Clackamas Water Environment Services (WES) Storm System Master Plan (SSMP) 2022 Appendices

Otak

Appendix A

Technical Memorandum:
Preliminary Soil Infiltration Characterization -
Clackamas County WES Storm System Master Plan

Water Solutions, Inc.

TECHNICAL MEMORANDUM

Preliminary Soil Infiltration Characterization – Clackamas County WES Storm System Master Plan

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1 Introduction

This technical memorandum provides a summary of a preliminary soil infiltration characterization that was performed to support development of the Clackamas Water Environment Services (WES) Storm System Master Plan. The study centers on two service areas, referenced as Service Area 2 and Service Area 3 by the county (Figure 1). Service Area 2 is located in northwest Clackamas County, roughly centered in Happy Valley, and is subdivided into nine subareas (Figure 2). The Clackamas WES Service Area 2 includes additional subareas (e.g., Hoodland and Boring), but they are not shown or included in this analysis because monthly stormwater management fees are not billed in those subareas. Service Area 3 is located south of Lake Oswego, roughly centered on the Interstate 205 Tualatin River crossing (Figure 3).

This memo first describes the geologic setting of the study areas, which informs the feasibility of stormwater infiltration. Next, using readily-available soil, geologic, and topographic data, surface infiltration potential was evaluated and qualitatively ranked for the entirety of both service areas (no field investigations were conducted for this work). Lastly, deep infiltration potential (i.e., infiltration below low-permeability, surficial silts) was evaluated for Service Area 2, based on water well driller logs and United States Geological Survey (USGS) depth-to-groundwater data. The conclusions and recommendations of this preliminary study are intended to provide guidance for planning-level evaluations for potential stormwater infiltration facilities within the study area.

2 Geologic Setting

2.1 Service Area 2

The Service Area 2 study area is located in a relatively-complex geologic setting along the southern boundary of a regional structural feature known as the Portland Basin (Figure 4). The basin floor consists of multiple basalt flows that constitute the Columbia River Basalt Group (CRBG). Within Service Area 2, the top of the CRBG basalt is quite deep, ranging from approximately 500–600 feet (ft) deep in the southeast part of the area, to perhaps 1200 ft deep in the northwest part of Service Area 2 (USGS, 1993).The following sections discuss the geologic units that have filled the basin over time (Section 2.1.1) and the depth to bedrock (Boring Lava, lithified Troutdale Formation, and CRBG) in Service Area 2 (Section 2.3).

2.1.1 Basin-Fill Sediments

Alluvial sediments, including the regionally extensive Troutdale Formation, have filled the subsiding Portland basin. Sediments in the Portland Basin are grouped into geologic units (i.e., sediments with similar characteristics), which are listed below from youngest to oldest:

Alluvial deposits: consist of unconsolidated Quaternary period stream deposits of sand, gravel, and silt that are largely confined to channels and floodplains of local streams, rivers, and valley bottoms.

Catastrophic Flood Deposits: consist of sediments deposited by catastrophic floods during the Pleistocene age. Locally, the catastrophic flood deposits consist of fine-grained material (predominantly silt-sized) deposited over large areas, with localized occurrences of coarser material ranging up to boulder size (channel deposits). In the study area, the fine-grained deposits are the uppermost sedimentary layer for most of the area.

Boring Lava: consists of relatively-young basalt and basaltic andesite that erupted from several small volcanic eruptive centers (vents) in the greater Portland area. The Boring Lava flows intruded existing sediments within the Basin, and together with associated resistant outcrops of sedimentary rocks, form the characteristic uplands within and near the study area.

Troutdale Formation sediments: a thick sequence of sedimentary deposits that have filled the Portland Basin. Deposition of the upper Troutdale Formation was marked by faulting and localized volcanic activity that occurred either contemporaneously with, or after, sediment deposition. Consequently, there are areas where the Boring Lava has intruded through sediments of the Troutdale Formation and interfingers with the Troutdale Formation. These areas are most notably in the characteristic upland areas, but also in areas not marked by such obvious topographic features.

Columbia River Basalt Group (CRBG): Laterally extensive stacked flood basalt flows of Miocene age. Flows originated in eastern Oregon and Washington, and flowed through the Columbia River trans-arc lowland to inundate the Portland, Tualatin, and northern Willamette Basins. The CRBG constitute the floor of the Portland Basin, estimated to range from approximately 500 to 1200 ft deep within the study area.

Topographic relief across the study area is on the order of approximately 1000 ft, with most of the area characterized as generally hilly. Flatter, lower-lying terrain is present in the westernmost subareas (the eastern part of Kellogg Creek, Three Creeks, and NCRA), with smaller flat or gently sloping areas also present in the south along the Clackamas River, and in some portions of the PVNC subarea. However, most of the study area is generally hilly, with prominent features such as Mount Scott, Mount Talbert and other unnamed upland areas formed by intrusion of the Boring Lava, and further enhanced by tectonic uplift.

2.2 Service Area 3

The Service Area 3 study area is located in a relatively-complex geologic setting along the southeast boundary of a regional structural feature known as the Tualatin Basin (Figure 5). Along its western side the basin floor is comprised of the Siletz Terrane, an oceanic seamount chain accreted onto North America roughly 50 million years ago (Ma), and exposed within the Oregon Coast Range. To the east, basement consists of Eocene Basalt of Waverly Heights, an accreted ocean island which may be related to the Siletz Terrane (McPhee et al., 2014). The eastern edge of the basin is bounded by faulted and uplifted Miocene age Columbia River Basalt and Basalt of Waverly Heights. The following sections discuss the geologic units that have filled the basin over time (Section 2.1.1) and the depth to bedrock (CRBG and lithified fluvial deposits) in the study area (Section 2.3).

2.2.1 Basin-Fill Sediments

Alluvial sediments, including fluvial deposits from the Tualatin and Willamette Rivers, have filled the Tualatin Basin during subsidence, forming a sedimentary package greater than 6500 feet thick at the basin's depocenter. Sediments in the Tualatin Basin are grouped into geologic units (i.e., sediments with similar characteristics), which are listed below from youngest to oldest:

Alluvial deposits: consist of unconsolidated Quaternary period landslide and stream deposits. Stream deposits consist of sand, gravel, and silt that are largely confined to channels and floodplains of local streams, rivers, and valley bottoms. Landslide deposits are found on steep slopes throughout West Linn and Pete's Mountain uplands.

Catastrophic Flood Deposits: consist of sediments deposited by catastrophic floods during the Pleistocene age. Locally, the catastrophic flood deposits consist of fine-grained material (predominantly silt-sized) deposited over large areas, with localized occurrences of coarser material ranging up to boulder size (channel deposits). Within Service Area 3 these fine-grained deposits are the uppermost sedimentary layer for most of the area.

Boring Lava: consists of relatively-young basalt and basaltic andesite that erupted from several small volcanic eruptive centers (vents) in the greater Portland area. The Boring Lava flows intruded existing sediments within the Portland and Tualatin basins. Boring Lava can be found along the east edge of the Tualatin Basin, and has been mapped just north of Service Area 3 at Cooks Butte.

Hillsboro Formation sediments: consists of fluvial sandstone, siltstone, and mudstone which unconformably overlie the CRBG. These sediments originated in creeks and streams draining the Coast Range, and were deposited under relatively low energy conditions.

Troutdale Formation sediments: a thick sequence of sedimentary deposits that have filled the Portland and Tualatin Basins. Deposition of the upper Troutdale Formation was marked by faulting and localized volcanic activity that occurred either contemporaneously with, or after, sediment deposition. Consequently, there are areas where the Boring Lava has intruded through sediments of the Troutdale Formation and interfingers with the Troutdale Formation. These areas are most notably in the characteristic upland areas, but also in areas not marked by such obvious topographic features.

Columbia River Basalt Group (CRBG): Laterally-extensive stacked flood basalt flows of Miocene age. Flows originated in eastern Oregon and Washington, and flowed through the Columbia River trans-arc lowland to inundate the Portland, Tualatin, and northern Willamette Basins. Uplifted CRBG cover much of the study area.

Marine Sediments: include mudstones, siltstone, and minor sandstones of the Scappoose and Yamhill Formations. These marine sediments underlie and interfinger with the base of the CRBG.

Basement Volcanics: comprised of Eocene accreted basaltic terranes, including the Siletz Terrane and Basalt of Waverly Heights, these volcanics form the base of the Tualatin basin.

Topographic relief across the study area is on the order of approximately 700 ft, with most of the area characterized as hilly. Flatter, lower-lying terrain is present in the northwest and central portions of the study area, mostly near the Tualatin River and west of Oswego Lake. Upland areas consist of areas of uplifted Columbia River Basalt, such as Pete's Mountain and nearby Cook's Butte.

2.3 Depth to Top of Bedrock

Bedrock in the Service Area 2 study area consists of the Boring Lava, lithified or semi-lithified portions of the Troutdale Formation sedimentary deposits (typically low-permeability siltstones, sandstones, or shales), and the CRBG basalts that form the floor of the Portland Basin.

