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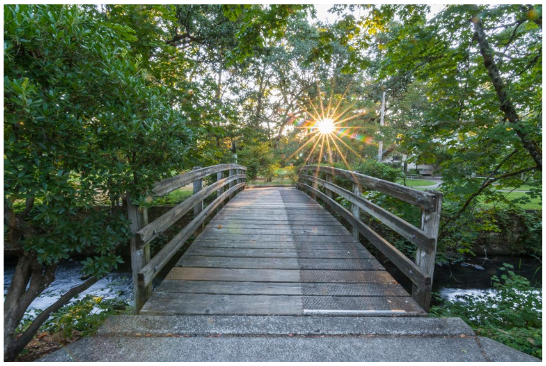
PRINGLE CREEK BASIN PLAN

September 2019

WEST Consultants, Inc.

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PRINGLE CREEK BASIN DESCRIPTION

General Overview

Pringle Creek Basin is a drainage area located in the City of Salem between the Battle Creek Basin to the south and the Mill Creek Basin to the north. The majority of Pringle Creek Basin is developed residential, commercial, and industrial land use. The southwest portion of the basin contains undeveloped agricultural land, forest, and grassland.

The Pringle Creek Basin has a drainage area of 13.4 square miles. The City of Salem Urban Growth Boundary (UGB) encompasses approximately 93% of the basin. The minimum and maximum basin elevations are 121 feet and 673 feet, respectively. The mean elevation for the basin is 329 ft. [Unless otherwise stated, all elevations mentioned in this document are in the National Geodetic Vertical Datum of 1929 (NGVD 29).]

The outlet for Pringle Creek Basin is the Willamette Slough, a backwater area of the Willamette River next to Minto Brown Island. Prior to its confluence with the Willamette Slough, two Mill Creek diversion channels, Shelton Ditch and Mill Race, discharge into Pringle Creek. Since the primary source of these diversion channels is Mill Creek, the channels and their contributing drainage areas are considered to be part of the Mill Creek Basin. **Figure 1** shows the extents of the Pringle Creek Basin and its drainage network.

The western half of the Pringle Creek drainage system is hydraulically and hydrologically distinct from the eastern half. It is largely composed of developed residential and commercial land use. It has hilly topography, steep channel slopes, significant impervious areas, and an extensive storm drain pipe network. These conditions combine to produce a relatively fast runoff response during large storm events. The existing stormwater conveyance system is able to quickly convey floodwaters downstream, limiting the flood risk in the western half of the Pringle Creek Basin.

The main tributaries in the western half of the basin include Clark Creek, West Fork Pringle Creek, West Middle Fork Pringle Creek, and Middle Fork Pringle Creek. While Clark Creek and West Fork Pringle Creek are generally developed, large portions of West Middle Fork Pringle Creek and Middle Fork Pringle Creek are currently undeveloped, but are assigned as Developing Residential in the Salem Comprehensive Plan (City of Salem, 2015). Two major detention basins are located in the western portion of the Pringle Creek basin, one at Gilmore Field with an area of 5.7 acres and the other at Clark Creek Park with an area of 1.9 acres, both located along Clark Creek.

The eastern portion of the Pringle Creek Basin is generally mildly sloped; however, some hilly terrain is located along the basin's southeastern boundary. The northeast portion includes McNary Field, developed industrial land use, and pockets of residential area. The southeast portion of the basin includes developed medium and low-density industrial land use, undeveloped open space, cropland, and a small amount of forest. The main tributaries in the eastern half of the basin include East Fork Pringle Creek, a branch of West Fork

Pringle Creek, and a branch of West Middle Fork Pringle Creek. Because this area is composed of fairly flat terrain, flooding is common, especially in the industrial area west of the airport and east of the railroad. Most drainage channels within the eastern portion of the basin are constructed ditches that are often heavily vegetated with blackberry and other non-native vegetation. In the southeast portion of the Pringle Creek basin (south of Kuebler Blvd), outside of the City Limits but within the UGB, the East Fork Pringle channels are used as irrigation ditches and are managed by the Santiam Water Control District. Because the ground in the eastern portion of the Pringle Creek Basin is both of low elevation and in close proximity to Mill Creek, high flows along Mill Creek can lead to an interbasin exchange of floodwaters into Pringle Creek. The eastern half of the Pringle Creek Basin does not contain any large engineered detention facilities; however, a few large abandoned quarry ponds are located along East Fork Pringle Creek, including Waller Pond and Spinnaker Lake, that provide some amount of flood storage during storm events.

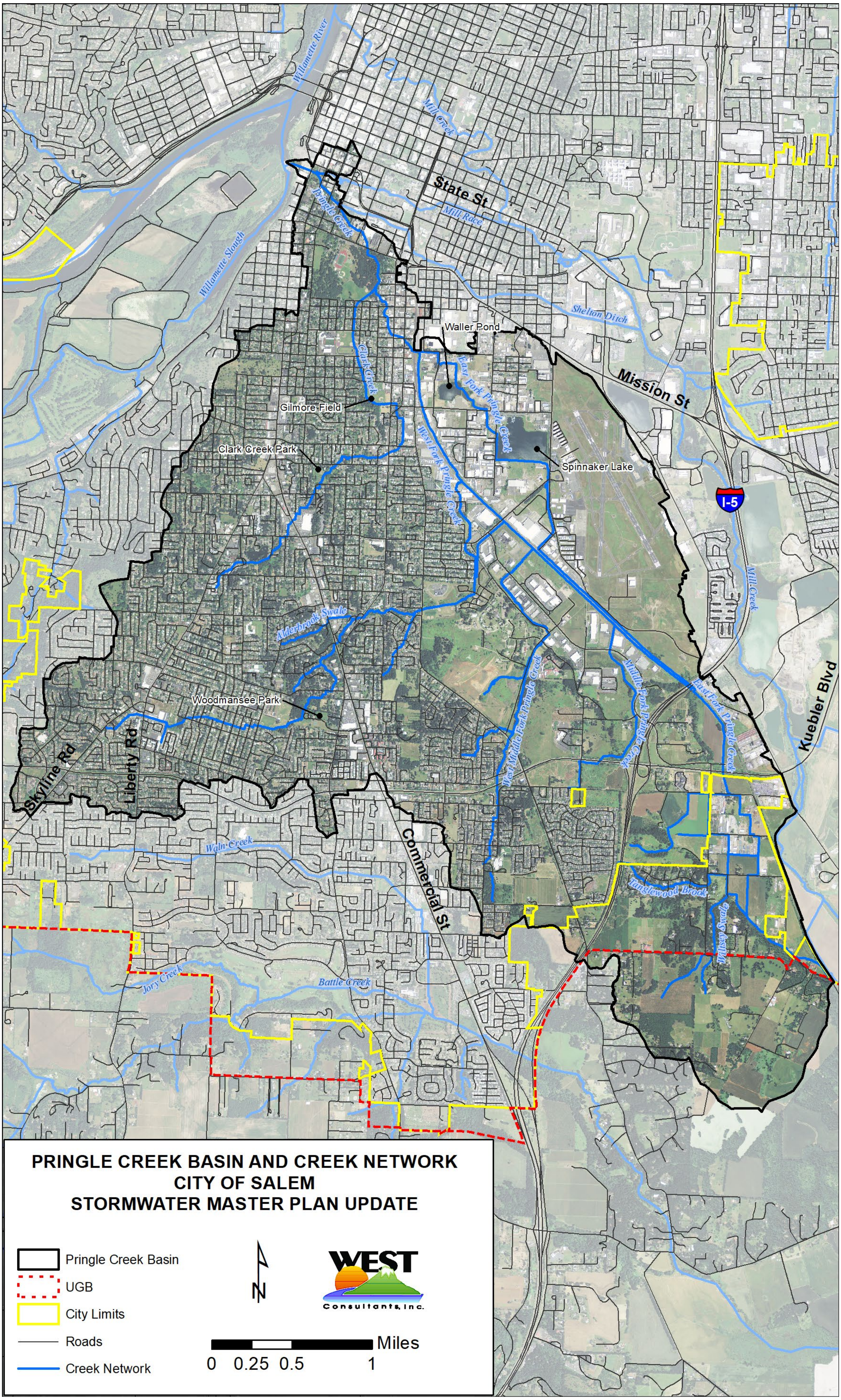

Figure 1 – Pringle Creek Basin and channel network

Areas of Concern

There are several areas that have a history of flooding during large storm events within the Pringle Creek Basin. The most recent major flood events occurred in January 2012 and February 1996. Two recent minor flooding events occurred in December 2015.

During the January 2012 and December 2015 storm events, photos were taken by the City of Salem and/or WEST Consultants Inc. to document the observed flooding (see **Appendix 13.A**). Following the February 1996 event, the approximate observed flood extents were mapped by the City. The February 1996 flood inundation extents and the January 2012 and December 2015 observed flooding locations are shown in **Figure 2**.

Historic flooding has been documented along Pringle Creek during the 1996 and 2012 events. During both events, floodwater spilled out of Pringle Creek between 12th Street and 13th Street, inundating a few city blocks north of Pringle Creek.

There is little record of flooding along the portions of Clark Creek located in the steeper sloped upper portion of that drainage basin. Floodwaters have been observed overtopping the Summer Street crossing at Clark Creek, but recent culvert upgrades have reduced the flood risk at that location. Further downstream, historic flooding has been observed north of the Gilmore Field Detention Facility. During the January 2012 flood event, the Gilmore Field Detention Facility filled to capacity, overtopped its spillway and inundated the residential area located to the north.

There is little record of flooding along the portions of West Fork Pringle Creek located in the steeper sloped upper portion of the drainage basin. Flooding during the January 2012 event was documented along the upper portion of West Fork Pringle Creek at the Woodmansee Park parking lot. Further downstream, where West Fork Pringle Creek enters the mildly sloping terrain of the industrial area, flooding is more common. Flooding was documented for the 1996, 2012, and 2015 storm events along West Fork Pringle Creek at and downstream of Pence Loop including large segments of 19th Street SE and McGilchrist Street.

Flooding was observed along Reed Road between Battle Creek Road and Old Strong Road as a result of high flows in West Middle Fork Pringle Creek for both the 2012 and 2015 storm events. During the 2012 storm event, floodwaters spilled out of West Middle Fork Pringle Creek and inundated a business park and portions of Fairview Industrial Drive.

There are many flood prone areas along East Fork Pringle Creek. Upstream of Boone Road, between the city limits and the UGB, flooding has been observed along roadways, in open spaces, and in some industrial areas during the 2012 and 2015 events. Further downstream, East Fork Pringle Creek floodwaters often overtop portions of Airway Drive, resulting in road closures. During the 2012 event, high waters from East Fork Pringle Creek spilled over a berm that divides it from Spinnaker Lake. Despite pumping by the property owner, the water level in the lake continued to increase. Water eventually began spilling out of the lake at the boat ramp near its northwest corner and into 22nd Street SE. The overtopping resulted in flooding of properties located south of McGilchrist Street between East Fork Pringle Creek and 22nd Street. During the 1996 storm event, water spilled out of East Fork Pringle Creek along the reach located upstream of its confluence with West Fork Pringle

Creek. The flooding extended northward into residential and industrial areas located between Mission Street and Oxford Street.

As mentioned previously, during large storm events in the Mill Creek Basin, floodwaters can overflow into the Pringle Creek basin at several locations. The most significant overflows occur at the I-5 at Turner Road overpass. From there, the Mill Creek floodwaters travel west through McNary Field and through residential and industrial areas located north of McGilchrist Street and west of 25th Street. Ultimately, the Mill Creek floodwaters reach East Fork Pringle Creek, significantly increasing the flooding conditions in the residential areas located north of Oxford Street. The additional flows from Mill Creek also increase flooding along Pringle Creek between 12th Street and 13th Street.

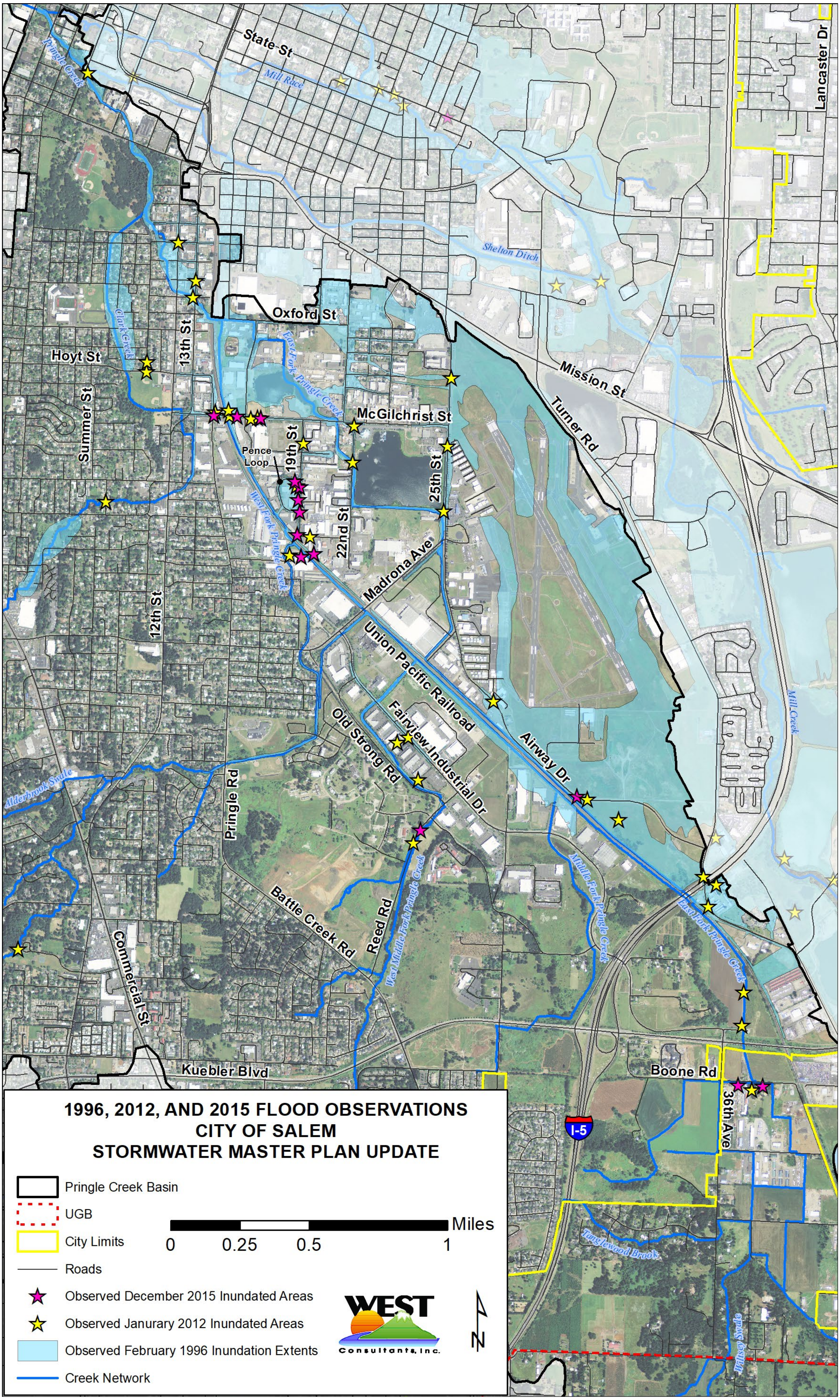

Figure 2 – Approximate 1996 flood inundation extents and observed January 2012 and December 2015 flooding locations

Findings of 2000 Stormwater Master Plan

In the Stormwater Master Plan (SWMP) and Drainage System Improvement Plan (DSIP) developed for the City of Salem by Montgomery Watson (2000), the Pringle Creek Basin was modeled using a planning-level xpswmm model, which provided coupled hydrologic and hydraulic modeling of the watershed and stormwater system. In that effort, the Pringle Creek Basin was divided into 99 subbasins. The primary purpose of the model was to detect areas within the storm drainage network that were at-risk of surcharge during the 10-year 24-hour SCS Type-1A rainfall event. Models were developed for existing and full build-out conditions.

