resulting in stormwater inflow to nearby sanitary lift station. Culvert to be replaced (and up-sized?) during runway project.	Culvert is currently CMP (possibly elliptical, or round and squished), partially filled with sediment.
4	F-4	Foundation drains	Kickoff meeting	Flooding	Foundation drains "don't drain anywhere" - fill nearby wetland - stay ponded there. If water elevation gets high enough, it eventually drains to Swigert. This is a low point and water from levee drains does not have a mechanism to drain.	Did not visit.
5	F-5	Marine Drive/Frontage Road(near Motel 6)	Site visit	Flooding	Infrastructure installed as part of I-84 interchange improvements and Taco Bell development. Stormwater storage pipe installed (wraps around Motel 6) to move excess drainage to existing wetland.	Vegetated drainage channel - currently has two "beaver deceivers" installed which restrict flow slightly, one is partially blocked by a dam. Stormwater storage pipe installed between Frontage Road and the private road to Motel 6/ Taco Bell (unusual triangular section of pipes in model) .
6	F-6	SS Pump Station on Portland Airport (PDX) right-of-way (ROW)	Site visit	Flooding/Clogging	The pump station gets flooded when the airport culvert gets clogged. Will this be addressed in part by culvert replacement? Are there other BMPs we can implement to try and prevent inflow here?	Pump station is in a low lying area.
7	E-1	Culverted creek under Port Airport (north side of Marine Drive)	Site visit	Erosion	Bank erosion noted here.	Did not visit - MCDD staff reported erosion near fence where creek enters PDX ROW.
8	E-2	Drainage ditch by Hyster-Yale group property	Kickoff meeting	Erosion	Bank erosion noted during kickoff mtg	Did not visit.
9	F-7	Roger's circle (large drainage ditch)	Site Visit	Flooding	This vegetated drainage ditch that carries Arata Creek gets dammed frequently by beavers. East-west running drainage line here is abandoned.	Densely vegetated. Also location of Toyo Tanso process water discharge.
10	C-1	SDIC Pump Station	Site visit	Capacity	Need to assess pump capacity, and update model with accurate pump curves.	Field test of pumps to be performed (as of 6/25/19).
11	C-2	County-owned twin culverts to Pump Station	Site visit	Capacity	Multnomah County culverts have sediment issues, need inspection, may be old and in need of replacement	During site visit culverts were ~80% underwater.
12	C-3	Drainage ditch (leads to Hyster-Yale property)	Kickoff meeting	Capacity	Problem noted on kickoff meeting map, There are several culverts in the HiLift property that are old and likely rusted out or failing. This area is a low-lying wetland and no major water is conveyed through the area.	Did not visit.
13	I-2	Blue Lake/Connecting Infrastructure	Site visit	Flood Storage	Blue Lake eventually drains through failing infrastructure into SDIC. Cost-benefit analysis for repairing infrastructure vs removing and impact on flood storage for both districts Gate tower was rated "unacceptable" by 2015 USACE Periodic Rehabilitation and Inspection Program (RIP). This is also in violation of FEMA's 44 CFR 65.10 (need to operate mechanized infrastructure once per year).	Piped flow goes north from Blue Lake under Blue Lake Road. Pipe material switches halfway across Blue Lake Road, then enters a low-lying area with sluice gate and overflow weir with multiple rectangular notches. Sluice gate was currently closed. Flows through open channels until NE 223rd Avenue then travels under thru 60" CMP -> open channel -> twin 36" pipes under levee to Salmon Creek.
	I-3	Blue Lake Outfall	Site visit/Staff input	Infrastructure	The outfall pipe from Blue Lake under NE Blue Lake Road appears to be rusted out and in the very poor condition and likely needs replacement. The county has plans to repair or replace this pipe.	Visual inspection of the pipe revealed little pipe left and a lot of rust and decayed pipe.
14	C-4	Drainage ditch near Frontage Road	Site visit	Capacity	Beaver damning and some bank erosion.	Three beaver deceivers currently installed here. Dense vegetation.
15	I-1	Arata Creek culvert under Marine Drive	Site visit	Infrastructure	Culvert entrance is crushed, lots of debris.	There is a lot of debris in culvert entrance. Mention of upstream loads for debris/sediment - lumber yard (Carl Diebold lumber) close by, to the south.
16	E-3	Arata Creek by north-to-west turn (along south side of Marine Drive - Twelve Mile Disposal Services property)	Site visit	Erosion	There is a lot of erosion on banks here, and dirt driveway has erosion as well.	
17	F-8	North corner of Marine Drive and Sundial Road intersection	Kickoff meeting	Flooding	This is a low-lying area, that generally ponds during rain events. No complaints?	
18	F-9	Columbia River Hwy at railroad crossing	Kickoff meeting	Flooding	Water ponds at underpass of Columbia River Hwy and railroad tracks	
19	F-10	Low lying area north of Blue lake (Golf course)	Kickoff meeting	Flooding	Area frequently floods.	
20	F-11	Corporate Drive	Kickoff meeting	Flooding	Experiences occasional flooding.	
21	F-12	Dunbar Ave	Kickoff meeting/Troutdale GIS	Flooding	Area and properties occasionally flood. In meeting it was mentioned that east-west connection to Arata is abandoned/clogged. No public collection/conveyance system along Dunbar Ave.	
22	F-13	North Fedex Parking lot	Kickoff meeting	Flooding	Occasional ponding occurs here.	
23	E-4	Arata/Salmon Creek / near SDIC pump station	Site visit/Kickoff meeting	Erosion	Erosion noted on banks of Arata/Salmon creek near pump station along the forebay.	
24	C-5	Sundial and Rogers intersection	Troutdale Staff	Capacity	Troutdale city staff identified this as an area where drainage infrastructure stored water even during dry periods.	
25	C-6	Graham Road cul du sac	Troutdale Staff	Capacity	Troutdale city staff identified this as an area where drainage infrastructure stored water even during dry periods.	
26	C-7	Sundial Drive (west of 1535 NW Sundial)	Troutdale Staff	Capacity	Troutdale city staff identified this as an area where drainage infrastructure stored water even during dry periods.	
27	C-8	Various - beaver dams	Site visit/Kickoff meeting	Capacity	Beavers are very active in drainage ditches/creeks.	
28	F-14	NW Graham Rd, north of NE Harlow Rd	Public Comment - Port of Portland	Flooding	Ponding noted by the Port of Portland.	
29	F-15	NW Frontage Roadbetween NW Graham Road and S Entrance Rd	Public Comment - Port of Portland	Flooding	Ponding noted by the Port of Portland.	
30	F-16	NW Marine DriveSE of NW Sundial Road	Public Comment - Port of Portland	Flooding	Ponding noted by the Port of Portland.	
31	F-17	All properties west of NW Marine Drive between Sundial Road and 223rd Street exit	Public comment	Flooding	Public comment flagged all properties in this area.	
32	F-18	NW Perimeter Way	Public comment	Flooding	Public comment from Advanced Aircraft Services	
33	F-19 WQ also	End of NW Commerce Court	Public comment	Flooding/Clogging	Public comment from 30 Second Cleaners - storage pond with bio swale overgrown with invasive lillies.	
34	F-20	Marine Drive, east of NW Sundial Road	MCDD/Troutdale Staff	Flooding	Localized flooding has been observed at the intersection of Marine Drive and NW Sundial Road. A culvert empties into the area north of Marine Drive and south of Sundial and there is no culvert leaving this area, leading to frequent ponding in light rain events.	
35	SD-N26	Marine Drive culvert bypass. This is the same location as CIP I-1.	Previous Master Plan	Flooding	Install roadside swale along north side of Marine Drive to relieve Salmon Creek during high flows. Install culvert underneath Marine Drive to provide bypass for high flows. (This flooding is addressed in CIP I-1 and the Port of Portland is planning to replace the Salmon Creek pipe under the runway aleviating the flooding along Airport Way Road.	