Bedrock in the Service Area 3 study area consists of the lithified or semi-lithified portions of fluvial sedimentary deposits (typically low-permeability siltstones, sandstones, or clays), and the uplifted and exposed CRBG. Each of these basement rock types typically possess very low vertical permeability relative to the unconsolidated sediments in the area, and thus their presence at or near ground surface would limit infiltration potential. Thus, for this assessment of shallow infiltration potential, shallow bedrock occurrences were considered as an impermeable layer to infiltration.

Figures 6 and 7 show estimated depth to bedrock throughout Service Areas 2 and 3, respectively. Depth to bedrock figures were developed using information provided on select Water Supply Well Reports (well logs) obtained from the Oregon Water Resources Department (OWRD). The well logs were georeferenced, with preference given to logs with latitude and longitude coordinates, followed by those with street addresses, and lastly to logs that reported location to only the township/range/section level. From the varied descriptive information provided on the well logs, the top of bedrock was noted as the shallowest reported occurrence of "rock," "basalt," "siltstone," "shale," "claystone," etc. Well logs with insufficient or ambiguous geologic descriptions, or with inaccurate or unreliable location information, were not included for this assessment.

OWRD well logs that were used to develop Figures 6 and 7 are summarized in Table 1. For relevance to stormwater infiltration and storage capacity, and for visual clarity, the top of bedrock contouring depicted in the figures was limited to a maximum >100-ft depth contour interval (i.e., all well logs for which the depth to top of bedrock exceeded 100 ft were grouped into the ">100 ft" category, also listed as "Mapped Depth to Bedrock" in Table 1).

Because of the prevalence of Boring Lava intrusive emplacements east of Interstate 205 and north of Highway 212, it should be noted that there is likely a high degree of variability for the depth to bedrock estimates shown in Figure 6 and Table 1 for Service Area 2. Locations of some major Boring Lava intrusions are obviously evident by their subaerial expression as isolated uplands or hills. However, the *subsurface* distribution of the Boring Lava in the study area is not fully known, and is likely highly variable. For example, some well logs do show the presence of Boring Lava (often noted as "basalt" or just "black or gray rock"), whereas other nearby logs do not. Furthermore, in some areas, the Boring Lava is present as small-scale lateral intrusions into the existing sedimentary deposits, as evidenced by some well logs showing thick accumulations of sediments both above and below basalt.

There is likely a high degree of variability for the depth to bedrock estimates for Service Area 3 as well. The CRBG in the area are heavily faulted, and many of the lithified basin fill sediments are buried under more recent alluvium, making their subsurface distribution difficult to interpret.

3 Surface Soil Infiltration Capacity

This section discusses GSI's evaluation of surface soil infiltration capacity in Service Area 2 and Service Area 3, based on the following criteria:

- Depth to a restrictive layer
- Depth to groundwater (high water table)
- Saturated soil hydraulic conductivity
- Ground slope

Note that because bedrock is more than 15 ft deep in almost all of Service Area 2 (see Figure 6), the depth to bedrock was not used to evaluate surface soil infiltration capacity, i.e., it was not a determining factor. However, it was a factor in Service Area 3, where bedrock outcrops at the surface or is shallower than 15 ft in much of the study area (see Figure 7).

3.1 Methods

Surface soil infiltration characteristics were assessed for both service areas using available data from the National Resource Conservation Service's (NRCS) online Soil Survey Geographic Database (SSURGO) (NRCS, 2019). NRCS soil surveys provide estimates of several soil properties from depths of zero to 200 centimeters (cm) (or zero to 6.5 ft). Use and evaluation of the NRCS soil property data is adequate for planning-level infiltration estimates.

Figures 8 and 9 depict the study areas subdivided by shallow soil types and corresponding NRCS map symbols. The NRCS map symbols are correlated to respective descriptions provided in Table 2. Table 2 lists key physical parameters established by the NRCS, such as saturated hydraulic conductivity, that are generally representative for each respective soil type.

3.1.1 Soil Infiltration Criteria

It is understood that Clackamas WES does not have specific criteria for evaluating stormwater infiltration facilities (L. Gilliam/Otak, personal communication, September 19, 2019). Therefore, the following criteria provided in the City of Portland's *Stormwater Management Manual* (City of Portland, 2016) were used to develop soil infiltration rankings for this study:

- Saturated soil hydraulic conductivity of 2 inches per hour (in/hr) for all infiltration facilities
- Minimum setback of 100 ft for facilities with *ground slopes* exceeding 10 percent

In addition to saturated hydraulic conductivity and ground slope, GSI considered *depth to restrictive layers* and *depth to groundwater* as reported in the NRCS database, because these factors may also reduce soil infiltration potential.

3.1.2 Soil Infiltration Rankings

Using the criteria discussed above, soil infiltration potential rankings of "good," "moderate," and "poor" were established for the study areas. The rankings were established as follows:

- <u>Infiltration potential is POOR if the *depth to restrictive layer* or *shallow water table* is less than 200 cm below ground surface (bgs)</u>
    - Used as the initial screen to establish a "poor" infiltration potential ranking.
    - "Restrictive layer" refers to an altered subsurface soil layer that restricts water flow and root penetration, e.g., fragipan, duripan, hardpan.
    - "Water table" is considered a saturated zone lasting one month or longer.
    - Both criteria calculated as an average of the ranges provided in the NRCS data.
    - Estimated depths to a restrictive layer across the study areas are shown on Figures 10 and 11, and depths to shallow water table from the NRCS on Figures 12 and 13.
- <u>If *depth to restrictive layer* and *shallow water table* are greater than 200 cm bgs, infiltration potential is based on *saturated soil hydraulic conductivity* (K_{sat}) and *ground slope*</u>
    - Saturated soil hydraulic conductivity
        - Primary factor for characterizing infiltration potential.
        - Where depth to restrictive layer is >200 cm bgs, K_{sat} was calculated as the weighted average of ranges provided by NRCS.
        - Where depth to restrictive layer is <200 cm bgs, K_{sat} was calculated as the average greater than the depth range that includes the restrictive layer.
        - Estimated K_{sat} ranges for the study areas are shown on Figures 14 and 15.
        - Relative infiltration potential rankings were assigned as follows:
            - K_{sat} > 2 in/hr: GOOD
            - 0.5 in/hr < K_{sat} < 2 in/hr: MODERATE
            - K_{sat} < 0.5 in/hr: POOR
    - Ground slope
        - In areas where ground slope is greater than 10 percent, the infiltration ranking was reduced one full step (e.g., from "good" to "moderate").
        - If ground slope is not a design constraint (meaning the engineers decide a basin could be placed on a slope greater than 10 percent), then areas where the ground slope is greater than 10 percent could have their infiltration rankings increased one full step.
        - Portions of the study areas where the average ground slope is greater than 10 percent are shown graphically on Figures 16 and 17 (note these figures do <u>not</u> include a setback from steep slopes because it would not be visible at the scale of the map; we

assume that the 100 foot setback from steep slopes will be implemented when field-locating infiltration facilities).

3.2 Results

Using these criteria, rankings for infiltration potential are presented on Table 2 for each soil type and service area, and are also depicted spatially on Figures 18 and 19. These results are discussed in Section 4.

4 Sub-Silt (Deep) Infiltration Capacity

As shown on Figure 18, infiltration potential in the northeastern portion of Service Area 2 is poor. The “poor” infiltration potential primarily occurs because the K_{sat} in the northeast portion of Service Area 2 is very low (i.e., less than 2 inches per hour, see Figure 6). The low hydraulic conductivity is caused by silty surficial geologic units, specifically fine-grained Catastrophic Flood Deposits and weathered Boring Lavas. A potential solution in these areas with surficial silt is to infiltrate stormwater into deeper gravel deposits or fresh basalt beneath the silt. Sub-silt infiltration must occur at less than 100 ft bgs to meet DEQ requirements for drywell authorization by rule, and is therefore only feasible if at least 5 ft of permeable, unsaturated gravel or basalt rock are present between the silt and 100 ft bgs.

It is important to note that conventional drywells are not an option in much of Study Area 2 because the silts are commonly more than 40 ft deep (conventional drywells cannot be installed deeper than 40 ft bgs). In areas with over 40 ft of silt, drywells would have to be smaller-diameter and completed with a well drilling rig. Additional pretreatment would be required to prevent clogging of the drywell.

Sub-silt infiltration capacity was evaluated only for Service Area 2 because the geology in that area appears to be favorable to sub-silt infiltration. That is, much of Service Area 2 is comprised of thick silt deposits that overlie basalts of the Boring Lava or gravels of the Troutdale Formation, both of which can be conducive to deep infiltration due to their relatively-high vertical and lateral permeability.

While geologic conditions in some small portions of Service Area 3 may be favorable to sub-silt infiltration, conditions throughout most of the area are not conducive. Throughout much of Service Area 3, silt deposits overlie basalts of the Columbia River Basalt Group, a rock type which typically possesses extremely-low vertical permeability due to a layered structure in which permeable interflow zones are separated by much thicker low-permeability flow interiors. (It should be noted that Boring Lava basalts present in Service Area 2 do not typically possess the same laterally-extensive and thick layered structure as the CRBG basalts found in Service Area 3, and thus the former can be more favorable for deeper, or sub-silt, infiltration).