The findings of the 2000 DSIP included 58 recommended Capital Improvement Projects (CIPs) within the Pringle Creek Basin. The recommendations included bridge/culvert replacements, channelization, vegetation modifications, and detention facility construction. The total cost for the recommended CIPs was $61,413,000 in 2000 dollars.

PRINGLE CREEK BASIN MODEL

Model Selection Process

The 2000 SWMP xpswmm model was used to develop a planning-level model of Pringle Creek Basin. However, the planning-level model lacks the detail needed to accurately model natural channels, hydraulic structures, complex 2-dimensional (2-D) flow, and overflow routing during high flow conditions. Since the Pringle Creek Basin stormwater drainage system includes open channel conveyances (both natural channels and ditches), closed conduit stormwater systems (pipes and manholes), bridges and culverts, detention facilities, and complex two-dimensional flow conditions, XP Solutions' xpstorm with XP2D was selected as the most appropriate model. A detailed description of the model selection process is presented in **Appendix F** of the *Stormwater Master Plan*.

Model Development

The xpstorm model for the Pringle Creek Basin is divided into two components, runoff and hydraulics. The runoff component simulates the hydrologic processes in the watershed, including precipitation, hydrologic abstractions, hydrologic routing, and watershed storage. The hydraulics component simulates the conveyance and storage for channels, floodplains, weirs, bridges, culverts, pipes, and detention facilities.

Runoff Component Development

The development of the runoff component of the xpswmm model included:

- Subbasin delineation
- Watershed characteristics pre-processing
- Rainfall data collection and processing
- Design storm development

Each of these development steps is summarized in the following sections:

Subbasin Delineations

Since the development of the 2000 SWMP, high density topographic data for the Pringle Creek Basin has become available from the Oregon LiDAR Consortium (Watershed Concepts, 2009). This topographic data, along with current stormwater system information, land use data, and 2-ft contour mapping provided by the City of Salem were used to update and revise the subbasin boundaries from the 2000 SWMP. Subbasins were divided along topographic ridges according to the high-density LiDAR data and 2-ft contour mapping, while generally maintaining a minimum subbasin outlet pipe size of 15-24 inches. Subbasins were also delineated based on the locations of recognized flood water storage areas, stream confluences, clear distinctions in land use, and major bridges and culverts.

A total of one hundred thirty-one (131) subbasins were defined within the Pringle Creek Basin. **Figure 3** shows the resultant subbasins delineations. Of the 131 subbasins, six subbasins are predominantly located outside of the Salem City Limits and two subbasins are located predominantly outside of the UGB. During high flows in the Mill Creek Basin, Mill Creek floodwaters can overflow into the Pringle Creek basin. Consequently, models developed for the Mill Creek Basin and Pringle Creek Basin were merged into a single xpstorm model. The combined model extents are shown in **Figure 4**.

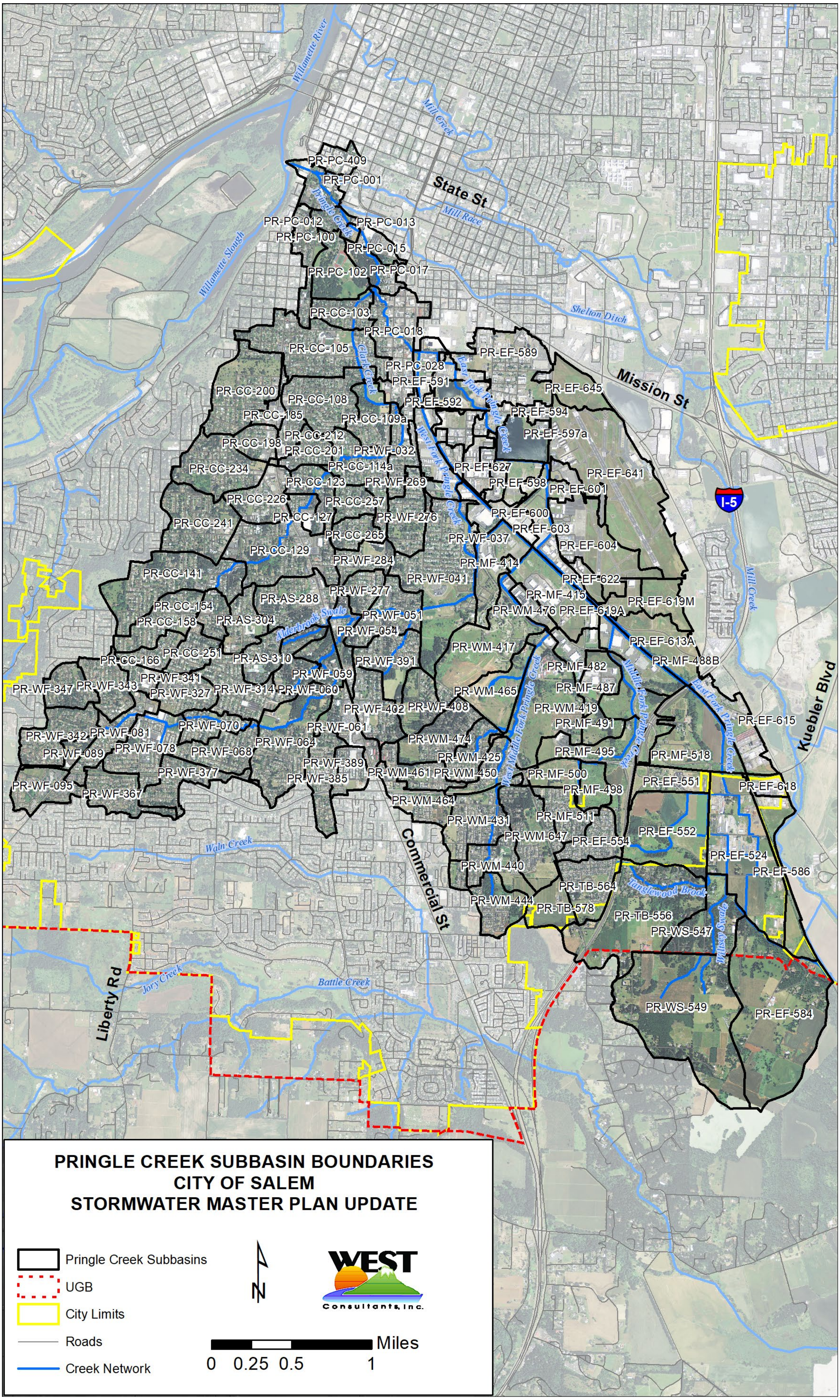

Figure 3 – Pringle Creek subbasin boundaries

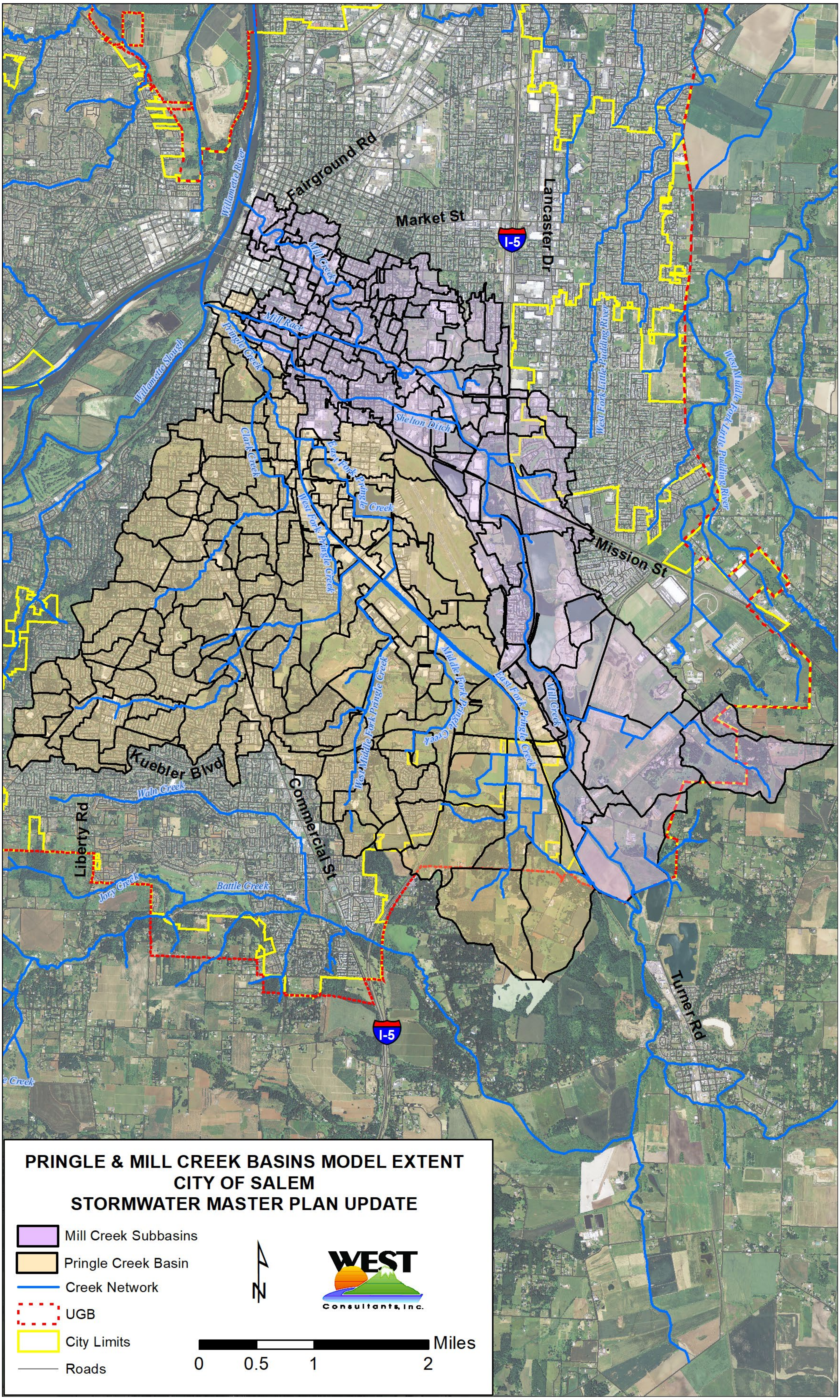

Figure 4 – Combined Pringle Creek Basin and Mill Creek Basin model extents

Watershed Characteristics Pre-Processing

The SWMM RUNOFF method of xpstorm was selected to simulate watershed hydrology due to its ability to continuously simulate non-linear soil infiltration rates via the Horton Infiltration Method. The pre-calibration watershed characteristics needed for the SWMM RUNOFF method were developed for each subbasin using the most current land cover, soil type, elevation, and impervious surface area coverage data that was either publicly available or provided by the City of Salem. Detailed descriptions of the watershed parameters used in the SWMM RUNOFF method and the processes used to develop the parameters are presented in **Appendix G** of the Stormwater Master Plan**.** A map of the Pringle Creek Basin land cover classifications, which was developed from City's impervious surface data and 2011 National Land Cover Data (MRLC, 2011) is shown in **Figure 5**. A map of the hydrologic soil group classification for the Pringle Creek Basin is shown in **Figure 6**. **Table 1** summarizes the name, drainage area, existing impervious surface percentage, full build-out impervious surface percentage, percent water cover, and average watershed slope of each Pringle Creek subbasin.