Appendix E: Recommended Projects

Project Table

Project Cost Estimates

SDIC and North Troutdale Recommended Capital Projects

CIP Number	Project #	Project Title	Location	Description	Design and Construction Considerations	Cost
1	C-1A	Sandy Pump Station (Structural/ Operational)	Sandy Pump Station	~ Structural and Operational improvements to pump station including: - Anti-cavitation improvements, Pump floor cones installation This project addresses problem area C-1	~ Need to consider doing in tandem with other Pump Station improvements. Station could be wholly replaced in future. ~ USACE is performing a Feasibility Study for the levee and associated infrastructure. Results from this study should be incorporated into the plans for the SDIC. Immediate needs, such as the addition of backup power, should be identified and addressed prior to any recommendations resulting from this study.	$ 182,000
2	C-1B	Sandy Pump Station (Outfall Pipes/ Infrastructure)	Sandy Pump Station	~ Upgrade connected Infrastructure to Pump station: - Replace flap gate on gravity outfall pipe - Replace corrugated metal pipe section upstream of flap gate at outfall - Replace isolation gates at gravity discharge influent structure - Slipline/CIPP gravity outfall pipes - Rehabilitate Inlet Wall This project addresses problem area C-1 See Project I-4, below for more on gravity outfall infrastructure.	~ The Gravity Outfall Improvements project would rehabilitate aging gravity outfall infrastructure. Improvements include replacing the a short section of corrugated metal pipe and attached flap gate, both of which are corroded and deteriorating, at the gravity discharge into the Columbia Slough. The isolation gates at the gravity discharge influent structure are nearing end of life and thus would be replaced. Additionally, past pipe condition inspection noted some minor leakage at pipe joints; installation of cured-in-place pipe would prevent future leakage. ~ Project does not include fish exclusion improvements ~ Need to consider doing in tandem with other Pump Station improvements. Station could be wholly replaced in future. ~ USACE is performing a Feasibility Study for the levee and associated infrastructure. Results from this study should be incorporated into the plans for the SDIC. Immediate needs, such as the addition of backup power, should be identified and addressed prior to any recommendations resulting from this study.	$ 904,000
3	C-1C	Sandy Pump Station (Capacity)	Sandy Pump Station	~ Increase capacity of pump station by: - new 85 MGD Station including wet well and screens - New outfall pipe, 26" to account for additional 3rd pump - New siphon breaker, vent, and vault - New discharge energy dissipator structure This project addresses problem area C-1	~ Need to consider doing in tandem with other Pump Station improvements. Station could be wholly replaced in future. ~ USACE is performing a Feasibility Study for the levee and associated infrastructure. Results from this study should be incorporated into the plans for the SDIC. Immediate needs, such as the addition of backup power, should be identified and addressed prior to any recommendations resulting from this study. ~ Installation of additional pumps would require the installation of additional force mains and piping underneath levy.	$ 13,200,000
4a	C-2A	Salmon Creek Marine Drive Culvert (Condition Assessment)	Salmon Creek at Marine Drive (Near 223rd/Marine Dr. Intersection)	~ The pipes under Marine Drive just east of the 223rd Ave interchange need to be rehabilitated or replaced. The double culverts are 72" pipes and 350 feet long. These pipes which drain from south to north historically are the primary conveyance path for Salmon and Arata Creeks. With the construction of the Sundial Wetland and the rerouting of some of the drainage, there is now an alternative path which reduces the critical nature of these culverts to a degree. The culverts are well past their design life and are reported to have wood beams placed vertically in the culverts to ensure they do not colapse. These culverts are owned by Multnomah County. While these culverts are no longer the only drainage path they are 'high' on the critical conveyance network and therefore should be a high priority. ~ This Project consists of a full condition assessment of the pipes, including CCTV survey and historical review of construction and maintenance activities. Visual inspection of the underground culvert crossings will be performed using a built-for-purpose, carbon fiber pole-mounted zoom camera with variable lighting, digital photo capture, and digital video recording system. When safe for inspectors to enter the culverts, the camera head can be removed and operated by hand. Visual observations will be supplemented with LiDAR laser scanning and measurement to quantify pipe deformation, ovality, structural defects, wall loss extents, and debris accumulation levels. Other systems such as Unmanned Aerial Systems (UAS) and/or a remote control boat system can also be utilized if required by site constraints. This project addresses problem area C-2	~ These culverts are owned by Multnomah County. Coordination and an IGA or other agreement with the county to highlight and address this infrastructure need should be completed to prioritize this project. These culverts are under Marine Drive and the on/off ramps for NE 223rd Ave. The pipes are long and nearly always inundated to some degree. A thorough condition assessment should be completed as a first step to understand the nature and condition of the pipes which will inform the rehabilitation or replacement. There may be opportunity to line these pipes or rehabilitate them in-place, thus reducing the capacity to some degree, due to the secondary flow path through the Sundial Wetland. However, any reduction in capacity should be reviewed and tested with the H and H model. A full replacement of the pipes will have considerable complexity with the length, size, and the overburden of the road on culverts. A full geotechnical analysis should be considered as part of the preliminary design. A design that can be completed in the wet or dry should be considered as the area may be challanging to dry out due to its low elevation even in the summer months.	$ 15,000

SDIC and North Troutdale Recommended Capital Projects

CIP Number	Project #	Project Title	Location	Description	Design and Construction Considerations	Cost
4b	C-2B	Salmon Creek Marine Drive Culvert (Replacement)	Salmon Creek at Marine Drive (Near 223rd/Marine Dr. Intersection)	~ The pipes under Marine Drive just east of the 223rd Ave interchange need to be rehabilitated or replaced. The double culverts are 72" pipes and 350 feet long. These pipes which drain from south to north historically are the primary conveyance path for Salmon and Arata Creeks. With the construction of the Sundial Wetland and the rerouting of some of the drainage, there is now an alterative path which reduces the critical nature of these culverts to a degree. The culverts are well past their design life and are reported to have wood beams placed vertically in the culverts to ensure they do not colapse. These culverts are owned by Multnomah County. While these culverts are no longer the only drainage path they are 'high' on the critical conveyance network and therefore should be a high priority. ~ This Project consists of the removal and replacing of the two culverts under Marine Dr. This project addresses problem area C-2	~ These culverts are owned by Multnomah County. Coordination and an IGA or other agreement with the county to highlight and address this infrastructure need should be completed to prioritize this project. These culverts are under Marine Drive and the on/off ramps for NE 223rd Ave. The pipes are long and nearly always inundated to some degree. A thorough condition assessment should be completed (refer CIP C-2A) as a first step to understand the nature and condition of the pipes which will inform the rehabilitation or replacement means and methods. There may be opportunity to line these pipes or rehabilitate them in-place, thus reducing the capacity to some degree, due to the secondary flow path through the Sundial Wetland. However, any reduction in capacity should be reviewed and tested. A full replacement of the pipes will have considerable complexity with the length, size, and the overburden of the road on culverts. A full geotechnical analysis should be considered as part of the preliminary design. A design that can be completed in the wet or dry should be considered as the area may be challanging to dry out due to its low elevation even in the summer months. ~ The cost estimate assumes that replacement via trenchless solutions is not feasible, and that considerable excavation and road closure and reconstruction is required. An assumption was made that roughly one third of the material excavated is contaminated and in need of proper disposal.	$ 4,039,000
5	I-1	Arata Creek Culverts at Marine Drive (Knapheide/Airport)	100 feet west of entrance to Knapheide Truck Equipment Center located at 2500 NW Marine Dr, Troutdale, and just North of here on Port Property	~ Two culverts provide conveyance across Marine Drive at this location, flowing south to north. One is a relatively new HDPE 48-inch culvert and the second is an older 48-inch CMP of unknown age with a damaged entrance. The damage limits the movement of water and potentially collects more debris. At this location the creek turns 90 degrees to the north which causes hydraulic losses. The bend here, in addition to the damaged pipe, and the protruding, newer HDPE culvert, provide several opportunities to improve the entrance configuration at this location to provide more efficient hydraulics. ~ The Marine Drive and airport culverts are proposed to be upsized from twin 4-foot to twin 5-foot culverts, to convey the 25-year design event. ~ The inlet of each pipe should be enhanced to reduce the hydraulic losses associated with a protruding pipe and limit the amount of debris that is collected in the pipe. A trash rack should also be constructed to protect both culverts from blockages and enable easy and safe removal of debris. This project addresses problem area I-1, C-7, and F-7	~ The culverts under Marine Drive are owned by Multnomah County. Coordination and an IGA or other agreement with the county to highlight and address this infrastructure need should be completed to prioritize this project. These culverts are under Marine Drive which is a primary transporation corridor for the area which should be protected from inundation. The pipes should be replaced based on the capacity assessment to ensure roadway flooding is reduced as the watershed develops. Inlet optimization should consider the most optimum geometry in coordination with a needed trash rack. Impacts to Marine Drive traffic and associated controls should be considered. Because the pipe is required to be replaced, significant coordination with area businesses, the Port of Portland, and others should be considered as part of the early design package. The culverts are relatively shallow so an open cut may be the best option. ~ Project cost developed under the assumptions that the airport culvert will be covered by the Port, that no contaminated material is encountered during construction, and that trenchless solutions are not applicable. ~ Hydraulic adjustments upstream of the Port culverts will require planning and coordination efforts with the Port to ensure upstream improvement do not negatively impact Port property and operations. ~ Arata Creek was modeled and projects were designed under the assumption that the siphoned crossing under Interstate-84 and the following railroad crossing culvert will not be modified or upsized in the future conditions scenario. Should these crossings get upsized, an increase in flow of approximately 50 cfs is anticipated.	$ 687,000