4.1 Methods

GSI reviewed OWRD well logs from Service Area 2 and compiled geologic information within a depth of 100 ft bgs (i.e., silt, gravel, fresh basalt). On the well logs examined, “grey” or “black” basalt was considered to be fresh basalt, while “brown” basalt was considered to be silt, or silt-like, in its hydraulic properties (because it may be basalt weathered to silt and not permeable). Generally, logs were only used if the well could be located by latitude/longitude (if provided by OWRD) or address. However, some wells locatable to quarter-quarter section were used in areas where no other logs were available.

At each well log location, GSI determined the depth to seasonal high groundwater, based on the median depth to groundwater from Snyder (2008) and the seasonal water table fluctuation for the Troutdale Gravel Aquifer from Table 2 of Snyder (2008). At wells with more than 5 ft of unsaturated soil above the seasonal high groundwater table, sub-silt infiltration was considered to be feasible. GSI plotted the data on a map and identified areas where sub-silt infiltration is feasible and areas where sub-silt infiltration was not feasible.

4.2 Results

The feasibility of sub-silt infiltration for different portions of Service Area 2 is shown on Figure 20, and the data used for the feasibility evaluation is presented in Table 1. Areas where sub-silt infiltration is not feasible tend to occur near rivers (e.g., Rock Creek, Scottie Creek) primarily due to the occurrence of shallow groundwater.

5 Conclusions

5.1 Service Area 2

5.1.1 Surface Soil Infiltration Capacity

As shown on Figure 18, based on the criteria established for this preliminary assessment, surface soil infiltration capacity is ranked as "poor" for most of the Service Area 2 study area. Low to moderate soil saturated hydraulic conductivity is the primary factor leading to poor infiltration capacity. In some areas steep ground slopes (i.e., greater than 10 percent) also limit infiltration potential. Overall "poor" soil infiltration capacity is present throughout most of the eastern portion of the study area, particularly in the PVNC, North Happy Valley, Sunnyside, Mount Talbert, and Mount Scott subareas.

There are areas that possess "moderate" and "good" soil infiltration capacity rankings in the lower-lying western and southwestern portions of the study area, within the NCRA, 3 Creeks, Kellogg Creek, and Clackamas River Drainage subareas. Southern portions of the PVNC subarea are also ranked as having "moderate" infiltration capacity.

5.1.2 Sub-Silt (Deep) Infiltration Evaluation

As shown on Figure 20, sub-silt infiltration is feasible over much of the northeastern portion of the study area. Areas where sub-silt infiltration is not feasible tend to occur near major rivers, due to shallow groundwater.

5.2 Service Area 3

5.2.1 Surface Soil Infiltration Capacity

Based on the criteria established for this preliminary assessment, surface soil infiltration capacity is ranked as "poor" for most of the Service Area 3 study area (Figure 19). Shallow depths to a restrictive soil layer at higher elevations, and a shallow depth to the water table at lower elevations, coupled with poor to moderate saturated soil hydraulic conductivity, contribute to the poor ranking. Steep slopes (slopes greater than 10 percent) throughout much of the study area further reduce soil infiltration potential. Overall "poor" soil infiltration capacity is present throughout most of the study area, particularly at higher elevations where slopes are steep and the depth to a restrictive layer or bedrock is shallow.

There are areas that possess "moderate" and "good" soil infiltration capacity rankings west of Lake Oswego near the Washington-Clackamas county line. "Moderate" infiltration potential has also been identified along the Tualatin River, and in the southwest corner of Service Area 3.

6 Recommendations

The infiltration evaluation described in this technical memorandum is a planning-level, desktop evaluation. No field work was conducted as a part of this evaluation.

Site-specific infiltration testing is a required part of infiltration facility development, to confirm the accuracy of NRCS data. Given the generally poor shallow infiltration capacity in the study areas, GSI recommends drilling pilot holes and infiltration tests to evaluate the feasibility of sub-silt infiltration in the northeastern portion of Service Area 2. Pilot holes will help to constrain the heterogeneous geological environment of the area, while infiltration testing will further inform feasibility.