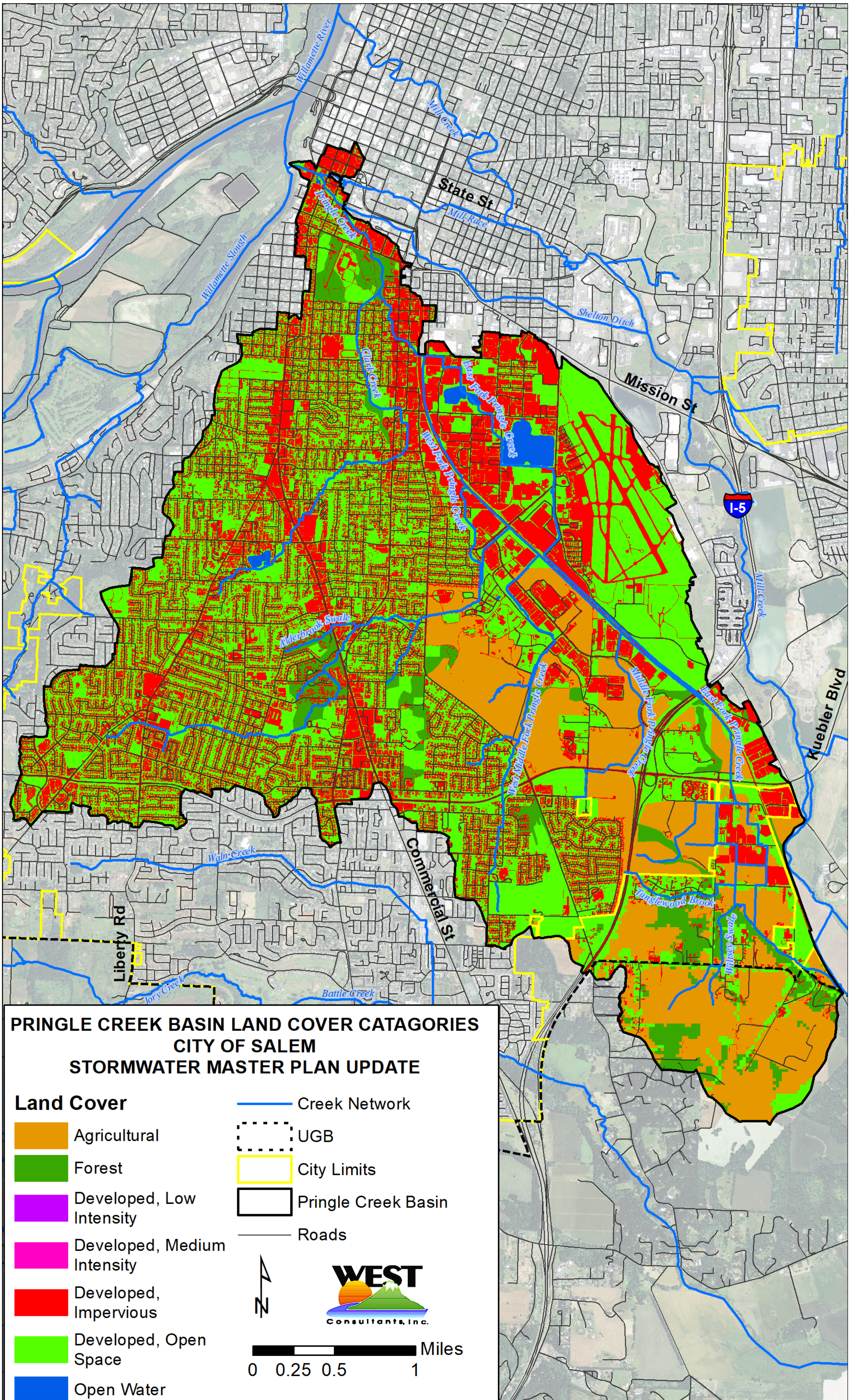

Figure 5 – Pringle Creek Basin land cover categories

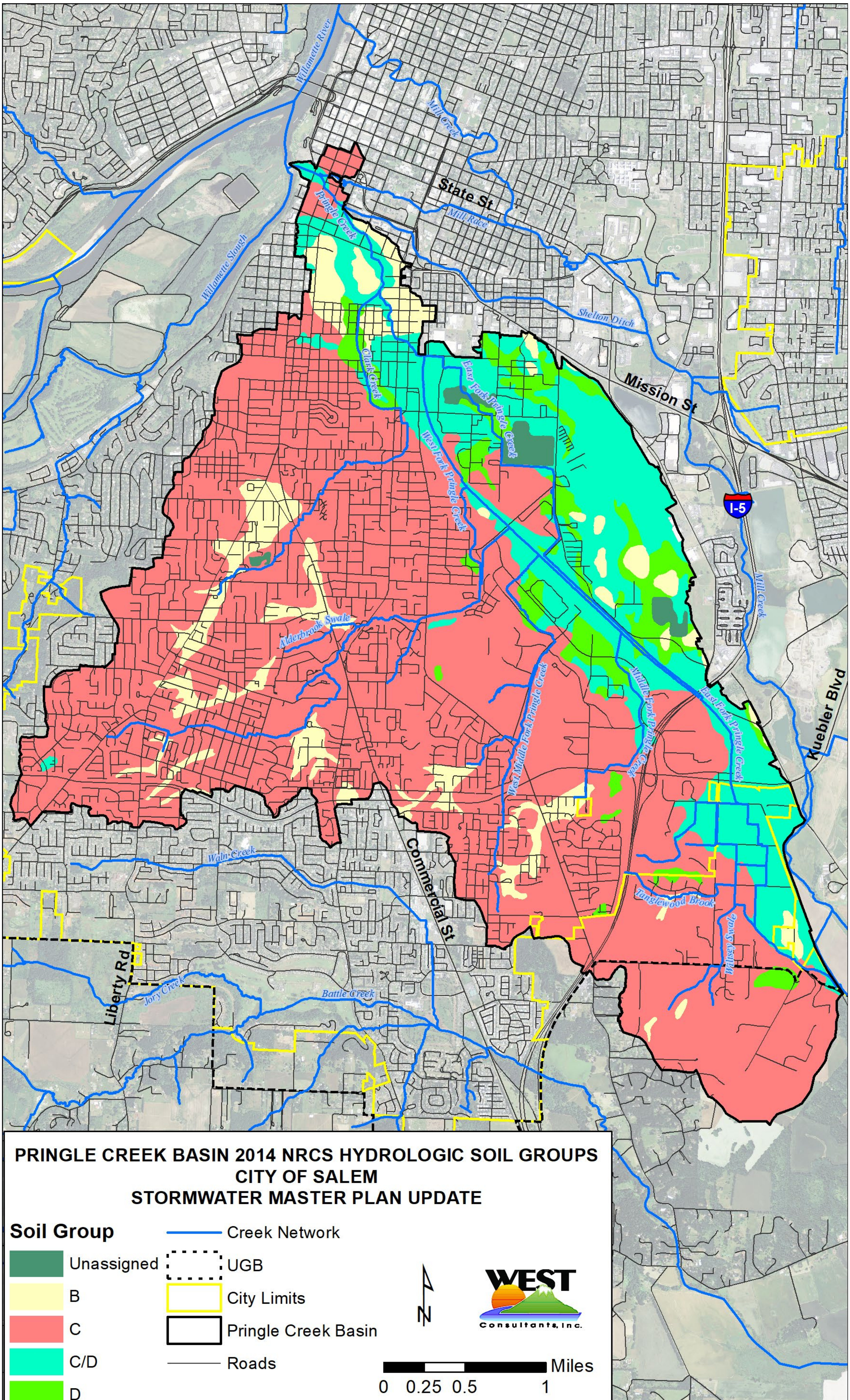

Figure 6 – NRCS 2014 hydrologic soil groups for the Pringle Creek Basin

Table 1 – Pringle Creek Basin watershed characteristics

Subbasin Name	Area (Acres)	Existing Directly Connected Impervious (%)	Full Build-Out Directly Connected Impervious (%)	Average Slope (%)	Water Coverage (%)
PR-AS-288	93.2	26.9	26.9	7.0	0.0
PR-AS-304	48.6	23.1	23.1	3.6	0.0
PR-AS-309	19.3	14.0	14.0	5.6	0.0
PR-AS-310	40.9	20.9	20.9	3.5	0.0
PR-CC-103	43.0	19.0	19.0	4.4	0.0
PR-CC-105	148.0	23.1	23.1	6.9	0.0
PR-CC-108	95.2	21.6	21.6	9.9	0.0
PR-CC-109	17.7	38.6	38.6	3.0	0.0
PR-CC-109a	54.1	13.5	13.5	12.2	0.0
PR-CC-109f	21.3	31.4	31.4	4.5	0.0
PR-CC-114a	82.2	18.0	18.0	8.4	0.0
PR-CC-123	44.6	15.9	15.9	12.5	0.0
PR-CC-127	25.7	31.1	31.1	11.8	0.0
PR-CC-129	137.3	27.2	27.2	8.2	4.5
PR-CC-141	148.1	24.1	24.1	7.9	0.0
PR-CC-154	30.0	28.1	28.1	5.5	0.0
PR-CC-158	69.5	26.8	26.8	5.3	0.0
PR-CC-166	31.7	34.2	34.2	5.4	0.0
PR-CC-185	20.2	43.9	43.9	6.2	0.0
PR-CC-198	32.2	28.2	28.2	7.1	0.0
PR-CC-200	116.2	15.9	15.9	8.0	0.0
PR-CC-201	33.0	21.6	21.6	8.7	0.0
PR-CC-212	23.4	34.4	34.4	6.2	0.0
PR-CC-226	61.5	30.1	30.1	8.0	0.0
PR-CC-234	98.0	17.7	17.7	9.8	0.0
PR-CC-241	108.4	18.3	18.3	8.5	0.0
PR-CC-251	38.8	31.9	31.9	3.5	0.0
PR-CC-257	31.2	14.1	14.1	8.9	0.0
PR-CC-265	33.4	16.8	16.8	8.6	0.0
PR-EF-524	208.8	8.6	36.7	2.9	0.0
PR-EF-551	47.8	22.7	37.3	7.5	0.0
PR-EF-552	150.1	1.6	36.5	10.3	0.0
PR-EF-554	48.2	26.3	28.0	7.6	0.0
PR-EF-584	316.9	1.7	5.7	15.7	0.0
PR-EF-586	61.6	6.2	27.3	5.0	0.0
PR-EF-589	131.1	37.2	45.9	2.2	0.0
PR-EF-591	25.5	40.5	45.1	2.6	0.0
PR-EF-592	37.4	36.9	49.4	5.2	29.7
PR-EF-594-1	34.4	41.3	41.3	3.5	0.5
PR-EF-594-2	30.2	42.7	53.5	2.8	0.0
PR-EF-597	22.7	51.6	51.6	3.6	0.0
PR-EF-597a	52.6	87.0	87.0	3.0	81.7
PR-EF-598	28.8	20.3	42.9	3.8	0.0
PR-EF-600	32.9	44.9	48.3	3.4	0.0
PR-EF-601	22.3	49.1	49.1	1.6	0.0
PR-EF-603	65.4	37.0	45.2	4.5	0.0
PR-EF-604	125.2	26.9	26.9	1.6	0.0
PR-EF-613A	81.9	3.4	3.4	3.9	0.0
PR-EF-615	71.9	22.5	33.1	4.9	0.0

Table 1 – Pringle Creek Basin watershed characteristics (continued)

Subbasin Name	Area (Acres)	Existing Directly Connected Impervious (%)	Full Build-Out Directly Connected Impervious (%)	Average Slope (%)	Water Coverage (%)
PR-EF-618	18.0	28.0	28.0	5.7	0.0
PR-EF-619A	24.5	11.5	11.5	2.8	0.0
PR-EF-619M	41.8	0.7	0.7	2.1	0.0
PR-EF-622	17.9	15.5	15.5	2.2	0.0
PR-EF-627	29.3	49.3	49.3	2.9	0.0
PR-EF-641	276.9	19.8	19.8	1.6	0.0
PR-EF-645	50.7	5.6	6.1	1.7	0.0
PR-MF-414	72.1	22.1	33.1	5.4	0.4
PR-MF-415	96.3	18.6	47.9	4.0	0.0
PR-MF-482	35.9	32.0	36.6	6.4	0.0
PR-MF-487	43.8	24.3	50.3	6.2	0.0
PR-MF-488B	60.6	27.0	38.5	8.9	0.0
PR-MF-491	74.2	8.5	37.5	7.8	0.0
PR-MF-495	101.5	12.5	33.5	13.1	0.0
PR-MF-498	33.1	3.0	22.5	12.4	0.0
PR-MF-500	34.0	12.0	52.7	5.7	0.0
PR-MF-511	49.5	25.8	25.9	7.7	0.0
PR-MF-516	26.2	3.5	36.6	7.3	0.0
PR-MF-518	129.3	7.5	42.6	10.7	0.0
PR-PC-001	39.3	39.7	39.7	12.2	7.2
PR-PC-012	20.2	23.1	23.1	8.6	1.2
PR-PC-013	6.7	26.3	26.3	5.9	4.5
PR-PC-015	24.3	45.6	45.6	5.3	1.4
PR-PC-017	35.5	19.9	19.9	5.0	4.1
PR-PC-018	92.7	40.3	40.3	3.3	1.0
PR-PC-028	31.0	37.9	37.9	4.8	0.0
PR-PC-100	47.1	34.7	34.7	4.5	0.0
PR-PC-102	67.3	6.6	6.6	4.3	0.0
PR-PC-268	8.8	48.8	48.8	3.8	0.0
PR-PC-409	25.6	57.0	57.0	3.6	0.0
PR-TB-556	229.5	6.5	25.3	9.4	0.0
PR-TB-564	69.3	19.6	24.9	7.3	0.0
PR-TB-578	44.7	3.5	32.0	7.3	0.0
PR-WF-032	46.4	46.8	47.3	4.8	0.0
PR-WF-034	15.4	44.7	44.7	5.2	0.0
PR-WF-036	18.2	41.6	41.6	6.2	0.0
PR-WF-037	27.6	44.3	44.3	4.2	0.0
PR-WF-041	212.3	15.9	33.4	8.2	0.0
PR-WF-051	70.9	23.1	23.1	10.0	0.0
PR-WF-054	36.2	33.4	33.4	10.2	0.0
PR-WF-059	38.3	18.4	18.4	13.0	0.0
PR-WF-060	30.8	18.0	18.0	10.2	0.4
PR-WF-061	53.6	40.6	40.9	6.0	0.0
PR-WF-064	135.2	17.2	18.1	7.5	0.0
PR-WF-068	63.7	22.2	22.2	5.6	0.0
PR-WF-070	38.8	21.3	21.3	3.8	0.0
PR-WF-078	88.3	29.2	32.0	4.7	0.0
PR-WF-081	59.1	28.4	29.8	6.4	0.0
PR-WF-089	16.6	19.4	37.4	6.1	0.0

Table 1 – Pringle Creek Basin watershed characteristics (continued)

Subbasin Name	Area (Acres)	Existing Directly Connected Impervious (%)	Full Build-Out Directly Connected Impervious (%)	Average Slope (%)	Water Coverage (%)
PR-WF-095	57.0	30.4	30.4	9.5	0.0
PR-WF-269	33.0	30.8	30.8	6.4	0.0
PR-WF-276	62.8	19.6	19.6	9.3	0.0
PR-WF-277	33.9	23.1	23.1	9.2	0.0
PR-WF-284	40.9	20.2	20.2	6.8	0.0
PR-WF-314	84.8	26.9	26.9	3.3	0.0
PR-WF-327	52.4	23.7	26.8	3.8	0.0
PR-WF-341	21.0	42.0	42.0	5.9	0.0
PR-WF-342	77.4	26.0	26.0	4.9	0.0
PR-WF-343	55.8	24.8	24.8	5.7	0.0
PR-WF-347	45.6	22.3	22.3	7.6	0.0
PR-WF-367	60.2	23.1	23.1	10.9	0.0
PR-WF-377	60.4	25.2	25.2	6.1	0.0
PR-WF-385	59.4	27.6	27.6	7.0	0.0
PR-WF-389	36.6	35.6	37.2	4.4	0.0
PR-WF-391	74.0	16.4	24.6	7.2	0.0
PR-WF-402	64.6	28.8	29.8	7.6	0.0
PR-WF-408	50.6	9.0	27.5	9.6	0.0
PR-WM-417	147.0	6.4	52.1	8.6	0.0
PR-WM-419	157.4	8.7	36.2	10.9	0.0
PR-WM-425	47.3	23.2	23.9	13.7	0.0
PR-WM-431	84.1	21.6	24.1	10.3	0.0
PR-WM-440	57.8	18.3	28.5	5.8	0.0
PR-WM-444	69.8	12.9	26.2	9.1	0.0
PR-WM-450	45.1	23.2	23.2	10.8	0.0
PR-WM-461	44.8	24.3	27.3	6.2	0.0
PR-WM-464	53.9	26.1	34.0	8.5	0.0
PR-WM-465	67.5	3.9	54.7	8.4	0.4
PR-WM-474	74.9	17.8	24.3	8.6	0.0
PR-WM-476	20.4	39.9	51.0	3.7	0.0
PR-WM-647	99.9	15.6	29.5	6.9	0.0
PR-WS-547	89.1	4.8	32.4	13.3	0.2
PR-WS-549	328.0	1.0	1.0	9.3	0.0

Rainfall Data Collection and Processing

Historic rainfall data are available for several gauges located in and near the Pringle Creek Basin, including gauges: RG2, RG7, RG8, RG10, RG12, RG17, RG19, RG24, and McNary Field. The RG2, RG7, RG8, RG10, RG12, RG17, RG19, and RG24 gauges are operated by the City of Salem. The McNary Field gauge is operated by the National Oceanic and Atmospheric Administration (NOAA) and has been collecting data since 1948. Gauges were assigned to individual subbasins within the model based on both proximity to the subbasin centroid as well as orographic similarities. **Table 2** contains a description of each rainfall gage used in the Pringle Creek Basin. **Figure 7** shows the location of the rainfall gauges used in the Pringle Creek Basin model and the sub-watersheds assigned to each rainfall gauge.