SDIC and North Troutdale Recommended Capital Projects

CIP Number	Project #	Project Title	Location	Description	Design and Construction Considerations	Cost
6	E-3	Arata Creek Culverts adjacent to Marine Drive and Underneath Carl Diebold Lumber	Arata Creek Along Marine Drive from 2172 NW Marine Drive to the entrance to 2500 NW Marine Drive.	~ This section of Arata Creek floods and has been a problem area in the past. Modeling suggests the system receives 74 cfs at the peak of the 10-year design event and is 6 inches from flooding. Flooding occurs during the 25-year design event. The 48-inch culverts passing under two driveway entrances are undersized for the design event and need to be replaced or augmented with additional capacity. The area where Arata Creek turns west along Marine Drive also floods and is causing erosion of the banks, contributing to sedimentation issues. ~ This project consists of upsizing the two 4-foot diameter driveway culverts to 6-feet, and upsizing the culverted upstream portion of Arata Creek under the Carl Diebold Lumber Company from 4' to 5'. Improvements are also recommended to regrade the natural channel adjacent to Marine Drive, to provide additional capacity, and also to stabilize the channel to reduce sedimentation. This project addresses problem area E-3 and associated downstream culverts.	~ Additional capacity needed may come in the form of a culvert replacement or an additional culvert. The cover on the existing culverts may be at a minimum and needs to be considered when planning for improvements. If a larger culvert is not feasible then a box culvert or additional culvert of similar or smaller size may work. Due to site constraints the ROW should also be considered to ensure there is room for a wider conveyance system. Debris from the upstream channel should be considered for the culverts and a trash rack may need to be required to maintain functionality of improved crossing. Access to the impacted businesses will need to be considered as construction methods are determined and how the design might facilitate identified goals for access. ~Need to consider future flows, debris blockages, culverts under Marine drive and capacity of natural channel. ~ Arata Creek was modeled and projects were designed under the assumption that the siphoned crossing under Interstate-84 and the following railroad crossing culvert will not be modified or upsized in the future conditions scenario. Should these crossings get upsized, an increase in flow of approximately 50 cfs is anticipated. Culverts are owned and maintained by Carl Diebold Lumber. Any project work to take place will need to consider ownership and coordinate gain approval with the owner.	$ 2,329,000
7	F-9	Columbia River Hwy	Columbia River Hwy underpass at railroad	~ The Historic Columbia River Highway underpass frequently experiences flooding issues underneath its intersection with a Union Pacific railroad line. The underpass of the road creates a low point to which a large upland watershed drains to, with only two grates currently installed in the roadway to collect water. ~ This project consists of the installation of additional grates to increase drainage capacity of the roadway, as well as upsizing existing culverts underneath the Columbia River Highway. Suggested sizing of the culverts is 3.5' in diameter to convey the 25-year design event. Two culverts are proposed to be upgraded, one culvert of 295' in length and a second culvert, underneath the Union Pacific railroad tracks just north of this, that is 120' in length. This project addresses problem area F-9	~ Increasing conveyance here will increase peak flow rates, which may have adverse effects downstream. Increased peak flows eventually reach Salmon Creek. Impacts of this project need to be quantified when implementing Salmon Creek improvements as well. ~ Project would require work under and around a Union Pacific railroad crossing. Union Pacific and Oregon Department of Transportation officials would need to be integrated into the project team to coordinate permitting and right-of-way agreements. Flows in this watershed eventually flow through Port property, so increased conveyance here should be coordinated and planned with Port culvert replacement project. ~ Discharge falls within Multnomah County's NPDES Phase I permit area, so discharges will need to be compliant with this Permit. Runoff here eventually flows under the Exit 17 interchange, and contributes to Salmon Creek - need to evaluate increased flows on this system.	$ 1,331,000
8a	I-2A	Gate Tower Decommission	Connecting structure to Blue Lake, West side of levee	~ The gate tower structure connecting the MCDD to the SDIC has been rated as being in an "unacceptable" condition according to the USACE Rehabilitation and Inspection Program (RIP) and is also non-compliant with FEMA's 44 CFR 65.10, which requires all mechanized internal drainage items to be inspected and operated once a year. ~ This project consists of the decommissioning of the gate tower and all associated infrastructure. This project addresses problem location I-2	~ Removal the gate tower and all associated infrastructure will have to be done to the standards of the USACE. This may include significant permitting and coordination. ~ Work will occur in water and will be a complicated effort, requiring geotechnical analyses, dewatering (and potential treatment of the pumped water), numerous permits from multiple state and federal agencies, and coordination between MCDD and SDIC The planning and design stage for this project will likely take signicantly longer than the actual construction. Consideration must be given to the timing of construction and other elements that may be needed to support this project. ~ The cost for this project was developed assuming that MCDD would need to build a small pump station to collect and convey the runoff from the area that drains to the low point where the gate tower and culvert currently exist. The cost for any pump station and assocated infrastructure is not included in this cost estimate.	$ 1,866,000

SDIC and North Troutdale Recommended Capital Projects

CIP Number	Project #	Project Title	Location	Description	Design and Construction Considerations	Cost
8b	I-2B	Gate Tower Replacement	Connecting structure to Blue Lake, West side of levee	~ The gate tower structure connecting the MCDD to the SDIC has been rated as being in an "unacceptable" condition according to the USACE Rehabilitation and Inspection Program (RIP) and is also non-compliant with FEMA's 44 CFR 65.10, which requires all mechanized internal drainage items to be inspected and operated once a year. ~This project consists of the replacement of the pipe and gate tower structure. Due to high costs associated with the demolition and decommissiong of associated infrastructure, the gate tower will be replaced to the point of meeting operational and safety standards as set forth in USACE and FEMA regulations. This project addresses problem location I-2	~ Replacement of the gate tower structure and pipe will require work in water and will be a complicated effort, requiring geotechnical analyses, dewatering (and treatment of the pumped water), numerous permits from multiple state and federal agencies, and coordination between MCDD and SDIC. The planning and design stage for this project will likely take signicantly longer than the actual construction. Consideration must be given to the timing of construction and other elements that may be needed to support this project.	$ 2,754,000
9	C-7	Arata Creek @ Sundial Road and Roger's Circle	Arata Creek @ Sundial Road and Roger's Circle	~ This project consists of the upsizing of twin culverts carrying Arata Creek underneath Sundial Road and Roger's Circle. The existing culverts are both 4' in diameter, and approximately 100' long. The Sundial Road culverts are recommended to be upsized from twin 4-foot to twin 6-foot, and the Roger's Circle culverts upsized from twin 4-foot to twin 7-foot culverts, in order to convey the 25-year design storm event. ~ Localized flooding has been reported nearby, on Port property, to the west of the runways, as well as to the west of this location and along the north side of Sundial Road. Increased conveyance in this area may alleviate these problems. There is also the potential here for the re-grading of nearby open areas for better drainage to Arata Creek. This project addresses problem area C-7 and may help reduce F-16 and F-8	~ Modification of culverts along Arata Creek will require the analysis of Arata Creek as a whole to assess impacts of increased flow rates on downstream infrastructure and natural systems. ~ Arata Creek was modeled and projects were designed under the assumption that the siphoned crossing under Interstate-84 and the following railroad crossing culvert will not be modified or upsized in the future conditions scenario. Should these crossings get upsized, an increase in flow of approximately 50 cfs is anticipated.	$ 1,450,000
10	F-12	Dunbar Avenue Feasibility	Dunbar Avenue Neighborhood from end of street at south end to Marine Drive at the north end.	~ Dunbar Avenue lacks stormwater infrastructure and therefore presents a drainage challenge for the adjacent properties. Compounding this lack of infrastructure is the geometry of the area where the roadway is generally at a slightly higher elevation than the surrounding properties and the properties are relatively low lying when compared to the surrounding area roadways and infrastructure. ~ This project consists of a feasibility study to determine the best method for alleviating flooding in the Dunbar Ave. neighborhood by providing drainage infrastructure along Dunbar Ave and the associated area. This project addresses problem area F-12	~ The discharge location of the drainage system should be identified early in the process by reviewing all potential options. Previous efforts to provide drainage for this area included pump stations which should be avoided if possible. Routing all drainage to the Port property and culverts which sit at approximately 21 feet in elevation may be the most viable option as the roadway sits at roughly 32 feet in elevation. This 11 foot elevation difference might allow for a gravity system to be feasible. ~ The previous design from 1998 included an engineers estimate and one bid. These number multiplied by the Engineering News Record Construction Cost Index (0.52) would forecast the same project to cost roughly $900,000 to $1,500,000. 1.52*$948,948 = $1,445,899 1.52*$57,8913 = $879,947	$ 50,000
					Total Cost:	$28,807,000