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Tables

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Table 1. Depth to Bedrock

Log ID	Service Area	Date Installed	Mapped Depth to Bedrock (ft bgs)	Depth to First Water (ft)	Depth to Water (static, ft)	XY Source	Address	Township-Range-Section	Elevation (ft)	Latitude	Longitude	Comments
CLAC 10735	Service Area 2	8/14/1992	58	–	152	WR FINAL PROOF MAP	318 SE 50th Portland, OR 97215	WM 2.00S 2.00E 1SWNE	385	45.4261685	-122.5028290	
CLAC 1206	Service Area 2	3/9/1989	36	–	158	WR FINAL PROOF MAP	11375 SE 232nd Ave Gresham OR 97080	WM 1.00S 3.00E 34SENW	550	45.4407725	-122.4255865	
CLAC 12303	Service Area 2	8/20/1991	100	160	140	UNKNOWN	–	WM 2.00S 3.00E 17NENW	240	45.3949032	-122.4118254	Just outside study area
CLAC 17900	Service Area 2	5/6/1992	100	25	160	WR FINAL PROOF MAP	11375 SE 232nd Gresham OR	WM 1.00S 3.00E 34SESW	555	45.4375152	-122.4264939	
CLAC 2455	Service Area 2	6/13/1970	41	–	194	MAP 24K	13515 SE McLaughlin Blvd. Milwaukie OR	WM 2.00S 1.00E 1SWNW	200	45.4263585	-122.6358935	Just outside study area
CLAC 304	Service Area 2	12/2/1969	100	–	40	MAP 24K	2323 Harvester Dr, Milwaukie OR	WM 1.00S 1.00E 25NWSW	50	45.4515638	-122.6364467	outside study area
CLAC 3046	Service Area 2	8/15/1986	30	–	30	MAP 24K	16025 SE Harold Milwauke OR 97222	WM 2.00S 1.00E 12SESE	180	45.4065422	-122.6206928	Outside Study Area
CLAC 315	Service Area 2	5/11/1982	100	95	45.5	OWNER MAP	–	WM 1.00S 1.00E 36NENE	107	45.4435800	-122.6241650	outside study area
CLAC 332	Service Area 2	5/12/1962	55	–	237	WELL LOG	9950 SE 132nd Portland, OR	WM 1.00S 2.00E 26NWSE	490	45.4508688	-122.5274417	USGS log, Boring Lavas and Troutdale Formation
CLAC 333	Service Area 2	9/27/1967	73	–	183	UNKNOWN	8750 SE 155TH Portland OR	WM 1.00S 2.00E 25	545	45.4590094	-122.5034237	
CLAC 337	Service Area 2	12/31/1950	29	576	487	UNKNOWN	–	WM 1.00S 2.00E 27NENE	735	45.4598423	-122.5425915	
CLAC 338	Service Area 2	7/10/1964	63	–	81	GPS	8210 Con Battin Rd Portland OR	WM 1.00S 2.00E 28NWSW	220	45.4533977	-122.5747034	
CLAC 341	Service Area 2	7/21/1959	81	–	78	MAP 24K	8951 SE Fuller Rd Portland OR	WM 1.00S 2.00E 28	208	45.4584532	-122.5753700	
CLAC 3905	Service Area 2	8/4/1977	90	190	100	MAP 24K	15301 SE Sunnyside Rd Clackamas OR 97015	WM 2.00S2.00E1SENE	348	45.4278653	-122.4971876	Boring Lava?
CLAC 3934	Service Area 2	7/2/1971	70	348	213	WR FINAL PROOF MAP	–	WM 2.00S 2.00E 2NWSE	330	45.4227891	-122.5243717	
CLAC 3946	Service Area 2	5/17/1974	20	96	58	GPS	14469 SE 142nd Clackamas	WM 2.00S 2.00E 2SESE	285	45.4180626	-122.5177013	
CLAC 3947	Service Area 2	7/28/1958	80	–	205	WR FINAL PROOF MAP	1136 SE 50th Ave, Portland OR	WM 2.00S 2.00E 2NWSE	346	45.4227739	-122.5262410	
CLAC 395	Service Area 2	3/19/1958	15	–	250	UNKNOWN	–	WM 1.00S2.00E34NWSW	395	45.4387313	-122.5570360	Boring Lavas
CLAC 3950	Service Area 2	4/5/1985	13	296	243	WR FINAL PROOF MAP	10602 SE 29th Ave Portland OR 97236	WM 2.00S2.00E3NWSE	380	45.4223867	-122.5482463	
CLAC 3979	Service Area 2	11/2/1957	92	–	4	UNKNOWN	Union High School, 2202 SE Willard Milwauke OR	WM 2.00S2.00E5NWSW	100	45.4228978	-122.5964812	
CLAC 3982	Service Area 2	9/25/1980	53	55	20	GPS	5205 SE Aldercrest Dr Milwaukie OR	WM 2.00S2.00E6NWSE	91	45.4226310	-122.6089788	
CLAC 3991	Service Area 2	7/10/1981	8	351	325	UNKNOWN	–	WM 2.00S2.00E7SESE	306	45.4043759	-122.6007102	
CLAC 4041	Service Area 2	2/23/1973	39	38	24	WR FINAL PROOF MAP	–	WM 2.00S2.00E11NESE	148	45.4091703	-122.5199740	
CLAC 4053	Service Area 2	5/25/1980	8	330	225	UNKNOWN	16109 SE Hwy 212 Clackamas OR	WM 2.00S2.00E12SENE	330	45.4126211	-122.4984230	Boring Lava?
CLAC 4058/4066	Service Area 2	5/7/1964	100	122	91	GPS	14848 SE 142nd Clackamas OR	WM 2.00S2.00E12	275	45.4133932	-122.5162456	
CLAC 4079	Service Area 2	3/12/1970	100	–	61	MAP 24K	5405 SE Glen Echo Gladstone OR 97027	WM 2.00S2.00E13NWNE	162	45.4015121	-122.5028671	
CLAC 4112	Service Area 2	3/5/1969	100	–	0.5	MAP 24K	8525 SE Orchard Ln Portland OR	WM 2.00S2.00E14SENE	75	45.3957298	-122.5188505	
CLAC 4120	Service Area 2	8/31/1978	40	299	263	UNKNOWN	16433 SE Ormae Rd Milwakie OR 97222	WM 2.00S2.00E8SWSW	122	45.4037890	-122.5976221	Outside Study Area
CLAC 4146	Service Area 2	6/30/1954	100	–	20	GPS WELL INSPECTION	–	WM 2.00S2.00E15NWNW	104	45.4017599	-122.5567195	
CLAC 4191	Service Area 2	11/29/1988	82	–	–	UNKNOWN	SE Jennings and Oatfield	WM 2.00S2.00E17NWSW	211	45.3958094	-122.5988909	Outside Study Area
CLAC 4196	Service Area 2	1/17/1961	59	–	175	UNKNOWN	17195 SE Valley View Rd Milwauke OR	WM 2.00S2.00E17SENW	320	45.3982307	-122.5912812	Outside Study Area
CLAC 4199	Service Area 2	9/26/1962	47	–	128	UNKNOWN	2202 Willard St Milwaukie OR	WM 2.00S2.00E18SWNE	154	45.3994186	-122.6091907	Outside Study Area
CLAC 4209	Service Area 2	7/13/1972	18	202	125	WR APPL MAP	4444 Lake Rd Milwaukie OR 97222	WM 2.00S2.00E18SENW	132	45.3983744	-122.6105545	Outside Study Area
CLAC 4547	Service Area 2	11/16/1977	50	195	178	MAP 24K	23255 SE Hwy 212 Boring OR 97009	WM 2.00S3.00E3SWSE	612	45.4184422	-122.4233427	Outside Study Area, Boring Lava?
CLAC 4579	Service Area 2	7/30/1963	38	–	190	WR FINAL PROOF MAP	–	WM 2.00S3.00E5SESE	548	45.4197195	-122.4593380	
CLAC 4596	Service Area 2	4/11/1973	74	230	100	WR FINAL PROOF MAP	–	WM 2.00S3.00E6SENW	350	45.4261337	-122.4868776	
CLAC 4614	Service Area 2	3/30/1952	80	–	75	GPS WELL INSPECTION	–	WM 2.00S3.00E6SENW	333	45.4272401	-122.4890399	Boring Lava
CLAC 4618	Service Area 2	8/24/1982	20	126	150	UNKNOWN	14897 SE 172nd Clackamas OR	WM 2.00S3.00E7NENW	418	45.4154006	-122.4895343	Boring Lava
CLAC 4662	Service Area 2	7/26/1977	15	275	215	UNKNOWN	19127 SE Highway 212 Clackamas, OR 97015	WM 2.00S3.00E8NENW	528	45.4148454	-122.4656451	
CLAC 4679	Service Area 2	2/24/1983	100	648	441	WR APPL MAP PROPOSED WELL	19750 SE Damascus Lane Boring, OR 97009	WM 2.00S3.00E9NENE	580	45.4171446	-122.4381513	
CLAC 4682	Service Area 2	4/4/1979	100	50	66	UNKNOWN	19750 SE Damascus Ln Boring OR 97009	WM 2.00S3.00E9SWNE	522	45.4126223	-122.4403670	
CLAC 4683	Service Area 2	4/7/1976	100	1.5	380	WR FINAL PROOF MAP	19751 SE Damascus Lane Boring, OR 97009	WM 2.00S3.00E9SWNE	522	45.4126209	-122.4400891	
CLAC 4817	Service Area 2	12/31/1948	100	–	–	MAP 24K	–	WM 2.00S3.00E14NWSW	190	45.3932558	-122.4117354	
CLAC 4847	Service Area 2	12/22/1971	100	104	40	UNKNOWN	–	WM 2.00S3.00E15SWSW	182	45.3904679	-122.4308418	CRBG
CLAC 4862	Service Area 2	9/5/1987	100	360	243	UNKNOWN	16450 Marion St SE Carver OR	WM 2.00S3.00E17NWNE	365	45.4017835	-122.4625308	
CLAC 4863	Service Area 2	9/12/1983	100	424	113	UNKNOWN	16561 SE Marna Rd Clackamas OR	WM 2.00S3.00E17NENW	312	45.3998434	-122.4672639	
CLAC 50082	Service Area 2	11/2/1995	35	445	370	WELL LOG	7925 SE Lake Rd Milwaukie OR 97222	WM 1.00S2.00E26SESW	580	45.4501066	-122.5308209	
CLAC 513	Service Area 2	7/15/1969	45	–	258	WR FINAL PROOF MAP	838 SE 136 Portland OR	WM 1.00S3.00E27SENW	668	45.4542187	-122.4267810	
CLAC 530	Service Area 2	7/24/1980	100	145	130	GPS	9200 SE Rodlun Rd Gresham, OR 97030	WM 1.00S3.00E28SENW	704	45.4562594	-122.4459789	
CLAC 53331	Service Area 2	5/19/1998	24	89	200	WR FINAL PROOF MAP	10602 SE 129th Ave Portland OR 97236	WM 2.00S2.00E1SWSW	301	45.4208189	-122.5125581	Boring Lava
CLAC 55211	Service Area 2	11/3/1999	45	–	250	WR APPL MAP	14486 SE 122nd Ave Clackamas OR 97015	WM 2.00S2.00E11NENW	330	45.4172088	-122.5308310	Boring Lava
CLAC 55914	Service Area 2	7/27/2000	45	–	228	WR FINAL PROOF MAP	11375 SE 232nd Gresham, OR	WM 1.00S3.00E35NWSW	621	45.4378614	-122.4110680	Boring Lava
CLAC 571	Service Area 2	3/3/1980	100	730	312	MAP 24K	918 NE 177th Portland OR	WM 1.00S3.00E29SENE	890	45.4569996	-122.4592773	