Table 2 – Pringle Creek Basin rainfall gauges

Gauge	Owner	Location	Period of Record	Elevation	Record Increment	Number of Subbasins Assigned to Gauge
McNary Field (KSLE)	NOAA	Salem Airport (McNary Field)	1948 - Present	205 ft	1-hour	none
Rain Gauge 2 (RG2)	City of Salem	Between 20th Street SE and 22nd Street SE, 400 feet south of Mission Street	1996 - Present	183 ft	15-minute	21 of 131
Rain Gauge 7 (RG7)	City of Salem	Near Mirror Pond between Liberty and Commercial Street	1996 - Present	165 ft	15-minute	8 of 131
Rain Gauge 8 (RG8)	City of Salem	Upstream of the Commercial Street crossing of Battle Creek	1996 - 1998 & 2002 - Present	389 ft	15-minute	9 of 131
Rain Gauge 10 (RG10)	City of Salem	Near the intersection of Liberty Road and Hrubetz Road	1997 - Present	470 ft	15-minute	29 of 131
Rain Gauge 17 (RG17)	City of Salem	Sprague High School	2002 - Present	568 ft	15-minute	4 of 131
Rain Gauge 19 (RG19)	City of Salem	East of the I-5 at Turner Road overpass	2005 - Present	222 ft	15-minute	28 of 131
Rain Gauge 24 (RG24)	City of Salem	Near the Mill Creek Correctional Facility on Turner Road	2008 - Present	306 ft	15-minute	7 of 24

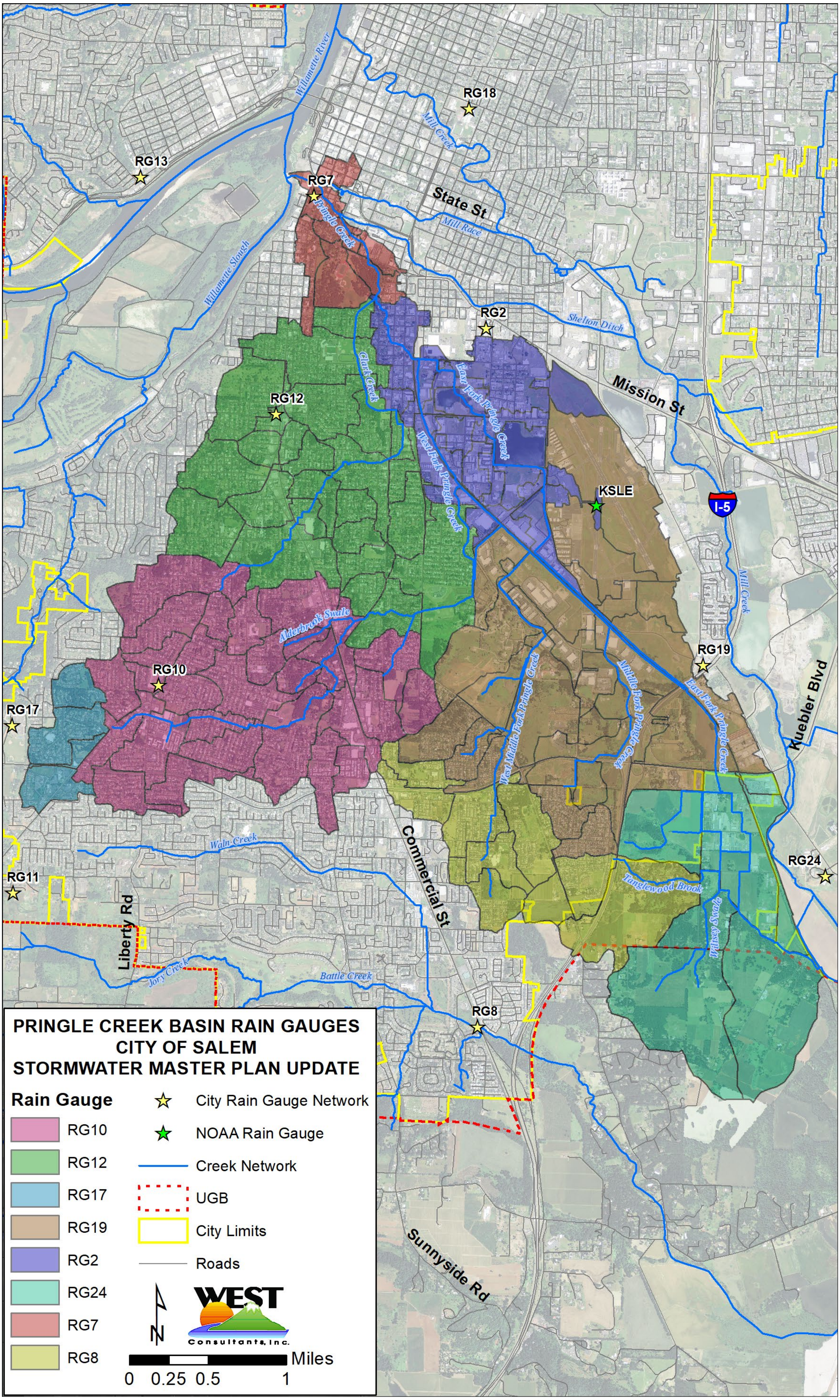

Figure 7 - Pringle Creek rainfall gauge locations and assigned subbasins

Design Storm Development

While the *City of Salem Public Works Design Standards* recommends the 24-hour SCS Type-1A storm distribution (City of Salem, 2014), initial modeling suggested that this distribution was inadequate for a basin wide model. Therefore, an evaluation of available rainfall data was conducted to determine the most appropriate design storms for use in the City of Salem SWMP Update. Ultimately, a 100-yr, 48-hr design storm using a normalized distribution based on a November 1996 event was recommended for evaluation of the flood risk for the Battle Creek basin. A rainfall frequency analysis of the McNary Field gauge data was used to developed base design storm depths. A comparative analysis of the rain gauge data was performed to develop a relationship between city rain gauges that are in close proximity to Pringle Creek Basin and the McNary Field rain gauge. A detailed description of the storm distribution analysis, rainfall frequency analysis, and rainfall gauge comparative analysis for the Pringle Creek Basin is provided in **Appendix 13.B**.

Hydraulics Component Development

The development of the Hydraulic component of the xpstorm model included:

- Data Collection and GIS Database Compilation
- Link Modeling Methods
- Node Modeling Methods
- Two-Dimensional Modeling
- Outfall Conditions

For a detailed description of the hydraulic modeling methods used for developing the Pringle Creek Basin model, refer to **Appendix H** of the *Stormwater Master Plan***.**

Data Collection and GIS Database Compilation

Much of the required pipe and culvert data was available either in the City's Hanson asset management database, the City's storm sewer GIS data, or as-built drawings. However, site visits were required for some areas to verify and collect data for portions of the Pringle Creek Basin drainage network. A small portion of West Fork Pringle Creek, East Fork Pringle Creek, West Middle Fork Pringle Creek, Pringle Creek, and Clark Creek were contained in existing HEC-RAS models, which provided necessary channel, bridge, and control structure data. Data had to be gathered through field work and surveys for bridges, control structures, and channels not contained in the HEC-RAS models. Elevation data for areas located outside of the UGB and in drainage areas less than one square mile were developed from available LiDAR data (Watershed Concepts, 2009). Likewise, dimensions of hydraulic structures located outside of the UGB and in drainage areas less than one square mile were either determined in the field with a tape measure or estimated.

Portions of the Pringle Creek drainage network contained within the UGB and having a drainage area greater than one square mile were designated as being high priority in discussions with the City. For these areas detailed survey data and measurements were collected for cross sections, bridges, control structures, culverts, and pipe systems not available in HEC-RAS models, the Hansen asset management database, the City's storm sewer GIS data, or as-built drawings. Topographic data for high priority ditches without dense vegetation was extracted from the LiDAR data.

Survey data and measurements were collected in the Pringle Creek Basin for 19 bridges, 193 cross sections, 44 culverts, and 7 storm sewer pipes. Surveyed cross sections were extended through the dense vegetation on both banks. For surveyed cross sections that needed to be extended beyond that point, elevation data were extracted from LiDAR and merged with the field survey data. **Figure 8** shows the data sources for the open channels within Pringle Creek Basin.

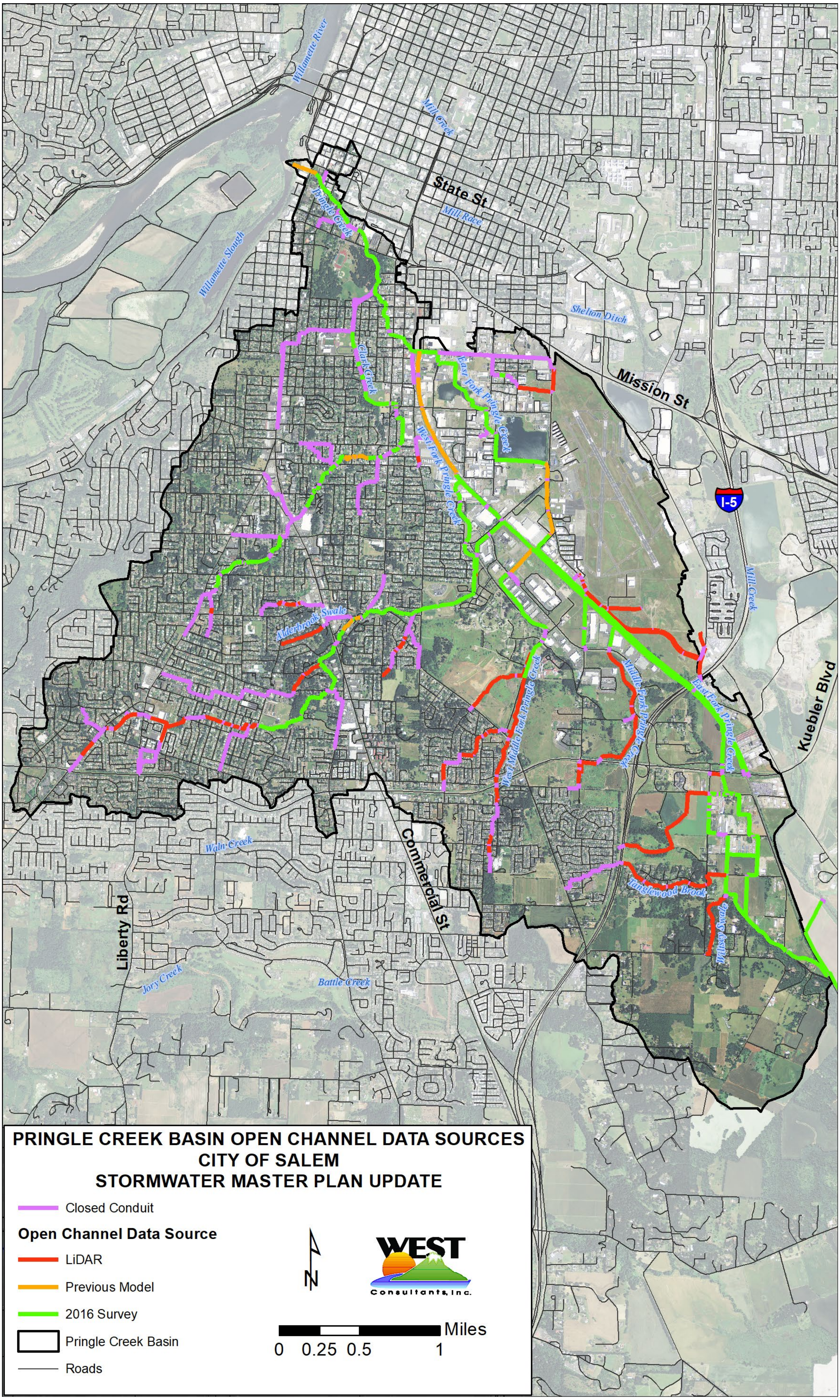

Figure 8 – Pringle Creek Basin open channel data sources

Link and Node Modeling Methods

The hydraulic conveyance routes in the xpstorm model are represented by features defined as links and nodes. Nodes represent manholes, junctions, confluences, and storage areas. The modeling methodologies and techniques used when developing the nodes are described in **Appendix H** of the *Stormwater Master Plan*. Specific nodes in the model were named using the following convention: The first two letters in the node name indicate the primary drainage basin it is located in (e.g., PR for Pringle Creek). The third and fourth letters in the name refer to the subbasin in which the node is located (e.g. PC for Pringle Creek or CC for Clark Creek). The last three numbers are a unique identifier of the node. For example, PR-CC-113 is node number 113 located in the Clark Creek (CC) subbasin within the Pringle Creek Basin (PR).

Links in the xpstorm model represent channels, pipes, bridges, culverts, and control structures. The modeling methodologies and techniques used when developing the links are described in **Appendix H** of the *Stormwater Master Plan*. The naming convention for links is based on the upstream node identifier, except it uses lower case lettering and no hyphen between the basin and creek identifiers. For example, prcc-113 is link 113, located just downstream of node number 113, along Clark Creek, in the Pringle Creek Basin. For overflow links, an "o" was placed at the end of the link name. **Figure 9** though **Figure 12** show the link and node network developed for the xpstorm model.