Cost estimates are in 2019 dollars

SDIC and North Troutdale CIP Cost Summary

CIP Number	CIP ID	Project Title	Capital Expense Total (excluding contingency)[1]	Engineering and Permitting	Construction Administration	Capital Project Implementation Cost Total[2]	Total Cost (w/ contingencies)[3]
1	C-1A	Sandy Pump Station (Structural / Operational)	$70,000	$30,000	$5,000	$105,000	$182,000
2	C-1B	Sandy Pump Station (Outfall Pipes / Infrastructure)	$470,000	$165,000	$35,000	$670,000	$904,000
3	C-1C	Sandy Pump Station (Capacity)	$7,800,000	$1,200,000	$390,000	$9,390,000	$13,200,000
4a	C-2A	Condition Assessment: Salmon Creek Culverts at Marine Drive and 223rd Street NE	$15,000	$0	$0	$15,000	$15,000
4b	C-2B	Remove and Replace: Salmon Creek Culverts at Marine Drive and 223rd Street NE	$2,244,000	$561,000	$112,000	$2,917,000	$4,039,000
5	I-1	Arata Creek Culverts at Marine Drive (Knapheide/Airport)	$382,000	$95,000	$19,000	$496,000	$687,000
6	E-3	Arata Creek Culverts and Bank Stabilization Along Marine Drive	$1,294,000	$323,000	$65,000	$1,682,000	$2,329,000
7	F-9	Historic Columbia River Highway	$700,000	$245,000	$35,000	$980,000	$1,331,000
8a	I-2A	Gate Tower Decommission	$982,000	$344,000	$49,000	$1,375,000	$1,866,000
8b	I-2B	Gate Tower Replacement	$1,449,000	$507,000	$72,000	$2,028,000	$2,754,000
9	C-7	Salmon Creek Culverts at Sundial Road and Roger's Circle	$805,000	$201,000	$40,000	$1,046,000	$1,450,000
10	F-12	Dunbar Avenue Feasibility Study	$50,000	$0	$0	$50,000	$50,000
		CIP Project Total				$20,754,000	$28,807,000

Cost estimates are in 2019 dollars.

1. Capital Expense Total - Total cost of material and capital expenses
2. Capital Project Implementation Cost - Capital Expense Total plus engineering and administration expenses
3. Total Cost - Capital Project Implementtation Cost plus contingencies

CIP 4a - Condition Assessment
Salmon Creek Culverts at Marine Drive and 223rd Street NE

Refer to CIP concept table for design assumptions

ITEM	UNIT	Unit Cost (2019)	Quantity	Total Cost
Design Efforts				
Inspection				
Mainline Video Inspection*	FT	$ 3.7	4050	$14,997
Earthwork				
Miscellaneous				
Structure Installation				
Restoration/Resurfacing				
Pipe Unit Cost				
Construction Item Subtotal				$ 14,997
Contingencies and Multipliers (applied to construction subtotals)				
General Conditions	LS	0%		$ -
Mobilization/Demobilization	LS	0%		$ -
Traffic Control/Utility Relocation	LS	0%		$ -
Erosion Control	LS	0%		$ -
Overhead and Profit	LS	0%		$ -
Construction Item Total				$ 14,997
Contingencies and Multipliers (applied to construction Totals)				
Estimating Contingency	LS	0%		$ -
Market Climate	LS	0%		$ -
Engineering and Permitting	LS	0%		$ -
Design Services	LS	0%		$ -
Construction Administration	LS	0%		$ -
Project Total			TOTAL	$ 14,997

Notes:

*Mainline Video quantity manipulated to equal estimated cost of evaluation

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CIP 4b - Culvert Replacement
Salmon Creek Culverts at Marine Drive and 223rd Street NE

Refer to CIP concept table for design assumptions

ITEM	UNIT	Unit Cost (2019)	Quantity	Total Cost
Design Efforts				
Inspection				
Earthwork				
General Earthwork/Excavation	CY	$ 21	14700	$311,052
Contaminated Dredged Material	CY	$ 277	100	$27,720
Clear and Grub brush including stumps	AC	$ 8,570	0.5	$4,285
Energy dissapation pad - Rip-Rap, Class 50	CY	$ 69	4	$275
Miscellaneous				
Cofferdams	SF	$ 61	2800	$170,800
Structure Installation				
Pipe demo and disposal	LF	$ 74	700	$51,842
Headwall with wingwalls, pipe larger than 48"	EA	$ 14,812	4	$59,248
Bypassing - weekly	EA	$ 6,348	12	$76,176
Guard Rails	EA	$ 270		$0
Outfall Improvements	EA	3,000-10,000		$20,000
Restoration/Resurfacing				
Hydroseed, large quantities	AC	$ 2,645	2	$5,290
Trench resurfacing, Permanent ACP, 6-Inch Depth	SY	$ 74	187	$13,825
Pipe Unit Cost				
HDPE Pipeline w/asphalt resurfacing (72", 5-10' deep)	FT	$ 1,026	700	$718,382
Extra depth pipe	FT	$ 53	700	$37,030
Construction Item Subtotal				$ 1,495,924
Contingencies and Multipliers (applied to construction subtotals)				
General Conditions	LS	15%		$ 224,389
Mobilization/Demobilization	LS	10%		$ 149,592
Traffic Control/Utility Relocation	LS	5%		$ 74,796
Erosion Control	LS	5%		$ 74,796
Overhead and Profit	LS	15%		$ 224,389
Construction Item Total				$ 2,243,886
Contingencies and Multipliers (applied to construction Totals)				
Estimating Contingency	LS	40%		$ 897,554
Market Climate	LS	10%		$ 224,389
Engineering and Permitting	LS	25%		$ 560,972
Design Services	LS	0%		$ -
Construction Administration	LS	5%		$ 112,194
Project Total			TOTAL	$ 4,038,995

Notes:

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CIP #5

Arata Creek Culverts at Marine Drive (Knapheide/Airport)

Refer to CIP concept table for design assumptions

ITEM	UNIT	Unit Cost (2019)	Quantity	Total Cost
Design Efforts				
Inspection				
Earthwork				
Miscellaneous				
Structure Installation				
Pipe demo and disposal	LF	$ 74	235	$17,404
Trash Rack Installation	SF	$ 106	30	$3,174
Restoration/Resurfacing				
Pipe Unit Cost				
HDPE Pipeline w/asphalt resurfacing (60", 5-10' deep)	FT	$ 857	235	$201,390
Extra depth pipe	FT	$ 53	235	$12,432
Construction Item Subtotal				$ 254,400
Contingencies and Multipliers (applied to construction subtotals)				
General Conditions	LS	15%		$ 38,160
Mobilization/Demobilization	LS	10%		$ 25,440
Traffic Control/Utility Relocation	LS	5%		$ 12,720
Erosion Control	LS	5%		$ 12,720
Overhead and Profit	LS	15%		$ 38,160
Construction Item Total				$ 381,600
Contingencies and Multipliers (applied to construction Totals)				
Estimating Contingency	LS	40%		$ 152,640
Market Climate	LS	10%		$ 38,160
Engineering and Permitting	LS	25%		$ 95,400
Design Services	LS	0%		$ -
Construction Administration	LS	5%		$ 19,080
Project Total			TOTAL	$ 686,880