Table 1. Depth to Bedrock

Log ID	Service Area	Date Installed	Mapped Depth to Bedrock (ft bgs)	Depth to First Water (ft)	Depth to Water (static, ft)	XY Source	Address	Township-Range-Section	Elevation (ft)	Latitude	Longitude	Comments
CLAC 57354	Service Area 2	10/16/2001	66	60	220	WR APPL MAP	11850 SE 242nd Ave Boring, OR 97009	WM 1.00S3.00E35NWSW	613	45.4376955	-122.4136885	outside Study Area
CLAC 609	Service Area 2	11/5/1976	81	92	102	MAP 24K	9330 SE Wooded Ct Portland OR 97236	WM 1.00S3.00E29NESE	620	45.4506762	-122.4550899	
CLAC 625	Service Area 2	9/29/1986	40	--	60	GPS	17951 SE Hemrick Rd. Boring, OR	WM 1.00S3.00E30SESE	338	45.4476651	-122.4787428	"Hard Black Rock"
CLAC 68	Service Area 2	5/4/1990	33	--	105	GPS	11501 SE Sunnyside Rd Clackamas OR 97015	WM 1.00S2.00E34SWSE	325	45.4334399	-122.5450717	
CLAC 68713	Service Area 2	5/15/2012	14	--	80	SITE VISIT AND IMAGERY	--	WM 2.00S2.00E13		45.3981500	-122.4975572	
CLAC 70075	Service Area 2	10/25/2013	50	547	428	OTHER	17665 S Carlson Rd Oregon City OR	WM 2.00S2.00E13SWSE	531	45.3889926	-122.5058986	Outside Study Area
CLACL 4058	Service Area 2	5/5/1964	76	--	57	GPS	--	WM 2.00S2.00E12	275	45.4133932	-122.5162456	
CLAC 64947	Service Area 2	7/23/2008	12	--	10	GOOGLE EARTH	11400 SE 147th Ave Happy Valley OR 97086	WM 1.00S 2.00 E 36SENW	736	45.4405130	-122.5111430	
CLAC 359	Service Area 2	10/1/1967	72	--	93	WR FINAL PROOF MAP	--	WM 1.00S3.00E31SWSW	353	45.4359037	-122.4917256	
CLAC 19196	Service Area 2	4/26/1994	97	--	168	GPS	17088 SE Wqooded Heights Rd Portland OR	WM 1.00S3.00E30NESW	439	45.4515512	-122.4879263	
CLAC 57534	Service Area 2	11/21/2001	37	--	--	GOOGLE EARTH	SE 147th Ave between Monner and Sunnyside	WM 1.00S 2.00E 36NENW	600	45.4293700	-122.5127000	Geotechnical hole
CLAC 56935	Service Area 2	6/6/2001	20	--	--	GOOGLE EARTH	SE 145th Ave, 600 ft south of King Road	WM 1.00S 2.00E 36NWNW	604	45.4550920	-122.5146240	Geotechnical hole
CLAC 66446	Service Area 2	8/27/2009	28	--	--	GOOGLE EARTH	8750 SE 155th Ave Happy Valley OR 97086	WM 1.00S 2.00E 25SWNE	540	45.4579030	-122.5032250	
CLAC 59582	Service Area 2	8/22/2003	32	--	58	GOOGLE EARTH	11300 SE 147th Ave	WM 1.00S 2.00E 25NENW	685	45.4435580	-122.5108050	
CLAC 324	Service Area 2	12/21/1985	39	358	347	GOOGLE EARTH	9595 Vrandenberg Rd. Portland OR 97236	WM 1.00S 2.00E 25SWNE	667	45.4534060	-122.5042630	
CLAC 634	Service Area 2	1/30/1980	80	300	250	GOOGLE EARTH	10150 SE Vrandenberg Rd Portland OR 97236	WM 1.00S 3.00E 30SWSW	758	45.4475520	-122.4964410	
CLAC 51500	Service Area 2	2/13/1997	18	--	--	GOOGLE EARTH	9600 SE Vrandenberg Rd Portland OR	WM 1.00S 2.00E 25NESE	795	45.4530350	-122.4991330	
CLAC 59103	Service Area 2	7/6/2003	29	--	399	GOOGLE EARTH	16321 SE Maple Hill In Boring OR 97009	WM 1.00S 3.00E 30SWSW	658	45.4507840	-122.4939360	
CLAC 62995	Service Area 2	10/28/2006	49	--	275	GOOGLE EARTH	16859 SE Maple Hill Ln Boring OR 97009	WM 1.00S 3.00E 30SENW	602	45.4507980	-122.4920130	
CLAC 68977	Service Area 2	6/27/2012	43	271	211.5	GOOGLE EARTH	9747 SE 172nd Ave Happy Valley OR 97086	WM 1.00S 3.00E 30NESW	434	45.4529050	-122.4887230	
CLAC 75126	Service Area 2	5/6/1987	55	--	180	GOOGLE EARTH	9700 SE 162nd Portland OR 97236	WM 1.00S 2.00E 25NESE	530	45.4560160	-122.4967720	
MULT 2903	Service Area 2	9/5/1967	0	--	571	UNKNOWN	11800 SE Mt Scott Blvd Portland OR	WM 1.00S2.00E22SESE	800	45.4623440	-122.5398138	
MULT 2894	Service Area 2	8/8/1963	100	--	48	GPS	8314 SE 52nd Ave Portland OR	WM 1.00S2.00E19SWSE	170	45.4633639	-122.6094517	
MULT 63234	Service Area 2	1/10/2001	100	--	96	GPS	SE 39th Ave and SE Bybee Blvd Portland OR	WM 1.00S1.00E24SENE	198	45.4726359	-122.6233216	
MULT 4279	Service Area 2	7/14/1994	18	--	52	GPS	--	WM 1.00S3.00E20SWNW	382	45.4691204	-122.4703959	
MULT 2901	Service Area 2		70	--	275	UNKNOWN	10500 SE Mt. Scott Blvd Portland OR	WM 1.00S2.00E22SWSW	400	45.4626215	-122.5564809	
MULT 2334	Service Area 2	2/1/1954	64	--	200	Unknown	--	WM 1.00S3.00E22NWSE		45.4670648	-122.4167565	
CLAC 71887	Service Area 3	12/15/2015	45	705	592	GPS WELL INSPECTION	Stafford Development Co. LLC 485 S. State St. Lake oswego OR, 97034	3.00S 1.00E 3NWSW	670	45.4165080	-122.6970394	CRBG
CLAC 63662	Service Area 3	7/12/2007	27	570	483	WR APPL MAP EXISTING WELL	FR Manka and Associates 3115 Stphenson St Portland OR 97219	3.00S 1.00E 4SWSE	765	45.3351203	-122.6904960	CRBG
CLAC 66339	Service Area 3	9/14/2009	24	350	118	WR APPL MAP	CTR SW Cescent Dr. West Linn OR	2.00S 1.00E 21NESW	180	45.3822279	-122.6933023	CRBG
CLAC 69118	Service Area 3	9/6/2012	39	368	153	GPS	18771 S. Whitten Ln, West Linn OR 97068	2.00S 1.00E 22NENE	570	45.3871200	-122.6663200	CRBG
CLAC 69129	Service Area 3	9/4/2012	4	--	189	GPS	18771 S. Whitten Ln, West Linn OR 97068	2.00S 1.00E 22NWNE	512	45.3887700	-122.6711900	CRBG
CLAC 58293	Service Area 3	10/22/2002	4	75	571	WR APPL MAP	930 Rosemont Rd. West Linn OR	2.00S 1.00E 23SWSW	737	45.3779033	-122.6580873	CRBG
CLAC 3033	Service Area 3	4/29/1905	0	--	75	MAP 24K	--	2.00S 1.00E 9NENW	225	45.4165080	-122.6970394	CRBG
CLAC 72095	Service Area 3	3/15/2016	16	680	647	GPS WELL INSPECTION	26110 French Oak Dr West Linn OR 97068	3.00S 3.00W 3NESE	744	45.3369400	-122.6830000	CRBG
CLAC 9083	Service Area 3	8/31/1981	26	139	92	WR APPL MAP EXISTING WELL	2882 Homesteder Rd West Linn OR 97068	3.00S 1.00E 8NENE	272.39	45.3287900	-122.7051700	CRBG
CLAC 54913	Service Area 3	8/24/1999	14	381	201	WR APPL MAP	6061 SW Meridian Way Stafford OR	2.00S1.00E31SENW	390	45.3547578	-122.7370760	CRBG
CLAC 66944	Service Area 3	6/21/2010	27	--	173	WR APPL MAP	3600 Olson Ct Rovergrove OR 97034	2.00S 1.00E 20NENW	295	45.3884932	-122.7132897	CRBG
CLAC 03869	Service Area 3	8/19/1988	43	395	335	Map 24K	23010 SW Salamo (?) Rd West Linn	2.00S 1.00E 35NENE	585	45.3585835	-122.6455332	sandstone overlying basalt
CLAC 03526	Service Area 3	8/25/1988	6	364	308	MAP 24K	4760 SW Trail Rd Tualatin OR	2.00S 1.00E 30SESE	435	45.3642168	-122.7270999	CRBG
CLAC 03477	Service Area 3	10/3/1989	5	281	79	MAP 24K	2100 SW Boreland Rd West Linn OR 97068	2.00S 1.00E 28SWNW	180	45.3689668	-122.6985332	clay and cemented gravel overlying basalt (basalt at 161 ft bgs)
CLAC 2954	Service Area 3	4/1/1991	20	--	--	MAP 24K	3120 S Ross Rd West Linn OR 97068	2.00S 1.00E 35NENE	580	45.3583001	-122.6455332	CRBG
CLAC 8900	Service Area 3	10/21/1980	46	496	412	WELL LOG AND TAX LOT MAP	24100 SW MT Rd West Linn OR	3.00S1.00E 5	--	45.3456518	-122.7080800	CRBG
CLAC 19217	Service Area 3	5/2/1994	38	--	471	WELL LOG AND TAX LOT MAP	24700 SW Valley View Rd West Linn OR	3.00S 1.00E 3	--	45.3438579	-122.6801066	CRBG
CLAC 19931	Service Area 3	11/22/1994	14	--	400	WELL LOG AND TAX LOT MAP	400 SW Willamette Heights Rd	3.00S 1.00E 3	--	45.3423657	-122.6753251	CRBG
CLAC 58195	Service Area 3	8/24/2002	5	113	108	WELL LOG AND TAX LOT MAP	25000 SW Stafford Summit Ct West Linn OR	3.00S 1.00E 3	--	45.3397720	-122.6710976	CRBG
CLAC 19760	Service Area 3	8/23/1994	17		485	WELL LOG AND TAX LOT MAP	35136 SW Petes Mtn. Rd West Linn OR	3.00S 1.00E 3	--	45.3350681	-122.6622040	CRBG
CLAC 0193	Service Area 3	8/15/1990	4	331	205	WELL LOG AND TAX LOT MAP	25165 SW Petes Mtn Rd West Linn OR	3.00S 1.00E 3	--	45.3389609	-122.6639189	CRBG
CLAC 52289	Service Area 3	4/22/1959	5	--	--	WR FINAL PROOF MAP	--	2.00S 1.00E 20NWNW	--	45.3878298	-122.7187440	CRBG
CLAC 3078	Service Area 3	4/10/1905	38.5	--	280	WR APPL MAP	Marylhurst OR	2.00S1.00E14NENW	--	45.4006604	-122.6527514	CRBG
CLAC 51779	Service Area 3	4/30/1997	87	68	67	WR FINAL PROOF MAP	3944 SW Haleyon Rd Tualatin OR 97062	2.00S 1.00E 20SWSW	172	45.3787456	-122.7202000	clay overlying basalt