Two-Dimensional Modeling

The eastern half of Pringle Creek Basin is relatively flat and prone to flooding at multiple locations. The complex flow patterns that occur in the wide floodplains necessitated the use of the two-dimensional (2-D) modeling component of xpstorm. Various grid cell sizes were tested to find the optimum balance of accuracy and model runtime. Ultimately, a 2-D computational grid, with 20-ft by 20-ft cells, containing approximately 650,000 cells was defined. The extents of the 2-D grid and the land cover types used to assign the 2-D overland roughness values are shown in **Figure 13**.

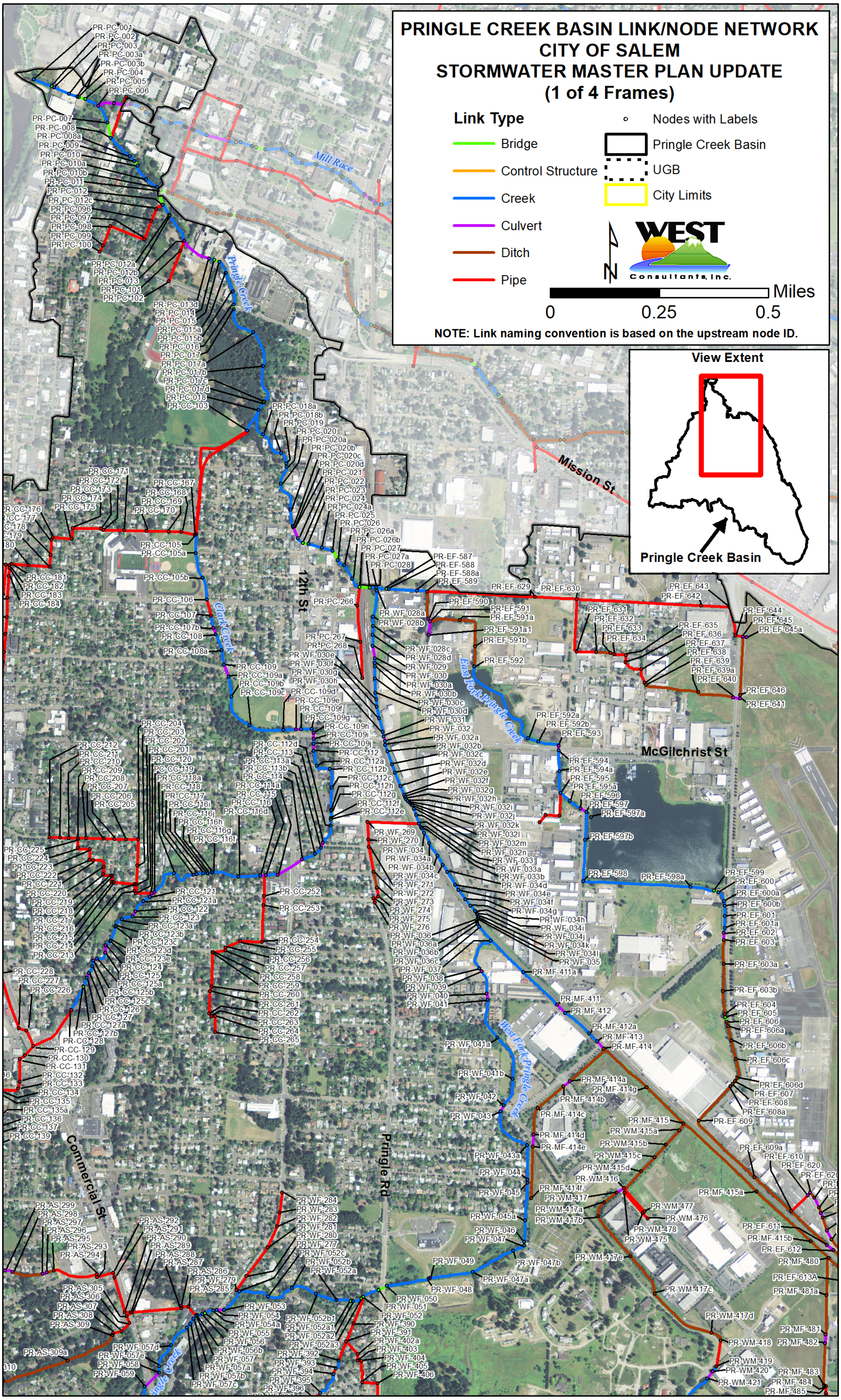

Figure 9 – Pringle Creek Basin xpstorm link and node network (1 of 4)

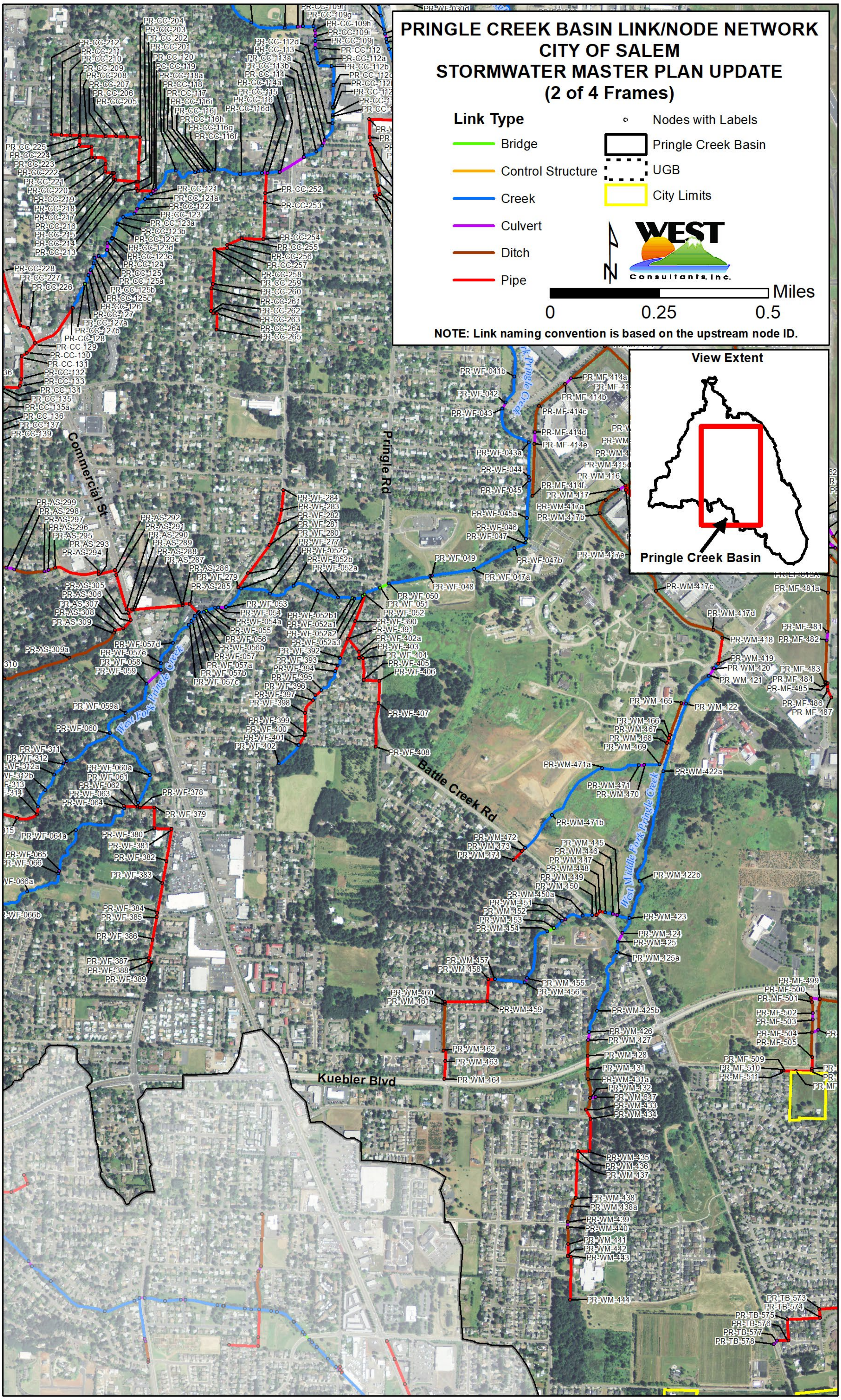

Figure 10 – Pringle Creek Basin xpstorm link and node network (2 of 4)

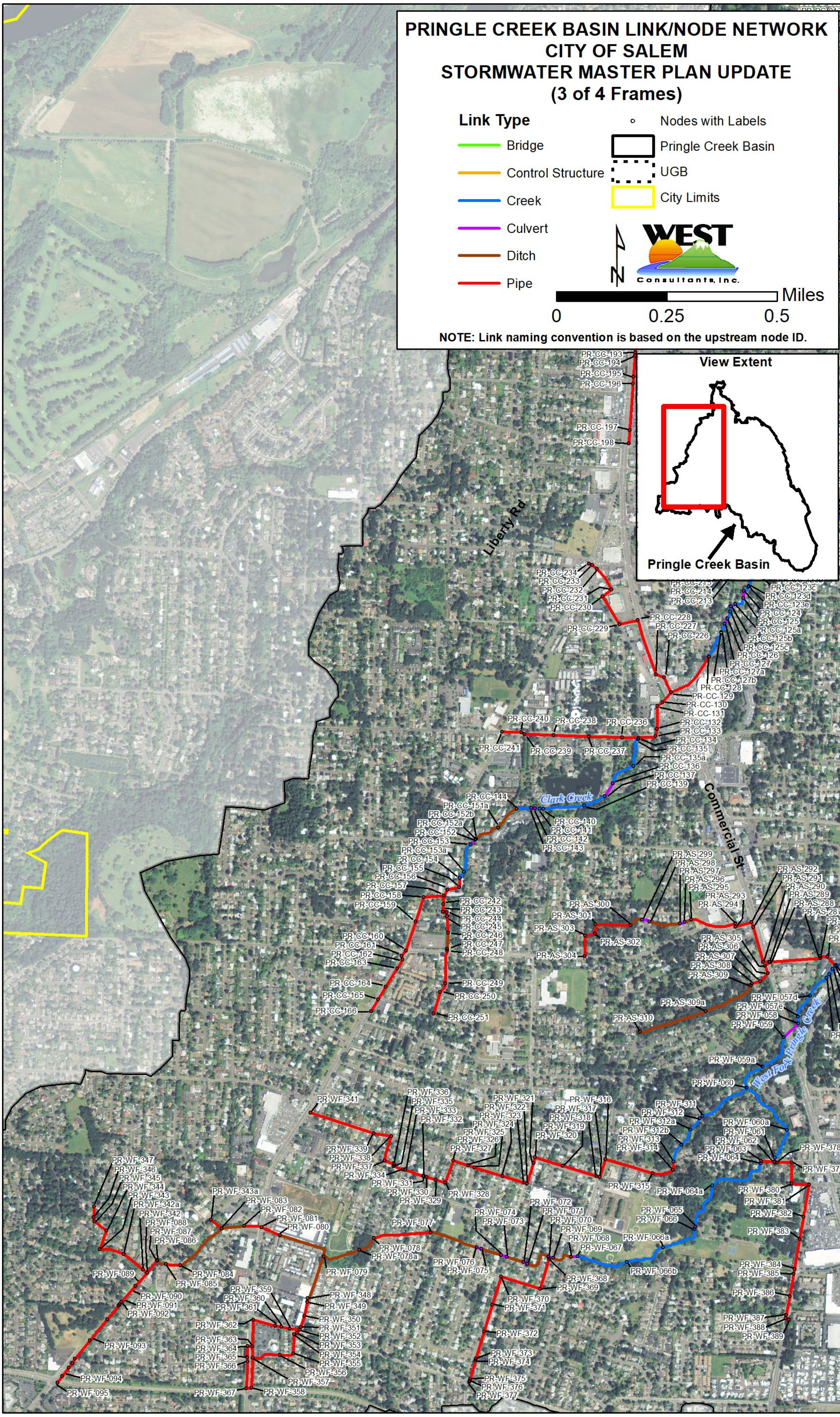

Figure 11 – Pringle Creek Basin xpstorm link and node network (3 of 4)

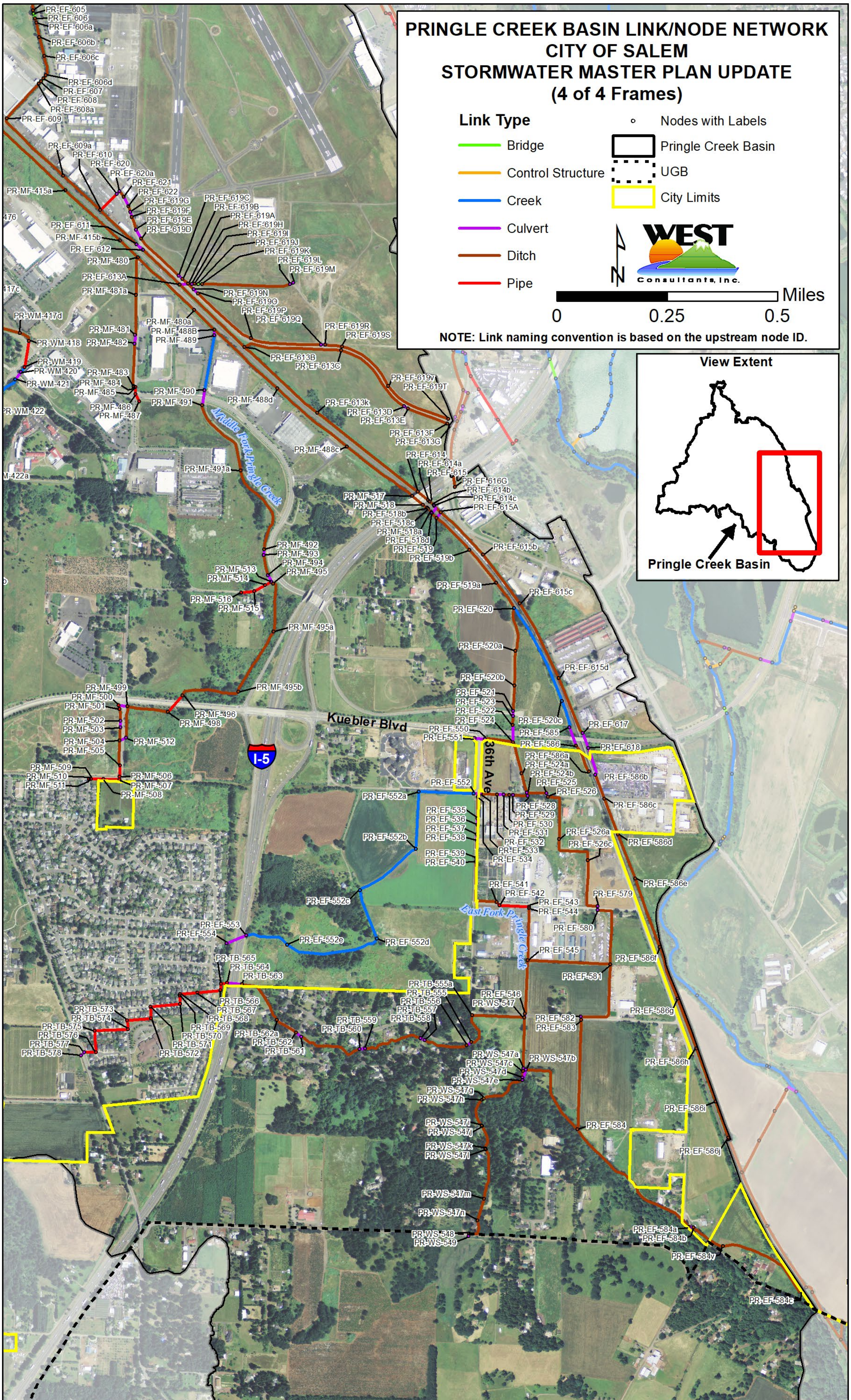

Figure 12 – Pringle Creek Basin xpstorm link and node network (4 of 4)