Notes:

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CIP #6

Arata Creek Culverts and Bank Stabilization Along Marine Drive

Refer to CIP concept table for design assumptions

ITEM	UNIT	Unit Cost (2019)	Quantity	Total Cost
Design Efforts				
Inspection				
Earthwork				
Miscellaneous				
Structure Installation				
Pipe demo and disposal	LF	$ 74	800	$59,248
Headwall with wingwalls, pipe larger than 48"	EA	$ 14,812	5	$74,060
Bypassing - weekly	EA	$ 6,348	4	$25,392
Outfall Improvements	EA	3,000-10,000		$15,000
Restoration/Resurfacing				
Pipe Unit Cost				
HDPE Pipeline w/asphalt resurfacing (60", 5-10' deep)	FT	$ 857	660	$565,607
HDPE Pipeline w/asphalt resurfacing (72", 5-10' deep)	FT	$ 1,026	120	$123,151
Construction Item Subtotal				$ 862,458
Contingencies and Multipliers (applied to construction subtotals)				
General Conditions	LS	15%		$ 129,369
Mobilization/Demobilization	LS	10%		$ 86,246
Traffic Control/Utility Relocation	LS	5%		$ 43,123
Erosion Control	LS	5%		$ 43,123
Overhead and Profit	LS	15%		$ 129,369
Construction Item Total				$ 1,293,687
Contingencies and Multipliers (applied to construction Totals)				
Estimating Contingency	LS	40%		$ 517,475
Market Climate	LS	10%		$ 129,369
Engineering and Permitting	LS	25%		$ 323,422
Design Services	LS	0%		$ -
Construction Administration	LS	5%		$ 64,684
Project Total			TOTAL	$ 2,328,637

Notes:

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CIP #7

Historic Columbia River Highway

Refer to CIP concept table for design assumptions

ITEM	UNIT	Unit Cost (2019)	Quantity	Total Cost
Design Efforts				
Inspection				
Earthwork				
Trenchless Pipe Installation	LF	$ 2,116	120	$253,920
Miscellaneous				
Structure Installation				
Precast Concrete Manhole (72", 0-8' deep)	EA	$ 10,157	1	$10,157
Catch Basin, all types	EA	$ 2,116	2	$4,232
Connection to Existing Structure, standard	EA	$ 2,116	2	$4,232
Pipe demo and disposal	LF	$ 74	415	$30,735
Outfall Improvements	EA	3,000-10,000		$10,000
Restoration/Resurfacing				
Hydroseed, large quantities	AC	$ 2,645	1	$2,645
Trench resurfacing, Permanent ACP, 6-Inch Depth	SY	$ 74	20	$1,481
Pipe Unit Cost				
HDPE Pipeline (42", 5-10' deep)	FT	$ 360	415	$149,284
Construction Item Subtotal				$ 466,686
Contingencies and Multipliers (applied to construction subtotals)				
General Conditions	LS	15%		$ 70,003
Mobilization/Demobilization	LS	10%		$ 46,669
Traffic Control/Utility Relocation	LS	5%		$ 23,334
Erosion Control	LS	5%		$ 23,334
Overhead and Profit	LS	15%		$ 70,003
Construction Item Total				$ 700,029
Contingencies and Multipliers (applied to construction Totals)				
Estimating Contingency	LS	40%		$ 280,011
Market Climate	LS	10%		$ 70,003
Engineering and Permitting	LS	35%		$ 245,010
Design Services	LS	0%		$ -
Construction Administration	LS	5%		$ 35,001
Project Total			TOTAL	$ 1,330,054

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CIP #8b
Gate Tower and Culvert Replacement

Refer to CIP concept table for design assumptions

ITEM	UNIT	Unit Cost (2019)	Quantity	Total Cost
Design Efforts				
Inspection				
Earthwork				
General Earthwork/Excavation	CY	$ 21	15,200	$321,632
Embankment	CY	$ 10	15,200	$144,734
Contaminated Dredged Material	CY	$ 277	380	$105,334
Clear and Grub brush including stumps	AC	$ 8,570	0.5	$4,285
Miscellaneous				
Structure Installation				
Abandon Existing Structure	EA	$ 1,058	1	$1,058
Pipe demo and disposal	LF	$ 74	740	$54,804
Headwall with wingwalls, pipe larger than 48"	EA	$ 14,812	2	$29,624
Bypassing - weekly	EA	$ 6,348	2	$12,696
Outfall Improvements	EA	3,000-10,000		$3,000
Restoration/Resurfacing				
4-foot Chain Link Fence	LF	$ 23	300	$6,983
Pipe Unit Cost				
HDPE Pipeline (60", 5-10' deep)	FT	$ 709	370	$262,278
Extra depth pipe	FT	$ 53	370	$19,573
Construction Item Subtotal				$ 966,002
Contingencies and Multipliers (applied to construction subtotals)				
General Conditions	LS	15%		$ 144,900
Mobilization/Demobilization	LS	10%		$ 96,600
Traffic Control/Utility Relocation	LS	5%		$ 48,300
Erosion Control	LS	5%		$ 48,300
Overhead and Profit	LS	15%		$ 144,900
Construction Item Total				$ 1,449,003
Contingencies and Multipliers (applied to construction Totals)				
Estimating Contingency	LS	40%		$ 579,601
Market Climate	LS	10%		$ 144,900
Engineering and Permitting	LS	35%		$ 507,151
Design Services	LS	0%		$ -
Construction Administration	LS	5%		$ 72,450
Project Total			TOTAL	$ 2,753,106

Notes:

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CIP #8a

Gate Tower Decommission

Refer to CIP concept table for design assumptions

ITEM	UNIT	Unit Cost (2019)	Quantity	Total Cost
Design Efforts				
Inspection				
Earthwork				
General Earthwork/Excavation	CY	$ 21	15,200	$321,632
Embankment	CY	$ 10	15,200	$144,734
Contaminated Dredged Material	CY	$ 277	380	$105,334
Clear and Grub brush including stumps	AC	$ 8,570	0.5	$4,285
Miscellaneous				
Structure Installation				
Abandon Existing Structure	EA	$ 1,058	1	$1,058
Pipe demo and disposal	LF	$ 74	740	$54,804
Bypassing - weekly	EA	$ 6,348	2	$12,696
Outfall Improvements	EA	3,000-10,000		$3,000
Restoration/Resurfacing				
4-foot Chain Link Fence	LF	$ 23	300	$6,983
Pipe Unit Cost				
Construction Item Subtotal				$ 654,527
Contingencies and Multipliers (applied to construction subtotals)				
General Conditions	LS	15%		$ 98,179
Mobilization/Demobilization	LS	10%		$ 65,453
Traffic Control/Utility Relocation	LS	5%		$ 32,726
Erosion Control	LS	5%		$ 32,726
Overhead and Profit	LS	15%		$ 98,179
Construction Item Total				$ 981,790
Contingencies and Multipliers (applied to construction Totals)				
Estimating Contingency	LS	40%		$ 392,716
Market Climate	LS	10%		$ 98,179
Engineering and Permitting	LS	35%		$ 343,627
Design Services	LS	0%		$ -
Construction Administration	LS	5%		$ 49,090
Project Total			TOTAL	$ 1,865,402

Notes:

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CIP #9
Salmon Creek Culverts at Sundial Road and Roger's Circle