Table 1. Depth to Bedrock

Log ID	Service Area	Date Installed	Mapped Depth to Bedrock (ft bgs)	Depth to First Water (ft)	Depth to Water (static, ft)	XY Source	Address	Township-Range-Section	Elevation (ft)	Latitude	Longitude	Comments
CLAC 115	Service Area 3	7/9/1990	100	400	80	MAP 24K	19875 SW Stafford Rd Tualatin OR	2.00S 1.00E 20SESE	180	45.3766335	-122.7036999	thick sed package overlying basalt @223
CLAC 8728	Service Area 3	6/29/1992	38	78	62	MAP 24K	22800 SW 55th Tualatin OR 97062	2.00S 1.00E 31SWNE	435	45.3549029	-122.7321453	CRBG
CLAC 3733	Service Area 3	11/12/1959	28	--	90	MAP 24K	corner of Meridian and Stafford	2.00S 1.00E 31NWSW	415	45.3532190	-122.7423097	CRBG
CLAC 3014	Service Area 3	9/25/1971	35	150	89	WR FINAL PROOF MAP	--	3.00S 1.00E 7NWNW	265	45.3289435	-122.7383779	CRBG
CLAC 3778	Service Area 3	12/14/1966	21	--	350	MAP 24K	23273 SW Mountain Rd West Linn OR 97068	2.00S 1.00E 32NWSE	510	45.3510388	-122.7102433	just outside study area
CLAC 9094	Service Area 3	5/4/1973	9	225	190	MAP 24K	--	3.00S 1.00E 8NWNW	340	45.3301584	-122.7197688	outside study area
CLAC 3709	Service Area 3	2/12/1962	40	--	184	MAP 24K	--	2.00S 1.00E 31SWNE	435	45.3544810	-122.7322777	clay/sandstone over basalt
CLAC 3643	Service Area 3	11/29/1976	29	193	124	MAP 24K	--	2.00S 1.00E 30SWNW	295	45.3694593	-122.7398614	
CLAC 3617	Service Area 3	10/9/1973	34	82	80	MAP 24K	--	2.00S 1.00E 30SENE	235	45.3701769	-122.7262346	
CLAC 3057	Service Area 3	3/23/1972	28	80	55	MAP 24K	--	2.00S 1.00E 28SWSE	160	45.3609953	-122.6913148	
CLAC 8983	Service Area 3	7/10/1968	3	--	140	MAP 24K	--	3.00S 1.00E 6SENW	385	45.3402671	-122.7378827	
CLAC 3214	Service Area 3	11/7/1987	3	336	291	WR FINAL PROOF MAP	19727 SW Johnson Rd Lake Oswego OR	2.00S 1.00E 21SENW	358	45.3856823	-122.6930608	
CLAC 3233	Service Area 3	11/6/1969	20	--	254	WR FINAL PROOF MAP	--	2.00S 1.00E 21NESE	319	45.3822496	-122.6841675	
CLAC 56719	Service Area 3	4/18/2001	55	55	328	WR APPL MAP	135 Rosemont, Lake Oswego OR 97034	2.00S 1.00E 16SESE	445	45.3930975	-122.6866507	clay/sandstone over basalt
CLAC 19777	Service Area 3	9/26/1994	5	260	246	WR FINAL PROOF MAP	18550 S Whitten ln West Lnn OR	2.00S 1.00E 15SWSE	560	45.3928519	-122.6698172	
CLAC 8865	Service Area 3	11/21/1987	17	460	--	GPS	1701 SW Shaeffer Rd West Linn OR	3.00S 1.00E 4SWNE	808	45.3424801	-122.6905999	
CLAC 10322	Service Area 3	6/18/1991	25	--	331	Unknown	26880 SW Pete's Mtn Rd West Linn OR 97068	3.00S 1.00E 10NENW	550	45.3289672	-122.6726330	just outside study area
CLAC 20515	Service Area 3	9/8/1995	100	28	87	Unknown	4564 SW Borland Rd Tualatin OR	2.00S 1.00E 30NENE	185	45.3747018	-122.7234433	clay/sand over basalt @ 307
CLAC 12346	Service Area 3	9/28/1991	20	10	11	Unknown	4455 SW Halcyon Rd Tualatin OR	2.00S 1.00E 20NWSW	113	45.3799822	-122.7202020	cemented gravel over basalt
CLAC 3635	Service Area 3	10/23/1962	0	--	175	MAP 24K	--	2.00S 1.00E 30SESW	360	45.3642761	-122.7343349	basalt at surface
CLAC 3171	Service Area 3	3/10/1967	64	--	55	Unknown	Stafford School	2.00S 1.00E 20SESE	170	45.3775040	-122.7030215	
CLAC 3189	Service Area 3	5/8/1967	19	--	185	WR APPL MAP	Rivergrove water district, 17725 SW Boones Ferry Rd Lake Oswego OR	2.00S 1.00E 20NWNW	320	45.3879081	-122.7123786	
CLAC 3767	Service Area 3	4/19/1972	4	602	557	MAP 24K	--	2.00S 1.00E 32NESE	670	45.3514642	-122.7047108	
CLAC 3244	Service Area 3	1949	3	--	114	WELL LOG AND TAX LOT MAP	--	2.00S 1.00E 21SENW	230	45.3834992	-122.6947790	clay/basalt
CLAC 3107	Service Area 3	5/8/1969	6	--	396	MAP 24K	Lake Oswego High School, 2455 SW Country Club Rd Lake Oswego OR	2.00S 1.00E 16SENW	480	45.3976194	-122.6945390	clay/sandstone over basalt
CLAC 3315	Service Area 3	1945	35	--	--	WR APPL MAP	--	2.00S 1.00E 22NENW	455	45.3875662	-122.6747679	
CLAC 3089	Service Area 3	6/20/1956	95	313	232	Unknown	252 SW Glenmorrie Dr Oswego OR	2.00S 1.00E 15NENE	320	45.4022347	-122.6654822	
CLAC 64598	Service Area 3	3/20/2008	50	--	609	SITE VISIT AND IMAGERY	3153 S Brabdywine Dr West Linn OR 97068	2.00S 1.00E 26NWSE	665	45.3646553	-122.6488330	clay over basalt
WASH 011613	Service Area 3	2/13/1990	55	452	101	GPS	15115 SW 72nd Ave Portland OR	2.00S 1.00W 12SENE	173	45.4115559	-122.7466058	clay/sand over basalt (outside study area)
CLAC 3119	Service Area 3	5/26/1958	25	--	16	GPS	--	2.00S 1.00E 18NESW	150	45.3969245	-122.7344289	gravels overlying clay
CLAC 17825	Service Area 3	3/30/1990	28	438	298	WR FINAL PROOF MAP	corner of Stafford and Rosemont Rd	2.00S 1.00E 16SWSE	425	45.3925978	-122.6893794	
CLAC 3092	Service Area 3	1935	10	--	--	UNKNOWN	--	2.00S 1.00E 15NENW	525	45.4017862	-122.6756497	
CLAC 53765	Service Area 3	8/25/1998	15	192	82	WR APPL MAP	1026 SW Rosemont, West Linn OR	2.00S 1.00E 26NENW	--	45.3719453	-122.6539969	
CLAC 3348	Service Area 3	8/3/1965	3	--	50	MAP 24K	William Armstrong Donation Land Claim	2.00S1.00E23NWNW	685	45.3857365	-122.6582212	clay over basalt

Abbreviations
bgs = below ground surface
CRBG = Columbia River Basalt Group
ft = feet or foot
GPS = global positioning system
USGS = U.S. Geological Survey
WR = water right