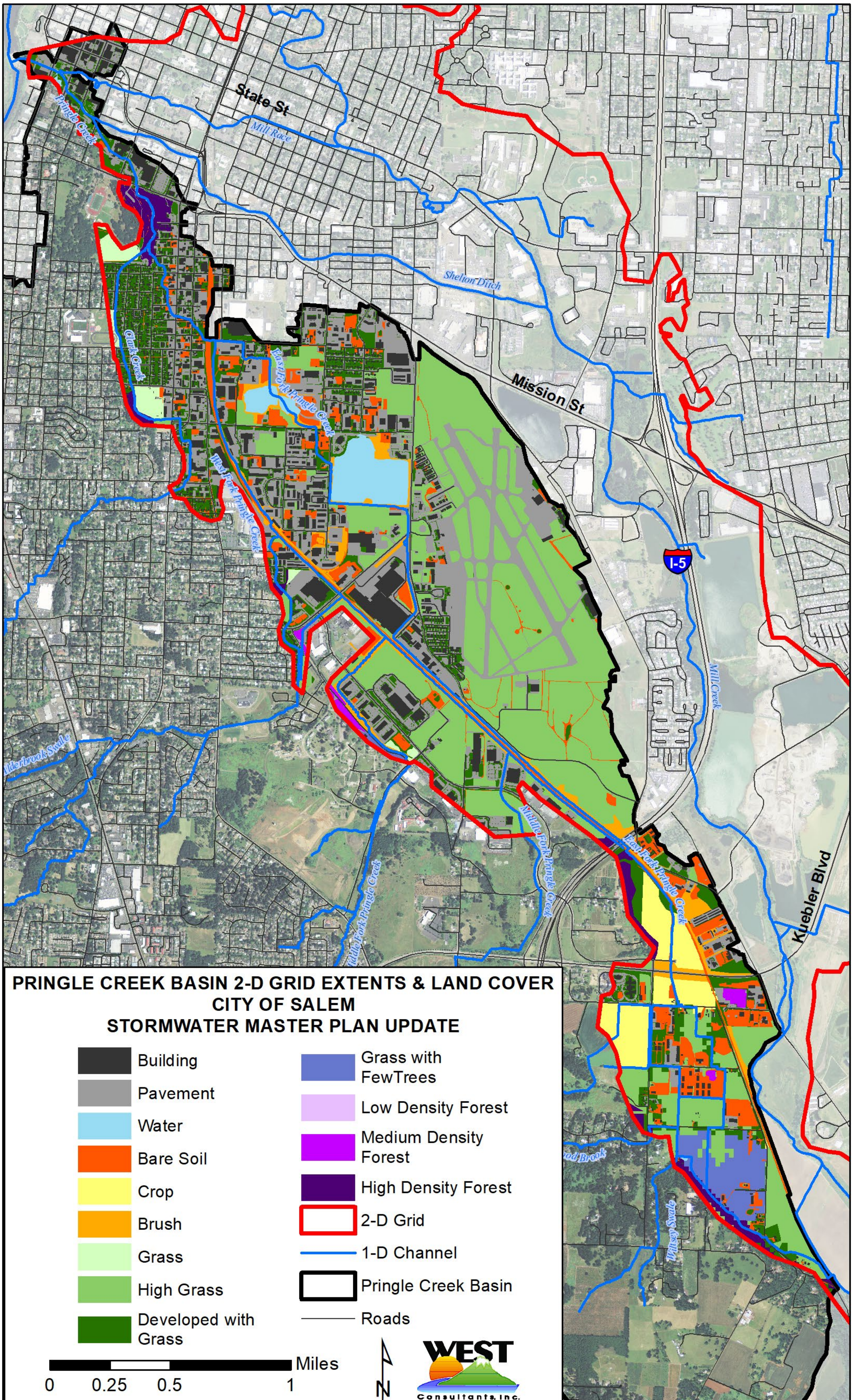

Figure 13 – Pringle Creek Basin 2-D grid extents and land cover

Outfall Conditions

Pringle Creek outfalls into the Willamette Slough, approximately one-half mile upstream of the Willamette River at Salem USGS streamflow gauge (USGS 14191000). To model calibration events, the Pringle Creek outfall used a stage time series outfall condition based on 1-hour adjusted stage data from the USGS streamflow gauge. The observed stages at the gauge were adjusted using the Willamette River's 100-year water surface profile slope from Marion County's Federal Emergency Management Agency (FEMA) Flood Insurance Studies (FIS) (FEMA, 2003). The resulting +1.28 ft stage adjustment accounts for the elevation difference between the Pringle Creek outfall and the USGS gauge location.

The outfall stage was developed using guidance from the Hydraulic Engineering Circular No. 22, 3rd Edition (HEC-22) (HEC, 2009). When a creek with a relatively small drainage area outfalls into a river with a relatively large drainage area the coincidental probability of a flood event occurring in both hydrologic systems at the same time should be considered when determining the appropriate outfall conditions. HEC-22 provides coincidental outfall recommendations based on the drainage area ratio of the main stream and the tributary.

Willamette River recurrence interval flows were developed by the US Army Corps of Engineers and published in Flood Frequency Curves for the Willamette River and its Major Tributaries Upstream of Salem, Oregon (USACE, 2014). The recurrence interval flows were converted to stages using the Willamette River at Salem USGS streamflow gauge stage-discharge rating curve. The stages were adjusted by +1.28 ft to account for the change in water surface elevation between the USGS gauge and the Pringle Creek outfall into the Willamette River. The resulting Willamette River recurrence interval outfall conditions for each Pringle Creek Basin flood event considered is summarized in **Table 3**.

Table 3 – Pringle Creek outfall conditions

Mill/Pringle Recurrence Interval (years)	Willamette River Recurrence Interval (years)	Pringle Creek outfall Water Surface Elevation (ft-NGVD29)
2	1.1	125.50
5	1.1	125.50
10	2	130.68
25	5	134.54
50	10	137.88
100	25	140.76

NOTES:

1. When developing the tributary drainage area, the Mill and Pringle Creek basins were combined since Shelton Ditch inflows into Pringle Creek shortly before Pringle Creek discharges into the Willamette River.
2. The Willamette River drainage area at the Salem USGS gauge is 7,280 square miles. The combined Mill and Pringle Creek Basin drainage area is approximately 110 square miles. The main stream to tributary ratio is 66 to 1. The 100 to 1 ratio recommendations in HEC-22 was selected to develop the outfall recurrence intervals.
3. The 2- and 5-year Mill and Pringle Creek basin recurrence interval outfall conditions were extrapolated from the HEC-22 recommendations.
4. The HEC-22 recommendations assume unregulated river systems. Although the Willamette River is heavily regulated, during the February 1996 event Mill Creek was estimated to have 90-year peak flows and the Willamette River had a 25-year peak flow. The 1996 event provides support for the use of the HEC-22 methodology for the Pringle Creek design storm outfall conditions.

Quality Assurance Review

Multiple reviews were conducted and documented as part of the Pringle Creek Basin model development. QA/QC check sheets are provided in **Appendix 13.C**. The existing conditions 100-year event model has an overall hydraulic continuity error of 0.46% and a runoff continuity of 0.000%, both of which are less than the maximum error of +/- 2% that XP Solution's documentation recommends (XP Solutions, 2014). Localized instabilities in the stage and/or flow were fixed where needed. All water was captured in the link/node network. The maximum water surface elevation that can be reached at each node without spilling or "smoke stacking" was documented in the node notes within xpstorm, as well as the "MAXWATER" field within the node's GIS attribute table. Channel cross sections were checked for vertical wall extrapolation and modified where necessary to contain all of the flow in the channel. The final cumulative 2-D Mass Error for the 100-year existing conditions model was -0.2%, which is within XP Solutions documented acceptable range of +/- 1% (XP Solutions, 2014).

Model Calibration/Verification

Historic Streamflow and Stage Records

Streamflow data are available at four permanent locations and one temporary location in the Pringle Creek Basin. Crest Stage Gauge (CSG) data, which provides the maximum water surface elevation for individual storm events, are available at three locations in the Pringle Creek Basin. **Figure 14** shows the location of the streamflow and crest stage gauges for the Pringle Creek Basin. A summary of the gauges is as follows:

The Clark Creek 1 (CLK1) streamflow gauge is located on Clark Creek upstream of its confluence with Pringle Creek in Bush's Pasture Park. The elevation of the gauge is 148.88 ft. The contributing drainage area at the gauge is 2.4 square miles and it is located entirely within the Salem city limits. The drainage basin has slopes that are moderately steep and it contains a significant amount of underground stormwater drainage system infrastructure. Stage records for the gauge were provided in 15-minutes intervals. The period of record for the gauge is from October 2006 to present. The Gilmore Field Detention Facility, located approximately 3,000 feet upstream of CLK1, attenuates the relatively flashy runoff response from the steeper portion of the upper watershed. During the model calibration process, the Gilmore Field outlet control orifice coefficient was set to best match known flooding in the local vicinity as well as observed streamflow at downstream CLK1 gauge.

The Clark Creek 12 (CLK12) streamflow gauge is located on Clark Creek just downstream of Ewald Road. The elevation of the gauge is 365.87 feet. The contributing drainage area at the gauge is 0.5 square miles and it is located entirely within the Salem city limits. The drainage basin has slopes that are moderately steep and it contains a significant amount of underground stormwater drainage system infrastructure. According to discussions with City staff, these conditions cause the stream to be flashy (quick rise and fall in flows during intense rainfall events). Stage recordings for the gage were provided in 15-minutes intervals, which may not be frequent enough to fully represent the flashiness of some high intensity short duration runoff events. The period of record for the gauge is from November 2006 to present.

The Pringle Creek 4 (PRI4) streamflow gauge is located on Pringle Creek approximately 150 ft downstream of Mission Street next to the Salem Hospital. The elevation of the gauge is 131.85 feet. The contributing drainage area at the gauge is 13.1 square miles and it is located mostly within the City of Salem UGB. The western half of the contributing drainage area is mostly developed residential with moderately steep slopes, and the eastern half is relatively flat and primarily composed of commercial and industrial land use. Stage records from the gauge were provided in 15-minutes intervals. The period of record for the gauge is from July 2012 to present. Before the spring of 2012, streamflow data was collected at the PRI3 gauge, which was located further downstream near the confluence with Shelton Ditch. During the January 2012 flood event, high backwater from Shelton Ditch resulted in an overestimate of discharge at PRI3. To limit the backwater influence on the gage from Shelton Ditch, the PRI4 streamflow gauge was installed further upstream, to replace PRI3. During the January 2012 storm event, multiple streamflow measurements were made at the PRI4 gauge site. These measurements were used to develop an approximate flow and stage hydrograph at the PRI4 site for the January 2012 storm event.

Besides the Gilmore Field regional detention facility in the Clark Creek drainage basin, no other significant detention facilities are located upstream of the PRI4 gauge. However, during significant flood events, high water can spill into Spinnaker Lake which then functions as a *de facto* detention facility. Of the calibration and verification events, only the January 2012 event was known to overtop the berm between East Fork Pringle Creek and Spinnaker Lake. Initial and peak water surface elevations for Spinnaker Lake for the January 2012 event were gathered from eye witness accounts, which were then used to calibrate the overtopping inflows into the lake. Another major consideration for the flows at PRI4 is the influence of overflows from Mill Creek into East Fork Pringle Creek during large flood events. Of the calibration and verification storm events, the overflow only occurred during the January 2012 storm event. Flood photographs were used to help calibrate the overflow at the I-5 at Turner Road overpass.

The Pringle Creek 12 (PRI12) streamflow gauge is located on East Fork Pringle Creek immediately upstream of Trelstad Avenue. The elevation of the gauge is 221.79 feet. The contributing drainage area at the gauge is 2.4 square miles and it is located mostly outside the city limits. Approximately one square mile of the contribution drainage area is located outside of the UGB. Land use upstream of the gauge is primarily agricultural with some commercial and industrial development within the city limits. Stage records for the gauge were provided in 15-minutes intervals. The period of record for the gauge is from October 2006 to present. During high flows in Mill Creek, water from Mill Creek can overflow into the Pringle Creek Basin upstream of the gauge through a 2.5-ft diameter culvert. Model results suggest that, during significant flood events, some flows spill out of the channel and bypass the PRI12 gauge, thereby reducing the accuracy of the rating curve for higher flows.

The West Fork Pringle Creek temporary streamflow gauge (WF-Temp) is located on West Fork Pringle Creek, near Salishan Street. The elevation of the gauge is 188.31 feet. The contributing drainage area at the gauge is 3.0 square miles and it is located entirely within the city limits. The drainage basin has slopes that are moderately steep and it contains a significant amount of underground stormwater drainage system infrastructure. Stage records for the gauge were provided in 15-minutes intervals. The temporary gauge was installed in 2016.

Along with streamflow and stage records, the City of Salem also provided flood photographs and a log of observed flooding that was reported during the calibration and verification events. These records are mapped in **Figure 2** for the 1996, 2012, and 2015 flood events.