Refer to CIP concept table for design assumptions

ITEM	UNIT	Unit Cost (2019)	Quantity	Total Cost
Design Efforts				
Inspection				
Earthwork				
General Earthwork/Excavation	CY	$ 21	100	$2,116
Miscellaneous				
Structure Installation				
Pipe demo and disposal	LF	$ 74	370	$27,402
Headwall with wingwalls, pipe larger than 48"	EA	$ 14,812	4	$59,248
Outfall Improvements	EA	3,000-10,000		$10,000
Restoration/Resurfacing				
Riparian/Wetland Planting (Non-irrigated)	AC	$ 21,266	0.5	$10,633
Hydroseed, large quantities	AC	$ 2,645	0.5	$1,323
Pipe Unit Cost				
HDPE Pipeline w/asphalt resurfacing (72", 5-10' deep)	FT	$ 1,026	203	$208,331
CMP Pipeline w/asphalt resurfacing (84", 5-10' deep)	FT	$ 1,201	167	$200,539
Construction Item Subtotal				$ 519,591
Contingencies and Multipliers (applied to construction subtotals)				
General Conditions	LS	15%		$ 77,939
Mobilization/Demobilization	LS	10%		$ 51,959
Traffic Control/Utility Relocation	LS	10%		$ 51,959
Erosion Control	LS	5%		$ 25,980
Overhead and Profit	LS	15%		$ 77,939
Construction Item Total				$ 805,366
Contingencies and Multipliers (applied to construction Totals)				
Estimating Contingency	LS	40%		$ 322,146
Market Climate	LS	10%		$ 80,537
Engineering and Permitting	LS	25%		$ 201,342
Design Services	LS	0%		$ -
Construction Administration	LS	5%		$ 40,268
Project Total			TOTAL	$ 1,449,659

Notes:

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CIP #10
Dunbar Avenue Feasibility Study

Refer to CIP concept table for design assumptions

ITEM	UNIT	Unit Cost (2019)	Quantity	Total Cost
Design Efforts				
Inspection				
Earthwork				
Miscellaneous				
Structure Installation				
Restoration/Resurfacing				
Pipe Unit Cost				
Construction Item Subtotal				$ 50,000
Contingencies and Multipliers (applied to construction subtotals)				
General Conditions	LS	0%		$ -
Mobilization/Demobilization	LS	0%		$ -
Traffic Control/Utility Relocation	LS	0%		$ -
Erosion Control	LS	0%		$ -
Overhead and Profit	LS	0%		$ -
Construction Item Total				$ 50,000
Contingencies and Multipliers (applied to construction Totals)				
Estimating Contingency	LS	0%		$ -
Market Climate	LS	0%		$ -
Engineering and Permitting	LS	0%		$ -
Design Services	LS	0%		$ -
Construction Administration	LS	0%		$ -
Project Total			TOTAL	$ 50,000

Notes:

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CIP #1
Project C-1A: Pump Anti-caviation Improvements

Item No.	Description	Est. Qty	Units	Cost $/Unit	Cost Total
1	Pump Floor Cones Install	1	LS	$ 70,000	$ 70,000
	Construction Subtotal				**$ 70,000**
			Contingencies and Multipliers (applied to construction subtotal)		
			General Conditions	15%	$ 10,500
			Mobilization/Demobilization	10%	$ 7,000
			Traffic Control/Utility Relocation	0%	$ -
			Erosion Control	0%	$ -
			Overhead and Profit	15%	$ 10,500
				Construction Item Total	**$ 98,000**
			Contingencies and Multipliers (applied to construction total)		
			Estimating Contingency	40%	$ 39,200
			Market Climate	10%	$ 9,800
			Engineering and Permitting	30%	$ 29,400
			Design Services	0%	$ -
			Construction Administration	5%	$ 4,900
				Project Total	**$ 181,300**

CIP #2
Project C-1B: Outfall Improvements
**Does not include fish exclusion improvements.

Item No.	Description	Est. Qty	Units	Cost $/Unit	Cost Total
1	Replace Gravity Outfall Flap Gate, 54"	1	EA	$ 20,000	$ 20,000
2	Replace Discharge Wall	1	LS	$ 25,000	$ 25,000
3	Replace Corrugated Metal Outfall Pipe Section	20	LF	$ 440	$ 8,800
4	Replace Isolation Gates	2	EA	$ 24,000	$ 48,000
5	Rehabilitate Inlet Wall	1	LS	$ 40,000	$ 40,000
6	CIPP 42" Pipe	160	LF	$ 450	$ 72,000
7	CIPP 54" Pipe	165	LF	$ 600	$ 99,000
	Construction Subtotal				**$ 312,800**
	Contingencies and Multipliers (applied to construction subtotal)				
			General Conditions	15%	$ 47,000
			Mobilization/Demobilization	10%	$ 31,300
			Traffic Control/Utility Relocation	5%	$ 15,700
			Erosion Control	5%	$ 15,700
			Overhead and Profit	15%	$ 47,000
				Construction Item Total	**$ 469,500**
	Contingencies and Multipliers (applied to construction total)				
			Estimating Contingency	40%	$ 187,800
			Market Climate	10%	$ 47,000
			Engineering and Permitting	35%	$ 164,400
			Design Services	0%	$ -
			Construction Administration	8%	$ 35,300
				Project Total	**$ 904,000**

CIP #3
Project C-1C: Station Replacement

Item No.	Description	Est. Qty	Units	Cost $/Unita	Cost Total
1	New 85 MGD Station (new wet well per HI, new screens)	1	LS	$ 5,000,000	$ 5,000,000
2	New Outfall Pipe (26" Dia, for 3rd Pump)	1	LS	$ 100,000	$ 100,000
3	New Siphon Breaker, Vent, and Vault	1	LS	$ 30,000	$ 30,000
4	New Discharge Energy Dissipator Structure	1	LS	$ 45,000	$ 45,000
	Construction Subtotal				**$ 5,175,000**
	Contingencies and Multipliers (applied to construction subtotal)				
	General Conditions			15%	$ 776,300
	Mobilization/Demobilization			10%	$ 517,500
	Traffic Control/Utility Relocation			5%	$ 258,800
	Erosion Control			5%	$ 258,800
	Overhead and Profit			15%	$ 776,300
				Construction Item Total	**$ 7,762,700**
	Contingencies and Multipliers (applied to construction total)				
	Estimating Contingency			40%	$ 3,105,100
	Market Climate			10%	$ 776,300
	Engineering and Permitting			15%	$ 1,164,500
	Design Services			0%	$ -
	Construction Administration			5%	$ 388,200
				Project Total	**$ 13,196,800**

Appendix F: Recommended Programs

Program Table

Program Cost Back-up Info

SDIC and North Troutdale Recommended Programs

ID	Program Title	Focus Area	Program Description	Notes	Cost	Timeline / Cost Share	Annual Cost
Program 1	Open Channel Sedimentation Control Program	SDIC	Establish a program to conduct routine maintenance (invasive vegetation removal, sediment removal) and restorative maintenance (regrading, addition of amended soils, replanting, bank stabilization measures) for natural channels and open drainage ditches. Problem areas previously identified should be of highest priority, and addressed first (i.e.., refer Problem Area Map). Due to increasing development in the contributing area to the basin, this program should also include a focus on mitigating impacts from existing and future construction site locations, and proper Stormwater Pollution Prevention Plan (SWPPP) implementation and enforcement. City should continue its construction stormwater permitting program (1200C and 1200CN) in collaboration with DEQ and in accordance with MS4 requirements to minimize erosion and sedimentation impacts from construction activity. Program benefits include stabilizing stream and channel banks to allow for natural plant growth, thus reducing sediment loads in the water, improving water quality and lessening maintenance demands. Controlling sediment would also provide an aesthetic improvement.	Due to the ambiguous ownership of natural channels and roadside open ditches, IGA's should be leveraged in order to share costs and responsibilities of this program. Partnerships with local businesses and property owners may be leveraged as well to share inspection responsibilities. Recommend creating a basin-wide GIS inventory of open channels and ditches, and develop ownership and O and M responsibility between SDIC, City and private properties owners. Maintenance staff have drawn attention specifically to areas near the Sandy Pump station forebay, where banks of the forebay are routinely sluffed off during large rain events.	$50,000	5 years	$10,000
Program 2	SDIC - CCTV Inspection, Condition Assessment, and Asset management Program	Critical Conveyance Network	This is an annual, ongoing program to systematically clean and inspect the pipes and culverts in the critical conveyance network. This program will allow the SDIC to identify, prioritize, and plan for short- and long-term infrastructure rehabilitation and/or replacement needs. Several pipes inside the SDIC have been inspected due to problems identified in the area or because the critical location of the pipe. Other pipes in the SDIC are known to be deteriorating based on visual inspections at culvert ends or structures. However, little information exists for large portions of the critical conveyance network regarding the current structural and operational condition. The program will fund CCTV inspection, NASSCO ratings, and engineering assessments of SDIC's infrastructure. NASSCO rating scores will be incorporated into the SDIC's risk tool to prioritize infrastructure projects. Program benefits include increased knowledge of system condition, and an improved ability to prioritize maintenance and rehabilitation needs based on data. Proactive condition assessments will also help to inform CIP budgetary needs.	Costs shown assume the SDIC will conduct CCTV inspections over a period of 5 years inspecting 20% of pipes every year. The costs represent the unit price given by the MCDD's On-Call pipe services. The SDIC may rely on local partners to complete and finance the program. The costs also include $25,000 per year for engineering assessment of CCTV reports. The engineering assessment interprets the inspection results and recommends projects (rehabilitation, replacement, priorities) based on the NASSCO standards and review of field conditions. Cost savings and administrative burden for this program may be reduced by partnering with the City for a cooperative combined CCTV inspection program through an IGA – See “Collaboration for operations and maintenance activities” above. This would likely be limited to collection of CCTV inspection data, and each agency would then perform its own data assessment, interpretation, and application for its own facilities, though consultation and coordination on project prioritization and selection will likely accrue additional benefit.	$286,000	5 years	$82,200