Table 2. Key Physical Parameters Established by NRCS

Map Units Symbol	Map Unit Name	Service Area	Acres in AOI1	Percent of AOI[1]	Depth to High Water Table (ft)	Depth to High Water Table (cm)	Depth to Restrictive Layer (in)	Depth to Restrictive Layer (cm)	Saturated Hydraulic Conductivity K_{sat} (in/hr)	Hydrologic Soil Group[2]	Representative Slope (%)	Infiltration Potential Ranking
11	Camas gravelly sandy loam	Service Area 2	3.71	0.02%	3	91.44	9.0	22.86	1.400	A	2	Poor
13B	Cascade silt loam, 3 to 8 percent slopes	Service Area 2	1037.69	5.69%	1.25	38.1	25.0	63.5	1.030	C/D	4	Poor
13C	Cascade silt loam, 8 to 15 percent slopes	Service Area 2	1980.09	10.86%	2	60.96	25.0	63.5	1.030	C	12	Poor
13D	Cascade silt loam, 15 to 30 percent slopes	Service Area 2	1145.56	6.28%	2	60.96	25.0	63.5	1.030	C	23	Poor
13E	Cascade silt loam, 30 to 60 percent slopes	Service Area 2	459.76	2.52%	2	60.96	25.0	63.5	1.030	C	45	Poor
14C	Cascade silt loam, stony substratum, 3 to 15 percent slopes	Service Area 2	477.00	2.62%	1.25	38.1	25.0	63.5	1.030	C/D	9	Poor
14D	Cascade silt loam, stony substratum, 15 to 30 percent slopes	Service Area 2	777.14	4.26%	2	60.96	25.0	63.5	1.030	C	23	Poor
14E	Cascade silt loam, stony substratum, 30 to 60 percent slopes	Service Area 2	67.68	0.37%	2	60.96	25.0	63.5	1.030	C	45	Poor
16	Chehalis	Service Area 2	--	--	3	91.44	>78	>200	1.325	B/D	2	Moderate
17	Clackamas silt loam	Service Area 2	653.62	3.58%	0.75	22.86	>78	>200	0.505	C/D	2	Moderate
18	Clackamas gravelly loam	Service Area 2	20.79	0.11%	0.75	22.86	>78	>200	0.505	C/D	2	Moderate
19	Cloquato silt loam	Service Area 2	48.44	0.27%	>6.5	>200	>78	>200	2.110	B	2	Good
1A	Aloha silt loam, 0 to 3 percent slopes	Service Area 2	47.19	0.26%	1	30.48	25.0	63.5	0.400	C/D	2	Poor
1B	Aloha silt loam, 3 to 6 percent slopes	Service Area 2	64.94	0.36%	1	30.48	25.0	63.5	0.400	C/D	4	Poor
2225A	Huberly silt loam, 0 to 3 percent slopes	Service Area 2	145.16	0.80%	0.4	12.19	29.0	73.66	0.017	C/D	1	Poor
23B	Cornelius silt loam, 3 to 8 percent slopes	Service Area 2	119.27	0.65%	1.55	47.24	30.0	76.2	1.300	C/D	4	Poor
23C	Cornelius silt loam, 8 to 15 percent slopes	Service Area 2	172.89	0.95%	1.55	47.24	30.0	76.2	1.300	C/D	12	Poor
25	Cove silty clay loam	Service Area 2	370.89	2.03%	1	30.48	>78	>200	2.195	D	1	Good
3	Amity silt loam	Service Area 2	69.55	0.38%	0.75	22.86	25.0	63.5	0.400	D	2	Poor
30C	Delena silt loam, 3 to 12 percent slopes	Service Area 2	344.81	1.90%	0.75	22.86	25.0	63.5	0.035	C/D	8	Poor
42	Humaquepts, ponded	Service Area 2	36.37	0.20%	1	30.48	>78	>200	0.400	D	1	Poor
45C	Jory silty clay loam, 8 to 15 percent slopes	Service Area 2	0.41	0.00%	>6.5	>200	>78	>200	0.595	C	12	Poor
48C	Kinton silt loam, 8 to 15 percent slopes	Service Area 2	38.32	0.21%	1.55	47.24	30.0	76.2	1.300	C/D	12	Poor
53A	Latourell loam, 0 to 3 percent slopes	Service Area 2	359.18	1.97%	>6.5	>200	>78	>200	1.840	B	2	Moderate
53B	Latourell loam, 3 to 8 percent slopes	Service Area 2	382.65	2.10%	>6.5	>200	>78	>200	1.840	B	6	Moderate
53C	Latourell loam, 8 to 15 percent slopes	Service Area 2	23.23	0.13%	>6.5	>200	>78	>200	1.840	B	12	Poor
53D	Latourell loam, 15 to 30 percent slopes	Service Area 2	22.68	0.12%	>6.5	>200	>78	>200	1.840	B	23	Poor
56	McBee silty clay loam	Service Area 2	14.80	0.08%	1.5	45.72	>78	>200	1.300	C/D	2	Moderate
61A	Multnomah silt loam, 0 to 3 percent slopes	Service Area 2	594.75	3.26%	>6.5	>200	>78	>200	5.590	B	2	Good
67	Newberg fine sandy loam	Service Area 2	26.34	0.14%	3	91.44	>78	>200	4.000	A	2	Moderate
68	Newberg loam	Service Area 2	47.08	0.26%	3	91.44	>78	>200	4.000	A	2	Moderate
69	Pits	Service Area 2	59.21	0.32%	--	--	--	--	--	--	45	Poor
70B	Powell silt loam, 0 to 8 percent slopes	Service Area 2	2749.95	15.08%	1	30.48	22.5	57.15	0.130	D	4	Poor
70C	Powell silt loam, 8 to 15 percent slopes	Service Area 2	256.83	1.41%	1	30.48	22.5	57.15	0.130	D	12	Poor
70D	Powell silt loam, 15 to 30 percent slopes	Service Area 2	51.16	0.28%	1	30.48	22.5	57.15	0.130	D	23	Poor
71A	Quatama loam, 0 to 3 percent slopes	Service Area 2	157.92	0.87%	1.5	45.72	25.0	63.5	0.400	C/D	2	Poor
71B	Quatama loam, 3 to 8 percent slopes	Service Area 2	142.04	0.78%	1.5	45.72	25.0	63.5	0.400	C/D	6	Poor
71C	Quatama loam, 8 to 15 percent slopes	Service Area 2	9.06	0.05%	2.5	76.2	>78	>200	0.670	C	12	Poor
73	Riverwash	Service Area 2	21.90	0.12%	1	30.48	>78	>200	--	--	2	Moderate
76B	Salem silt loam, 0 to 7 percent slopes	Service Area 2	642.45	3.52%	>6.5	>200	>78	>200	36.520	B	4	Good
76C	Salem silt loam, 7 to 12 percent slopes	Service Area 2	6.29	0.03%	>6.5	>200	>78	>200	36.520	B	10	Moderate
77B	Salem gravelly silt loam, 0 to 7 percent slopes	Service Area 2	135.53	0.74%	>6.5	>200	>78	>200	36.520	B	4	Good
78B	Saum silt loam, 3 to 8 percent slopes	Service Area 2	221.48	1.21%	>6.5	>200	50	127	0.400	C	6	Poor
78C	Saum silt loam, 8 to 15 percent slopes	Service Area 2	136.53	0.75%	>6.5	>200	50	127	0.400	C	12	Poor
78D	Saum silt loam, 15 to 30 percent slopes	Service Area 2	124.21	0.68%	>6.5	>200	50	127	0.400	C	23	Poor
78E	Saum silt loam, 30 to 60 percent slopes	Service Area 2	123.89	0.68%	>6.5	>200	50	127	0.400	C	45	Poor
7B	Borges silty clay loam, 0 to 8 percent slopes	Service Area 2	120.28	0.66%	0.75	22.86	25.0	63.5	0.031	D	4	Poor
82	Urban land	Service Area 2	91.95	0.50%	>6.5	>200	>78	>200	--	--	15	Poor
83	Wapato silt loam	Service Area 2	11.40	0.06%	1	30.48	>78	>200	0.640	C/D	2	Moderate
84	Wapato silty clay loam	Service Area 2	405.76	2.22%	1	30.48	>78	>200	0.610	C/D	2	Moderate