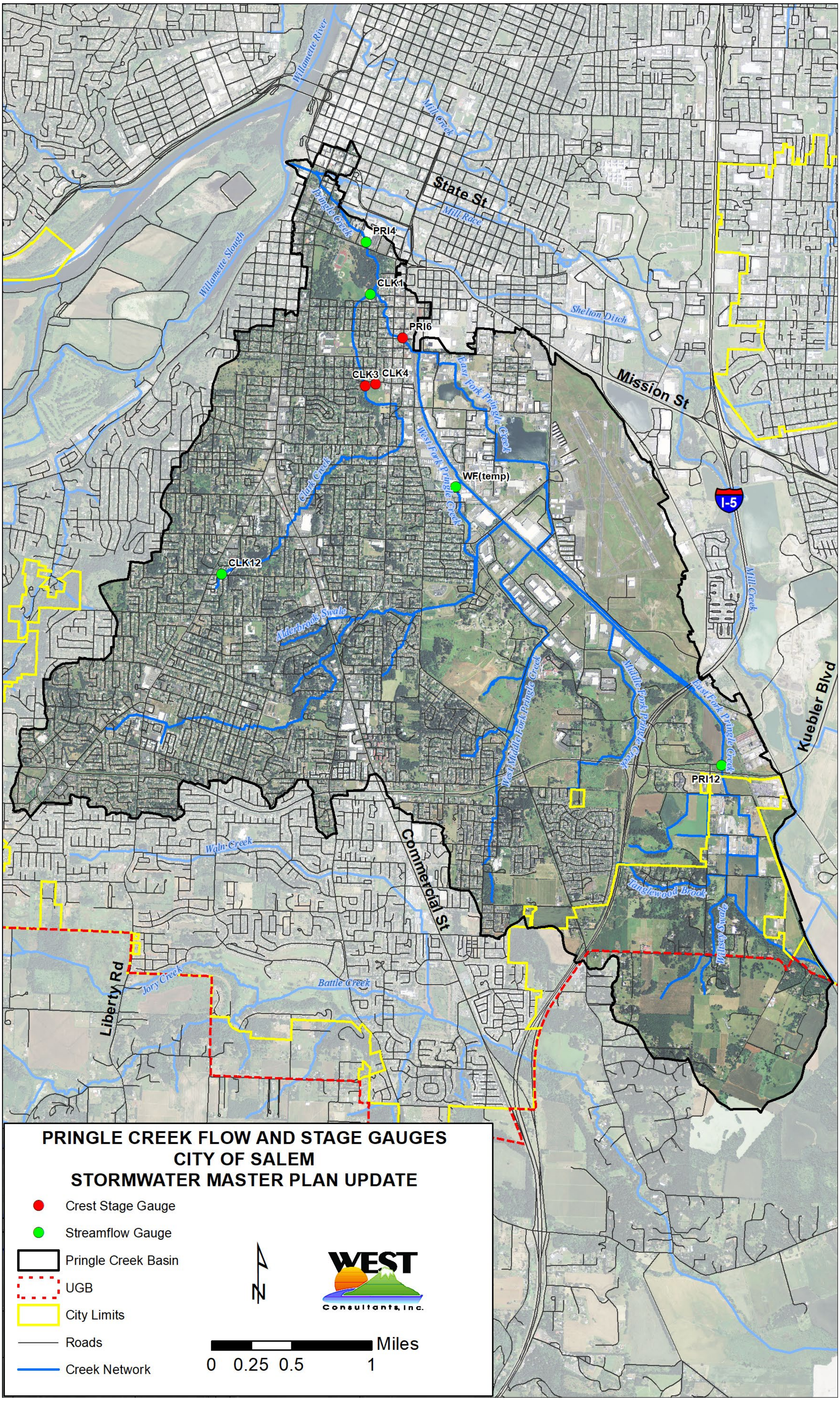

Figure 14 – Streamflow and crest stage gauge locations for Pringle Creek Basin

Storm Events

The available streamflow and precipitation data were evaluated in order to select the most appropriate storm events for calibration and verification of the xpstorm model. Because of the relatively short period of record available for the streamflow gauges, the choices for calibration and verification events were limited. The follow events were selected:

January 2012 (Calibration Event #1)

At the McNary Field NWS rainfall gauge the January 2012 storm produced 3.3 inches of rainfall during a 24-hour period, which had an approximate recurrence interval of 10-years. The same event produced 6.1 inches of rainfall during a 48-hour period, which had an approximate recurrence interval of 100-years. During a 72-hour period, 7.0 inches of rainfall was measured, which had an approximate recurrence interval of 50-years. This was the largest precipitation event in the City of Salem since 1996 and the largest precipitation event for the period of record for the Pringle Creek Basin streamflow gauges. Near the outlet of Pringle Creek Basin, the peak flow measured at the PRI4 gauge was 780 cfs, although backwater effects from high stages in Shelton Ditch may have caused inaccuracies in the streamflow measurements. Flows in Mill Creek were also high enough to spill into the Pringle Creek Basin at the I-5 at Turner Road overpass. Significant flooding was observed throughout the Pringle Creek Basin, making it ideal for model calibration. It is noted that some snow may have been present in the higher elevations of Pringle Creek Basin. The snowmelt impact was assumed to be minimal and it was not considered in the runoff model.

November 2016 (Calibration Event #2)

The November 2016 storm produced 2.5 inches of rainfall during a 24-hour period, which had an approximate recurrence interval of 5-years. Some flooding was observed along West Fork Pringle Creek north of McGilchrist Street. No floodwaters spilled into Pringle Creek Basin from Mill Creek. Near the outlet of Pringle Creek Basin, the peak flow measured at the PRI4 gauge was 459 cfs. Since this flood event is the most recent in the Pringle Creek Basin and best represents the existing development conditions within the basin, it was selected to be the secondary calibration event.

Early December 2015 (Verification Event #1)

In early December 2015, a storm event produced 2.6 inches of rainfall during a 24-hour period, which had an approximate recurrence interval of 5-years. Significant flooding was observed along West Fork Pringle Creek around McGilchrist Street and in the Pence Loop area. Additional flooding occurred along Airport Way and along Reed Road. No floodwaters spilled into the Pringle Creek Basin from Mill Creek. Near the outlet of Pringle Creek Basin, the peak flow measured at the PRI4 gauge was 509 cfs.

Mid-December 2015 (Verification Event #2)

In mid-December 2015, a storm event produced 2.6 inches of rainfall during a 24-hour period, which had an approximate recurrence interval of 5-years. Significant flooding was observed along West Fork Pringle Creek around McGilchrist Street and in the Pence Loop area. Additional flooding occurred along Airport Way and along Reed Road. No floodwaters spilled into the Pringle Creek Basin from Mill Creek. Near the outlet of Pringle Creek Basin, the peak flow measured at the PRI4 gauge was 545 cfs. This was the second largest precipitation event for the period of record for the Pringle Creek streamflow gauges.

Procedures

Initial model parameter sensitivity testing indicated that runoff volumes were most sensitive to the initial and critical infiltration rates and that the timing of the hydrograph peak was most sensitive to the subbasin width parameter. Calibration and verification of the Pringle Creek Basin xpstorm model was an iterative process. An initial calibration was performed and then tested with the verification events. Parameter adjustments were made and the model was rerun for the calibration event and then retested for the verification events. This process was repeated until the modeled results best matched the observed streamflow for the calibration and verification events.

To calibrate the storm runoff volume, the critical and initial infiltration rates were adjusted in areas that were assigned as silty-clay-loam soils. Silty-clay-loam soils are the dominate soil type in Pringle Creek Basin (NRCS, 2014). Initially, these areas were generally assigned critical infiltrations rates of 0.1 inch/hour based on their hydrologic soil classification of "C" as suggested by Musgrave (1955). However, according to Akan (1993), silty-clay-loam soils should have critical infiltration rates in the range of 0.00-0.05 inch/hour. When the critical infiltration rates within that range were used, the model's volume results more closely matched the observations.

The initial infiltration rates were reduced during calibration to represent near saturated conditions resulting in initial infiltration rates that have nearly the same value as the critical infiltration rate. This is considered appropriate since larger flood events in the region generally occur during the colder and wetter winter months when soils are likely to have little time to dry out between storm events.

The initial calibration model produced flashy hydrographs that did not mimic the shape of the hydrographs observed at the streamflow gauges. The initial calibration hydrographs had much steeper rising and falling limbs and greater peak flows which suggested that the overland flow travel time to the channel was too quick. Overland flow roughness and channel roughness adjustments had little influence on hydrograph shape. The parameter that had the greatest influence on the hydrograph shape was the subbasin width parameter, which was adjusted accordingly. This resulted in modeled and observed hydrographs that generally matched well for the calibration and verification events.

Gauge stage data, documented reports of flooding, and photos were available for the calibration of the Manning's roughness values for the various stream channels and bridges. Channel roughness values were modified accordingly to best match stage data and observed flooding. When stage data were available near hydraulic structures, entrance/exit loss coefficients, orifice coefficients, and weir coefficients were also adjusted. Observed versus modeled stage and discharge hydrograph plots for the PRI4, PRI12, CLK1, CLK12, and WF-Temp streamflow gauges are located in **Appendix 13.D**. Included on each plot is the highest flow or stage ever recorded at the involved gauge. The maximum flow and stage data are included on the plots to provide context for potential uncertainty that may be associated with values of flow or stage that are extrapolated from a limited record of observations.

Existing Conditions Results

The model parameters selected during calibration were used with the 10-, 25-, 50-, and 100-year, 48-hour design storms to develop the peak discharges and water surface elevations for the Pringle Creek Basin. **Table 13.E.1** and **Table 13.E.2** in **Appendix 13.E** shows the peak discharges for each link and the maximum water surface elevations for each node located within the UGB for the 10-, 25-, 50-, and 100-year 48-hr design storms, respectively. The 2-D model inundation extents for existing conditions within the Pringle Creek Basin area are shown in **Figure 13.E.1** to **13.E.4** in **Appendix 13.E**. **Figure 13.E.5** to **13.E.8** in **Appendix 13.E** categorize the hydraulic conditions at bridges, culverts, and manholes as below the pipe crown elevation, between pipe crown and ground/overflow elevation, or above ground/overflow elevation.

Full Build-Out Conditions

Full build-out conditions for the Pringle Creek Basin were estimated and modeled to assist in the development of the basin plan. To develop the full build-out conditions model, the percent impervious values for the existing undeveloped areas and agricultural areas within the UGB were modified according to the land use classifications provided in the July 2015 Salem Area Comprehensive Plan map. The Comprehensive Plan land use classifications were incorporated into the Pringle Creek Basin land cover classifications using the category mapping shown in **Table 4.** The percent impervious for each of the subbasins was updated to reflect the full build-out land cover classification. A comparison of the existing condition and full build-out condition percent impervious area for the primary subbasins is shown in **Table 5**.

Table 4 – Land cover classifications

Comprehensive Plan Classification	SWMP Model Land Cover
Commercial Business District	Developed, Commercial
Commercial	Developed, Commercial
Community Service	Developed, Medium Intensity
Community Service Cemetery	Developed, Open Space
Community Service Education	Developed, Medium Intensity
Community Service Government	Developed, Medium Intensity
Community Service Hospital	Developed, Medium Intensity
Community Service Sewage	Developed, Medium Intensity
Developed, Medium Intensity	Developed, Medium Intensity
Employment Center	Developed, Medium Intensity
Farm Resource Management	Cultivated Crops
Industrial Commercial	Developed, Industrial
Industrial Commercial	Developed, Industrial
Developed, Medium High Intensity	Developed, Medium High Intensity
Mixed Use	Developed, Commercial
Developed, Open Space	Developed, Open Space
River Oriented Mixed Use	Developed, Commercial
Single Family Residential	Developed, Medium Intensity

Table 5 – Existing and full build-out percent impervious area

Primary Subbasin Name	Existing % Impervious	Full Build-Out % Impervious
Clark Creek	25	25
East Fork Pringle Creek	19	28
Middle Fork Pringle Creek	10	27
Pringle Creek	32	32
West Fork Pringle Creek	24	27
West Middle Fork Pringle Creek	15	35

Because requirements for detention and the implementation of green infrastructure will be specific to each future development and because the full-build out modeling is for planning purposes, it was assumed that the percentage of connected impervious surface for each land cover type would be similar to current conditions.

Full build-out peak discharges for each link and maximum water surface elevations for each node located within the UGB for the 10-, 25-, 50-, and 100-year 48-hr design storms are provided in **Table 13.E.1** and **Table 13.E.2** in **Appendix 13.E**, respectively. The 2-D model inundation extents for full build-out conditions in the Pringle Creek Basin are shown in **Figure 13.E.9** to **5.E.12** in **Appendix 13.E**. **Figure 13.E.13** to **13.E.16** in **Appendix**

13.E categorize the full build-out hydraulic conditions at bridges, culverts, and manholes as below the pipe crown elevation, between the pipe crown and the ground/overflow elevation, or above the ground/overflow elevation.

In general, under full build-out conditions the 100-yr, 48-hr design storm peak discharge for Pringle Creek is expected to increase by 68 cfs or approximately 7% at the PRI4 streamflow gauge located downstream of Mission Street. At Kuebler Boulevard upstream of PRI12, the 100-yr, 48-hr design storm peak discharge for East Fork Pringle Creek is expected to increase by 44 cfs or approximately 18%. The West Fork Pringle Creek drainage basin is already mostly developed. As a result, the 100-yr, 48-hr design storm peak discharge is expected to increase by about 9 cfs or approximately 3% at Pringle Road. At Old Strong Road, the West Middle Fork Pringle Creek 100-yr, 48-hr design storm peak discharge is expected to increase by about 20 cfs or approximately 16%. Given the significant amount of undeveloped land remaining within the East Fork, Middle Fork, and West Middle Fork portions of the Pringle Creek basin, full build-out of the basin would be expected to significantly increase peak flows, volumes, and flooding extents and adequate flow controls are not provided. Limiting the amount of impervious surface and implementing green infrastructure should help offset the expected increases.

ALTERNATIVES ANALYSIS

To develop the list of recommended stormwater capital improvement projects (CIPs) for the Pringle Creek Basin Plan, an extensive alternatives analysis was performed using the calibrated xpstorm model. The calibrated existing conditions model results were reviewed and compared with documented flooding observations to develop an initial list of possible operation and maintenance (O&M) and CIP alternatives for Pringle Creek Basin. A description of each initial alternative and associated model results is provided in **Appendix 13.F**. Projects evaluated in the alternatives analysis were stormwater pipe replacements, culvert and bridge replacements, control structure modifications, channel vegetation maintenance and debris removal, detention facilities, flow diversions, floodplain grading, and channel improvements.

After evaluating the initial list of potential Pringle Creek Basin alternatives and eliminating projects that did not significantly decrease flood risk in the stormwater model, additional discussions were held between WEST and City staff to further refine the alternatives list. Input from City staff helped eliminates projects that were not feasible due to high costs, land ownership, environmental concerns, or planning conflicts.