SDIC and North Troutdale Recommended Programs

ID	Program Title	Focus Area	Program Description	Notes	Cost	Timeline / Cost Share	Annual Cost
Program 3	Troutdale - CCTV Inspection, Condition Assessment, and Asset Management Program	City Wide (northern Troutdale study area)	This is an annual, ongoing program to systematically clean and inspect the pipes and culverts for all pipes owned and/or operated by the city. This program will allow the city to identify, prioritize, and plan for short- and long-term infrastructure rehabilitation and/or replacement needs. The City is currently awaiting delivery of its new, first ever, CCTV inspection system/vehicle, and is training its operations crews and engineers in performing NASSCO CCTV pipeline inspection. Additionally, the City is about to integrate an asset management software platform (Lucity) for its storm sewer system. The program will fund CCTV inspection, NASSCO ratings, and engineering assessments of the cities infrastructure. NASSCO rating scores will be incorporated into the city's asset management platform to prioritize infrastructure projects. Program benefits include increased knowledge of system condition, and an improved ability to prioritize maintenance and rehabilitation needs, and optimize return on expenditures, based on data. Proactive condition assessments will also help to inform CIP budgetary needs.	Costs shown assume the City will conduct CCTV inspections over a recurring period of 5 year cycle with its own equipment and personnel inspecting 20% of pipes every year. The costs represent the unit price given by the MCDD's On-Call pipe services which are indicative of the industry standard pricing. The costs also include $25,000 per year for engineering assessment of CCTV reports. The engineering assessment interprets the inspection results and recommends projects (rehabilitation, replacement, priorities) based on the NASSCO standards and review of field conditions. Cost savings and administrative burden for this program may be reduced by partnering with the City for a cooperative combined CCTV inspection program through an IGA – See "Collaboration for operations and maintenance activities" above. This would likely be limited to collection of CCTV inspection data, and each agency would then perform its own data assessment, interpretation, and application for its own facilities, though consultation and coordination on project prioritization and selection will likely accrue additional benefit.	$543,000	5-years	$133,600
Program 4	Flow Control Requirements Evaluation		The City and therefore a large portion of SDIC follows BES standards for stormwater design related to new development and redevelopment. The standards were adopted by the city in 1997. For flow control, BES standards indicate that a new development in a drainage district does not require flow control. The SDIC has recently developed a design review manual with guidelines that new development should mitigate impacts to downstream flows. Although development in the SDIC area has increased in the past years, no active flow control measures have been imposed due to the flow control exemptions in the BES standards. This program will conduct the necessary studies to evaluate the impacts on the City and SDIC conveyance and pump stations related to new development and redevelopment. Based on those impacts, this study will evaluate whether flow control requirements for new development and redevelopment would be beneficial. The study could also evaluate whether a fee in lieu charge would be a more appropriate way to fund upgrades to conveyance and pump stations to accommodate increasing flows. Program benefits include an increased understanding of the impacts of development on stormwater runoff flows, as well as an opportunity to quantify those impacts and share cost of flow control measures proportionally among the SDIC, property owners and/or the City.	Engineering study only; detailed cost estimate not applicable. Study could be cost shared between SDIC and Troutdale. This was a recommendation for MCDD and PEN2 so its likely the same or similar study could be applied to SDIC/CoT. The cost of this is reflective of cost sharing. A study of flow control should also be considered as development occurs throughout the City of Troutdale and how downstream conveyance infrastructure is impacted due to the increased flows resulting from development.	$10,000	NA	NA

SDIC and North Troutdale Recommended Programs

ID	Program Title	Focus Area	Program Description	Notes	Cost	Timeline / Cost Share	Annual Cost
Program 5	Pump Station Testing and Monitoring	Sandy Pump Station	Ongoing program of annual testing and monitoring activities to measure the degradation and condition of the pump station. Annual activities include general inspection of motors, pumps, and switch gears; Annual meggar testing (motor); Annual vibration analysis for both motor and pump; Annual oil sampling, and annual thermal inspection for the switch gear. Program also includes comprehensive flow and pressure testing w/ inspection of discharge lines and wet well every 5 years.	Results of annual testing and monitoring could feed into the existing risk tool or a risk management strategy and SDIC plans for proactive maintenance activities.	$4,800	Ongoing cost per year (average)	$4,800
Program 6	Pump Station Maintenance Program	Sandy Pump Station	Recommended program to maintain pump station at needed capacity and plan for preventative maintenance and replacement ahead of failure. Recommended program includes: Rebuild Motor every 10-15 years Rebuild Pump at 15 and 25 years Replace Starter every 20 years These timeframes are contingent upon continued pump station testing and monitoring. Depending on testing, these timeframes may need to be shortended or may be extended.	Annual cost assuming rebuilding and replacements occur on rotating basis.	$8,100	Ongoing cost per year (average)	$8,100
Program 7	Pump Station Structural Program	Sandy Pump Station	Recommended program to inspect all major/minor structural elements of the pump station. Routine inspection should occur every 5 years and then every 2 years as specific elements of the pump station age and require more frequent assessment.	Elements of the pump station that should be considered for regualar inspection include the following: - Pump station structure (walls, roof, foundation, etc) - Wet well - Debris removal infrastructure	$10,000	Ongoing cost per year (average)	$10,000
Program 8	SDIC Wide Debris Barrier Program	SDIC trash racks for culverts in critical network.	The SDIC's current debris removal procedures are maintenance intensive and pose a potential health and safety risk for staff conducting debris removal during storm events. Installing dispersed debris barriers on culverts throughout the critical conveyance network could reduce the amount of debris collected at pump stations, culverts and other potential collection points. The proposed project will systematically install trash and debris barriers on culverts throughout the basin's critical drainage network. The debris barriers could be designed to allow flow of water, even as debris is collected and removed from the system. This improvement is expected to improve system performance, especially during rain events, and reduce maintenance efforts.	During the design process, the installation of automated debris removal systems at the pump station may be considered. Also, the access and installation process should be considered for each site when selecting the trash racks models. 31 culverts total in the critical network. Cost estimates is based on a 36" size culvert. Assumed that 50% of culverts will not require a debris barrier, and costs will be divided up over a 10 year program. Note: many of the proposed culvert replacement CIPs have debris barriers included in the cost so this program cost is conservative.	$1,195,000	10-years	$119,500

SDIC and North Troutdale Recommended Programs

ID	Program Title	Focus Area	Program Description	Notes	Cost	Timeline / Cost Share	Annual Cost
Program 9	Portable Generator Acquisition Program	Sandy Pump Station	Longer term priority to acquire back-up generator that would work for Sandy Pump Station in the case of a power outage or some other break in the power supply. The program includes a transfer switch. A permanent generator would be preferred with the criticality of the Sandy PS. However, if transfer switches and docking stations are installed at other pump stations within MCDD, PEN2 or PEN1 and a protable generator is provided for Sandy PS, it could be shared with other pump stations if desired and necessary. Note: that Electro EOPC provided two generator size alterantives.	Program is structured as an annual cost to acquire generator over 10 years. Recommend emergency power study to establish future protocols. Existing backup power cost listed ssumes one 200 HP pump and one 150 HP pump. A 500KW portable generator size for the existing SDIC Sandy PS pumps would only provide enough power to be adequately used at PS 2, Bridgestone/Firestone PS, Northeast 181st PS, and Airtrans PS. Future backup power costs are equal to $819,000. Assumes three 250 HP pumps. If a 1000KW portable generator is used, it could provide power at all pump stations except for PS 1 and 4.	$427,000	10 years	$42,700
Program 10	Water Quality Retrofit Program	City Wide (northern Troutdale study area)	Costs are based on anticipated efforts to retrofit identified opportunities annually, respond to public inquiries, conduct preliminary facility sizing, and provide oversight of detailed design/construction. Funds may be used internally or contracted externally. The total proposed annual allocation should prioritize locations currently identified by staff or those identified in this study (see Section 7 and Appendix A).	Retro fitting water quality into the developed portion of the City is important for protecting of water resources and for the City's MS4 compliance as undeveloped portions of the city are developed and implement water quality treatment.	$50,000	per year	$50,000
Program 11	Operations and Maintenance Collaboration	Basin-wide	Establish collaborative Intergovernmental Agreements (IGA) between the City, SDIC, and potentially other agencies in the basin, to leverage the strengths and capabilities of each agency in performing operation and maintenance activities. The City is well versed and well-equipped to perform operation and maintenance of closed pipe systems, and does so routinely, but is not well-equipped in maintaining open channel conveyances. In contrast, SDIC is well versed and well-equipped to perform operation and maintenance of open channel conveyances, and does so routinely, but is not well-equipped for maintaining closed pipe systems. Additionally, the City will soon have its own CCTV inspection vehicle and personnel. The two agencies can complement each other, and each provide the services they excel at under a cooperative IGA, with appropriate cost recovery provisions. Similar partnerships between SDIC and/or the City with other agencies in the basin could have similar benefits .	Agreements with SDIC (MCDD) and other partnering agencies could be used as a template for the development of an operation and maintenance agreement. Program and Agreements should be put in place by the end of FY 2021.	Cost to be developed	per year	Cost to be developed
Program 12	Design Review and Permitting Coordination	Basin-wide	The City and SDIC should continue to coordinate in the review and permitting of private development proposals within the basin to ensure design standards, requirements, and the needs of both agencies are served when property is developed or redeveloped within the basin. The City should continue to circulate preapplication invitations, land use applications, and building permit applications for site development with the SDIC. SDIC should actively participate in the preapplication and the design review processes in coordination with the City.	The coordination of development plans and proposals is currently occuring. The formalization of procedures and processes to ensure complete and continuous coordination may prove beneficial to both the City and SDIC. Program and Agreements should be put in place by the end of FY 2021.	Cost to be developed	Ongoing cost per year (average)	Cost to be developed

SDIC and North Troutdale Recommended Programs

ID	Program Title	Focus Area	Program Description	Notes	Cost	Timeline / Cost Share	Annual Cost
Program 13	System Reinvestment and Rehabilitation Program	Basin-wide	The City and SDIC should each incorporate in their financial and rate models a component for funding the repair and eventual replacing of aging components of the collection and conveyance system. These funds should be set aside and saved up for those future costs so that when the inspection, assessment, and asset management program identifies facilities that need costly major repair or replacement, funds will be available to do so before the facility fails.	Costs and size of revenue streams can be estimated through the application of asset management models (see above). Initially, this can be estimated as a depreciation percentage of total asset value in each agency's financial/rate models. Program and Agreements should be put in place by the end of FY 2021.	Cost to be developed	per year	Cost to be developed

Cost estimates are in 2019 dollars

SDIC and City of Troutdale
CCTV Inspection Programs
*Need to add additional cost for engineering assessment

SDIC

Diameter	Count	Length (LF)	Unit Cost*	Total
Pipeline ≤ 12 inch	99	9,372	$6.50	$60,918
Pipeline 15-18 inch	20	2,767	$8.80	$24,350
Pipeline 21-27 inch	17	2,686	$11.50	$30,889
Pipeline 30-36 inch	13	1,565	$11.50	$17,998
Pipeline 42-48 inch	23	4,612	$21.10	$97,313
Pipeline 54+ inch	15	2,538	$21.10	$53,552
Total	**187**	**23,540**		**$285,019**

*Cleaning and Inspection

Troutdale (does not include the pipes covered above for SDIC)

Diameter	Count	Length (LF)	Unit Cost*	Total
Pipeline ≤ 12 inch	104	12,946	$6.50	$84,149
Pipeline 15-18 inch	54	9,980	$8.80	$87,824
Pipeline 21-27 inch	65	12,641	$11.50	$145,372
Pipeline 30-36 inch	47	11,086	$11.50	$127,489
Pipeline 42-48 inch	12	2,829	$21.10	$59,692
Pipeline 54+ inch	5	1,782	$21.10	$37,600
Total	**287**	**51,264**		**$542,126**

*Cleaning and Inspection

SDIC and North Troutdale
Debris Barrier Program
Refer to CIP concept table for design assumptions

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Design Efforts				
Inspection				
Earthwork				
Miscellaneous				
Structure Installation				
Headwall - Culvert	`	$ 8,000	15	$ 120,000.00
Trash Rack Installation	SF	$ 100	3600	$ 360,000.00
Restoration/Resurfacing				
Hydroseed, large quantities	AC	$ 2,500	1	$ 2,500.00
Pipe Unit Cost				
Construction Item Subtotal				$ 482,500
Contingencies and Multipliers (applied to construction subtotals)				
General Conditions	LS	15%		$ 72,375
Mobilization/Demobilization	LS	10%		$ 48,250
Traffic Control/Utility Relocation	LS	5%		$ 24,125
Erosion Control	LS	5%		$ 24,125
Overhead and Profit	LS	15%		$ 72,375
Construction Item Total				$ 723,750
Contingencies and Multipliers (applied to construction Totals)				
Estimating Contingency	LS	25%		$ 180,938
Market Climate	LS	10%		$ 72,375
Engineering and Permitting	LS	25%		$ 180,938
Design Services	LS	0%		$ -
Construction Administration	LS	5%		$ 36,188
Project Total			TOTAL	$ 1,194,188

SDIC - Pump Station Testing and Monitoring Program

SDIC - Pump Station Maintenance Program

Item	Frequency (years)	Cost	Quantity	Cost per year
Pump Station Testing and Monitoring				
Annual General Inspection of Motors, Pumps and Switch Gears	1	$ -		$ -
Annual Meggar Testing (Motor)	1	$ 500	2	$ 1,000
Annual Vibration Analysis (Motor and Pump at Same Time)	1	$ 500	2	$ 1,000
Annual Oil Sampling (Motor)	1	$ 100	2	$ 200
Annual Thermal Inspection (Switch Gear)	1	$ -		$ -
Comprehensive flow and pressure testing w/ inspection of discharge lines and wet well every 5 years	5	$ 6,500	2	$ 2,600
		Total:		**$ 4,800**

Pump Station Maintenance Program			Pumps this size	
Rebuild Motor every 10 years*	10	$ 13,000	2	$ 2,600
Rebuild Small Pump at 15 and 25 years* (50HP and Below)	15	$ 15,000		$ -
Rebuild Medium Pump at 15 and 25 years* (Between 200HP and 50 HP)	15	$ 30,000	2	$ 4,000
Rebuild Large Pump at 15 and 25 years* (200HP > 700 HP)	15	$ 80,000		$ -
Rebuild Ex. Large Pump at 15 and 25 years* (700 HP)	15	$ 130,000		$ -
Replace Starter every 20 years	20	$ 15,000	2	$ 1,500
		Total:		**$ 8,100**

Notes:

*Pump, motor, and switch gear replacement expected every 30 years; not included in this maintenance estimate.

**Annual general inspection to include inspection of discharge piping. CCTV and repair/replacement of discharge pipes not included in this program estimate.

***Unless noted, all costs assume that activities will be conducted by outside contractors, performing inspections on multiple pump stations and submitting joint reports to the District.

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