To mitigate increases in flood risk for areas downstream of certain proposed projects, various combinations of alternatives were evaluated. The selected combinations of conveyance improvements and flood storage alternatives were chosen based on their ability to both lower peak flood elevations in problematic areas and reduce the potential for downstream stage and flow increases. The implementation of the projects should be ordered from downstream to upstream so that potential adverse downstream effects of upstream projects are mitigated by the implementation process.

The recommended combination of CIPs and O&M projects for the Pringle Creek basin include raising a portion of Airway Drive, replacement of a railroad culvert, and adding a flood storage area along Airway Drive (PC-01a); vegetation management along Pringle

Creek and its tributaries (PC-01b); replacing the railroad and McGilchrist Street culverts on West Fork Pringle Creek (PC-01c); adding a levee along West Fork Pringle Creek near Pence Loop (PC-01d); and replacing three culverts at various Ratcliff Drive crossings of Clark Creek (PC-01e). The specific locations and extents of these projects are shown in **Figure 15**. It should be noted that the Mill Creek Basin Plan (**Section 11**) includes several proposed CIPs that would further reduce the flood risk in a portion of Pringle Creek Basin by reducing overflows from Mill Creek into Pringle Creek.

The 2-D model output inundation maps that represent the results of implementing all of the recommended CIPs and O&M projects for existing conditions 10-, 25-, 50-, and 100-year, 48-hr design storms are shown in **Figures 13.G.1** to **13.G.4** in **Appendix 13.G**. Inundation maps for full build-out conditions 10-, 25-, 50-, and 100-year, 48-hr design storms are shown in **Figures 13.G.5** to **13.G.8** in **Appendix 13.G.**

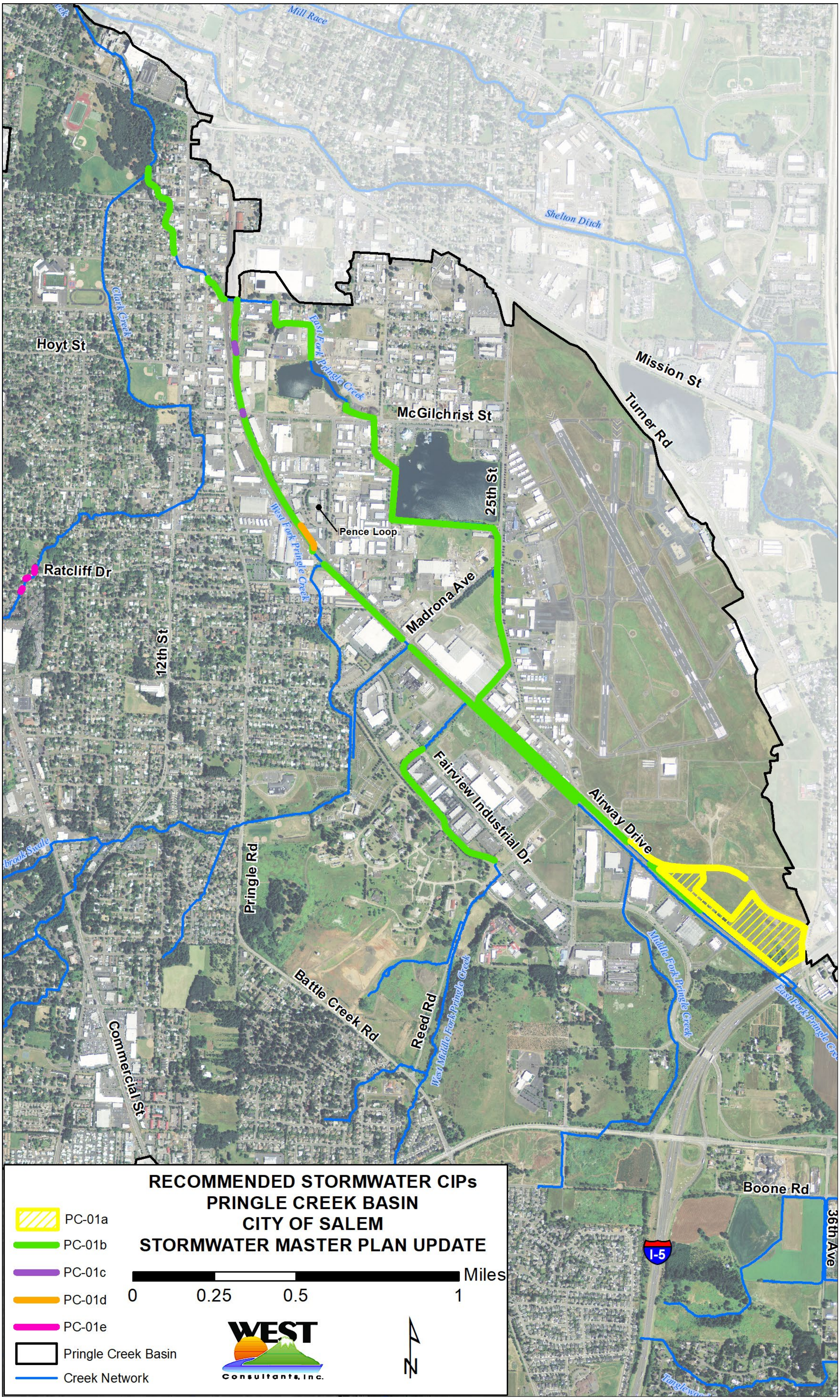

Figure 15 – Projects

RECOMMENDED STORMWATER CAPITAL IMPROVEMENT PROJECTS

The recommended stormwater capital improvement projects were divided into two categories, short- and long-term. Short-term project are recommended for implementation within the next 10 years. Long-term projects are recommended to be implemented after 10+ years. All cost estimates are in 2018 Dollars.

Short-Term CIPs

The following are the recommended list of short-term (< 5 years) stormwater CIPs in recommended order of implementation. Detailed cost estimates are provided in **Appendix 13.H**.

Project No. PC-01B - Vegetation Management along Pringle Creek and tributaries

Description: Remove invasive plant species and trim woody vegetation to acceptable limits along the following reaches in the Pringle Creek drainage network:

- 2,800 feet along Pringle Creek from the Clark Creek confluence to the West Fork Pringle Creek confluence
- 15,600 feet along East Fork Pringle Creek between West Fork Pringle Creek confluence and I-5. Note that vegetation management along East Fork Pringle Creek upstream of the railroad access culvert on Airway Drive should only occur after the railroad access culvert has been replaced (see Project no. PC-01A).
- 6,500 feet along West Fork Pringle Creek between East Fork Pringle Creek confluence and Madrona Avenue
- 2,700 feet along West Middle Fork Pringle Creek between Fairview Industrial Drive and Reed Road.

Note that this project will require the acquisition of an approximate 60 ft-wide stormwater maintenance easement along each of the creeks.

Results: The vegetation management decreases flood risk along Pringle Creek at 13th Street, East Fork Pringle Creek near Pence Loop, and along West Fork Pringle Creek in the airport and north of McGilchrist Road. The construction of the berm along West Fork Pringle Creek (Project No. PC-01D) and the West Fork Pringle Creek culvert replacements (Project No. PC-01C) help mitigate the additional flood risk near McGilchrist Road caused by the vegetation management.

Implementation (Administration, Survey, Design, Permitting):	$11,810
Total Construction:	$59,050
Implementation and Construction Total:	**$70,860**
Design Contingency (40%):	$28,344
Rounded Project Total:	**$100,000**
Easement Acquisition[1]:	$15,200,000
Grand Total:	**$15,300,000**

Annual Maintenance Cost:	**$33,333**

[1.] From City of Salem

Project No. PC-01D - Add Levee Along West Fork Pringle Creek Downstream of Railroad Crossing

Description: Construct a 650-ft long berm that averages 1.5-ft tall to elevation 193 ft on the east bank of West Fork Pringle Creek, downstream of the railroad crossing. This project will require the acquisition of a 30-ft wide stormwater maintenance easement along the east bank of West Fork Pringle Creek.

Results: The model output indicates a significant flood risk reduction in the Pence Loop area, east of West Fork Pringle Creek. Adding the levee causes more flow to remain in the channel which, in turn, increases downstream flood risk along West Fork Pringle Creek in the vicinity of McGilchrist Street. Project No. PC-01C helps offset the flood risk increase.

Implementation (Administration, Survey, Design, Permitting):	$9,547
Total Construction:	$31,822
Implementation and Construction Total:	**$41,369**
Design Contingency (40%):	$16,547
Rounded Project Total:	**$58,000**
Easement Acquisition[1]:	$180,000
Grand Total:	**$238,000**
Annual Maintenance Cost:	**$414**

[1.] From City of Salem

Intermediate-Term CIPs

The following are the recommended list of intermediate-term (5-10 years) stormwater CIPs in recommended order of implementation. Detailed cost estimates are provided in **Appendix 13.H**.

Project No. PC-01A - Raise a Portion of Airway Drive, Upsize Railroad Access Culvert on East Fork Pringle Creek, Add Flood Storage Area Next to Waste Treatment Facility

Description: Includes the creation of a 26-acre floodplain storage area between Airway Drive and East Fork Pringle Creek surrounding the City's Waste Treatment Facility. Construct a 1,200-ft long berm to elevation 215.5 ft between the creek and the storage area. Raise 1,400-ft of Airway Drive to elevation 212.5 ft to prevent water in the storage area from spilling northward into the airport. Replace East Fork

Pringle Creek culvert at railroad access along Airway Drive with a 10-ft wide by 6-ft tall by 90-ft long reinforced concrete box culvert.

Results: Model output indicates that the flood risk along Airway Drive, within the airport, and in the developed area north of McGilchrist Street will be significantly reduced. The raising of Airway Drive and the replacement of the railroad access culvert allows more flood waters to stay within East Fork Pringle Creek. This reduces the risk of flood waters routing through the airport to developed areas west of 25th Street and north of McGilchrist Street.

Implementation (Administration, Survey, Design, Permitting):	$765,405
Total Construction:	$3,754,968
Implementation and Construction Total:	**$5,102,703**
Design Contingency (40%):	$2,347,243
Rounded Project Total:	**$8,216,000**
Easement Acquisition[1]:	$332,000
Grand Total:	**$1,153,000**
Annual Maintenance Cost:	**$51,027**

1. From City of Salem

Project No. PC-01C - Replace Railroad and McGilchrist Culverts on West Fork Pringle Creek

Description: Includes the replacement of an existing railroad culvert in West Fork Pringle Creek with a 150-ft long 22-ft span x 10-ft rise concrete box culvert embedded 3-ft. The alternative also includes the replacement of the existing McGilchrist culvert over West Fork Pringle Creek with a 100-ft long 22-ft span x 10-ft rise concrete box culvert embedded 3-ft. This project should be completed before the implementation of upstream Project No. PC-01D.

Results: Model output indicates that the culvert replacements reduce flood risk along West Fork Pringle Creek both upstream and downstream of McGilchrist Street and partially offset the minor flood risk increase due to levee construction (Project No. PC-01D).

Implementation (Administration, Survey, Design, Permitting):	$384,995
Total Construction:	$1,283,318
Implementation and Construction Total:	**$1,283,318**
Design Contingency (40%):	$667,325
Rounded Project Grand Total:	**$2,336,000**
Annual Maintenance Cost:	**$12,833**

Long-Term CIPs

The following are the recommended list of long-term (> 10 years) stormwater CIPs in recommended order of implementation. Detailed cost estimates are provided in **Appendix 13.H**.

Project No. PC-01E - Replace Clark Creek culverts at three locations on Ratcliff Dr

Description: Replace Clark Creek culverts at three locations on Ratcliff Drive with 60-ft long 6-ft span x 6-ft rise concrete box culverts embedded 2-ft.

Results: Model output indicates that the roadways would no longer have a significant risk of overtopping up to the 100-year event.

Implementation (Administration, Survey, Design, Permitting):	$183,125
Total Construction:	$610,416
Implementation and Construction Total:	**$793,541**
Design Contingency (40%):	$317,416
Rounded Project Grand Total:	**$1,111,000**
Annual Maintenance Cost:	**$6,104**

REFERENCES

Akan, A. 0. (1993). *Urban Storm water Hydrology: A Guide to Engineering Calculations*. Technomic Publishing Co., Inc., Lancaster, PA.

City of Salem (2014). *Administrative Rules Chapter 109 Division 004 Stormwater System,* City of Salem Department of Public Works, January 2014.

City of Salem (2015). *Salem Comprehensive Plan Map,* City of Salem Planning Division, January November 2015.

Engineers Australia. (2012). *Australian Rainfall and Runoff Project 15: Two Dimensional Modelling in Urban and Rural Floodplains, Stage 1&2 Report.* November 2012.

FEMA (2003). *Marion Country, Oregon Flood Insurance Study 41047CV001*, Federal Emergency Management Agency, January 2003.

HEC (2009). *Hydraulic Engineering Circular No. 22 (HEC-22), Third Edition*, Federal Highway Administration, September 2009.

Huber, W. C. and R. E. Dickinson. (1988). *Storm Water Management Model User's Manual Version 4*. U.S. Environmental Protection Agency. August 1988.

Kidd, C. H. R. (1978). *Rainfall-runoff processes over urban surfaces.* Proc., Int. Workshop Institute of Hydrology, Wallingford, U.K.

Montgomery Watson (2000). Drainage System Improvement Plan (A Technical Supplement to the Stormwater Master Plan). City of Salem, Oregon. February 2000.

Musgrave, G.W. (1955). *How much of the rain enters the soil?* In Water: U.S. Department of Agriculture. Washington, DC. pp. 151–159

Multi-Resolution Land Characteristics (MRLC) Consortium (2011). *National Land Cover Database (NLCD).* Available online at http://mrlc.gov/. Accessed October 2014.

Natural Resources Conservation Service (NRCS) (2014). *Web Soil Survey (SSURGO).* Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed October 2014.

Watershed Concepts (2009). *Lidar Remote Sensing Data Collection, Department of Geology and Mineral Industries, Willamette Valley Phase 1*. July, 2009.

Sutherland, Roger. (2000). *Methods for Estimating the Effective Impervious Area of Urban Watersheds*. The Practice of Watershed Protection (Edited by T. R. Schueler and H. K. Holland). Center for Watershed Protection, Ellicott City, MD: 193-195.

U.S. Army Corps of Engineers (USACE) (2014). *Flood Frequency Curves for the Willamette River and its Major Tributaries Upstream of Salem, Oregon*. Portland District. July, 2014.

XP Solutions (2014). *Reviewing XP Models* [Webinar]. March 19, 2014. Retrieved from http://xpsolutions.com/Resources/XP-Live-Webinars/reviewing-xp-models/

XP Solutions (2014). *XP-2D Reference Manual for Integrated 1D/2D Modeling.*