Table 2. Key Physical Parameters Established by NRCS

Map Units Symbol	Map Unit Name	Service Area	Acres in AOI1	Percent of AOI[1]	Depth to High Water Table (ft)	Depth to High Water Table (cm)	Depth to Restrictive Layer (in)	Depth to Restrictive Layer (cm)	Saturated Hydraulic Conductivity K_{sat} (in/hr)	Hydrologic Soil Group[2]	Representative Slope (%)	Infiltration Potential Ranking
86A	Willamette silt loam, 0 to 3 percent slopes	Service Area 2	17.50	0.10%	>6.5	>200	>78	>200	1.300	B	2	Moderate
86B	Willamette silt loam, 3 to 8 percent slopes	Service Area 2	122.64	0.67%	>6.5	>200	>78	>200	1.300	B	4	Moderate
87A	Willamette silt loam, gravelly substratum, 0 to 3 percent slopes	Service Area 2	58.31	0.32%	>6.5	>200	>78	>200	2.200	B	2	Good
89D	Witzel very stony silt loam, 3 to 40 percent slopes	Service Area 2	10.96	0.06%	>6.5	>200	16.0	40.64	0.625	D	22	Poor
8B	Bornstedt silt loam, 0 to 8 percent slopes	Service Area 2	622.15	3.41%	1.5	45.72	>78	>200	1.160	C/D	4	Moderate
8C	Bornstedt silt loam, 8 to 15 percent slopes	Service Area 2	184.94	1.01%	1.5	45.72	>78	>200	1.160	C/D	12	Poor
8D	Bornstedt silt loam, 15 to 30 percent slopes	Service Area 2	132.89	0.73%	1.5	45.72	>78	>200	1.160	C/D	23	Poor
91A	Woodburn silt loam, 0 to 3 percent slopes	Service Area 2	127.78	0.70%	1.35	41.15	25.0	63.5	1.300	C/D	2	Poor
91B	Woodburn silt loam, 3 to 8 percent slopes	Service Area 2	1052.56	5.77%	1.35	41.15	25.0	63.5	1.300	C/D	4	Poor
91C	Woodburn silt loam, 8 to 15 percent slopes	Service Area 2	212.46	1.16%	1.35	41.15	>78	>200	0.871	C/D	12	Poor
92F	Xerochrepts and Haploxerolls, very steep	Service Area 2	639.88	3.51%	4.25	129.54	>78	>200	0.987	B	40	Poor
93E	Xerochrepts-Rock outcrop complex, moderately steep	Service Area 2	0.37	0.00%	--	--	25.0	63.5	1.100	C	15	Poor
W	Water	Service Area 2	32.48	0.18%	0	0	--	--	--	--	0	Poor
1A	Aloha silt loam, 0 to 3 percent slopes	Service Area 3	0.25	0.02%	1.75	53.34	>78	>200	0.430	C/D	2	Poor
1B	Aloha silt loam, 3 to 6 percent slopes	Service Area 3	30.63	2.30%	1.75	53.34	>78	>200	0.430	C/D	4	Poor
3	Amity silt loam	Service Area 3	0.06	0.00%	1	30.48	>78	>200	0.530	C/D	2	Poor
7B	Borges silty clay loam, 0 to 8 percent slopes	Service Area 3	8.76	0.66%	0.25	7.62	>78	>200	0.062	D	4	Poor
12A	Canderly sandy loam, 0 to 3 percent slopes	Service Area 3	29.12	2.19%	>6.5	>200	>78	>200	4.000	A	2	Good
13B	Cascade silt loam, 3 to 8 percent slopes	Service Area 3	53.33	4.01%	2	60.96	20.1	51.0	1.300	C	4	Poor
13C	Cascade silt loam, 8 to 15 percent slopes	Service Area 3	172.68	12.97%	2	60.96	20.1	51.0	1.300	C	12	Poor
13D	Cascade silt loam, 15 to 30 percent slopes	Service Area 3	15.59	1.17%	2	60.96	20.1	51.0	1.300	C	23	Poor
16	Chehalis silt loam	Service Area 3	4.84	0.36%	>6.5	>200	>78	>200	1.300	B	2	Moderate
17	Clackamas silt loam	Service Area 3	9.31	0.70%	1	30.48	>78	>200	0.435	C/D	2	Poor
19	Cloquato silt loam	Service Area 3	10.25	0.77%	>6.5	>200	>78	>200	1.630	B	2	Moderate
23B	Cornelius silt loam, 3 to 8 percent slopes	Service Area 3	5.08	0.38%	2.65	80.77	29.9	76.0	1.300	C	4	Poor
23C	Cornelius silt loam, 8 to 15 percent slopes	Service Area 3	115.54	8.68%	2.65	80.77	29.9	76.0	1.300	C	12	Poor
23D	Cornelius silt loam, 15 to 30 percent slopes	Service Area 3	27.34	2.05%	2.65	80.77	29.9	76.0	1.300	C	23	Poor
25	Cove silty clay loam	Service Area 3	3.83	0.29%	1	30.48	>78	>200	0.034	D	1	Poor
29	Dayton silt loam	Service Area 3	4.00	0.30%	0.75	22.86	>78	>200	0.046	D	1	Poor
36B	Hardscrabble silt loam, 2 to 7 percent slopes	Service Area 3	0.13	0.01%	1	30.48	>78	>200	0.040	D	5	Poor
36C	Hardscrabble silt loam, 7 to 20 percent slopes	Service Area 3	6.60	0.50%	1	30.48	>78	>200	0.040	D	14	Poor
37B	Helvetia silt loam, 3 to 8 percent slopes	Service Area 3	0.19	0.01%	4.5	137.16	>78	>200	0.528	C	4	Poor
37C	Helvetia silt loam, 8 to 15 percent slopes	Service Area 3	38.08	2.86%	4.5	137.16	>78	>200	0.528	C	12	Poor
37D	Helvetia silt loam, 15 to 30 percent slopes	Service Area 3	1.97	0.15%	4.5	137.16	>78	>200	0.528	C	23	Poor
45B	Jory silty clay loam, 2 to 8 percent slopes	Service Area 3	9.85	0.74%	>6.5	>200	>78	>200	0.471	C	5	Poor
45C	Jory silty clay loam, 8 to 15 percent slopes	Service Area 3	0.26	0.02%	>6.5	>200	>78	>200	0.471	C	12	Poor
45D	Jory silty clay loam, 15 to 30 percent slopes	Service Area 3	5.68	0.43%	>6.5	>200	>78	>200	0.471	C	23	Poor
48B	Kinton silt loam, 3 to 8 percent slopes	Service Area 3	9.99	0.75%	2.65	80.77	29.9	76	1.300	C	6	Poor
48C	Kinton silt loam, 8 to 15 percent slopes	Service Area 3	32.36	2.43%	2.65	80.77	29.9	76	1.300	C	12	Poor
48D	Kinton silt loam, 15 to 30 percent slopes	Service Area 3	12.87	0.97%	2.65	80.77	29.9	76	1.300	C	23	Poor
53A	Latourell loam, 0 to 3 percent slopes	Service Area 3	3.97	0.30%	>6.5	>200	>78	>200	1.503	B	2	Moderate
53B	Latourell loam, 3 to 8 percent slopes	Service Area 3	18.57	1.40%	>6.5	>200	>78	>200	1.503	B	6	Moderate
53C	Latourell loam, 8 to 15 percent slopes	Service Area 3	0.55	0.04%	>6.5	>200	>78	>200	1.503	B	12	Poor
53D	Latourell loam, 15 to 30 percent slopes	Service Area 3	1.44	0.11%	>6.5	>200	>78	>200	1.503	B	23	Poor
54B	Laurelwood silt loam, 3 to 8 percent slopes	Service Area 3	18.71	1.41%	>6.5	>200	>78	>200	0.852	B	4	Moderate
54C	Laurelwood silt loam, 8 to 15 percent slopes	Service Area 3	163.17	12.26%	>6.5	>200	>78	>200	0.852	B	12	Poor
54D	Laurelwood silt loam, 15 to 30 percent slopes	Service Area 3	43.04	3.23%	>6.5	>200	>78	>200	0.852	B	23	Poor
54E	Laurelwood silt loam, 30 to 60 percent slopes	Service Area 3	22.93	1.72%	>6.5	>200	>78	>200	0.852	B	45	Poor
56	McBee silty clay loam	Service Area 3	9.93	0.75%	2.5	76.2	>78	>200	0.897	C	2	Poor
57	McBee variant loam	Service Area 3	6.05	0.45%	1	30.5	>78	>200	1.300	B/D	2	Poor

Table 2. Key Physical Parameters Established by NRCS

Map Units Symbol	Map Unit Name	Service Area	Acres in AOI1	Percent of AOI[1]	Depth to High Water Table (ft)	Depth to High Water Table (cm)	Depth to Restrictive Layer (in)	Depth to Restrictive Layer (cm)	Saturated Hydraulic Conductivity K_{sat} (in/hr)	Hydrologic Soil Group[2]	Representative Slope (%)	Infiltration Potential Ranking
62B	Multnomah cobbly silt loam, 0 to 7 percent slopes	Service Area 3	131.32	9.87%	>6.5	>200	>78	>200	1.940	B	4	Moderate
64B	Nekia silty clay loam, 2 to 8 percent slopes	Service Area 3	6.01	0.45%	>6.5	>200	20.1	51	0.400	C	5	Poor
64C	Nekia silty clay loam, 8 to 15 percent slopes	Service Area 3	6.76	0.51%	>6.5	>200	20.1	51	0.400	C	12	Poor
70C	Powell silt loam, 8 to 15 percent slopes	Service Area 3	23.51	1.77%	1.6	48.8	15.0	38	1.300	D	12	Poor
71A	Quatama loam, 0 to 3 percent slopes	Service Area 3	4.93	0.37%	2.5	76.2	>78	>200	0.505	C	2	Poor
71B	Quatama loam, 3 to 8 percent slopes	Service Area 3	5.70	0.43%	2.5	76.2	>78	>200	0.505	C	6	Poor
71C	Quatama loam, 8 to 15 percent slopes	Service Area 3	4.77	0.36%	2.5	76.2	>78	>200	0.505	C	12	Poor
76B	Salem silt loam, 0 to 7 percent slopes	Service Area 3	11.09	0.83%	>6.5	>200	>78	>200	3.148	B	4	Good
76C	Salem silt loam, 7 to 12 percent slopes	Service Area 3	2.62	0.20%	>6.5	>200	>78	>200	3.148	B	10	Good
78B	Saum silt loam, 3 to 8 percent slopes	Service Area 3	9.12	0.68%	>6.5	>200	40.2	102	0.511	C	6	Poor
78C	Saum silt loam, 8 to 15 percent slopes	Service Area 3	24.77	1.86%	>6.5	>200	40.2	102	0.727	C	12	Poor
78D	Saum silt loam, 15 to 30 percent slopes	Service Area 3	7.40	0.56%	>6.5	>200	40.2	102	0.727	C	23	Poor
78E	Saum silt loam, 30 to 60 percent slopes	Service Area 3	5.92	0.44%	>6.5	>200	40.2	102	0.727	C	45	Poor
82	Urban land	Service Area 3	3.42	0.26%	>6.5	>200	>78	>200	--	---	15	Poor
83	Wapato silt loam	Service Area 3	17.36	1.30%	0	0	>78	>200	0.491	C/D	2	Poor
84	Wapato silty clay loam	Service Area 3	20.35	1.53%	0.25	7.6	>78	>200	0.494	C/D	2	Poor
88B	Willamette silt loam, wet, 3 to 7 percent slopes	Service Area 3	14.88	1.12%	3	91.4	>78	>200	1.300	C	5	Poor
89D	Witzel very stony silt loam, 3 to 40 percent slopes	Service Area 3	6.09	0.46%	>6.5	>200	11.8	30	0.520	D	22	Poor
91A	Woodburn silt loam, 0 to 3 percent slopes	Service Area 3	52.79	3.97%	2.94	89.6	>78	>200	0.302	C	2	Poor
91B	Woodburn silt loam, 3 to 8 percent slopes	Service Area 3	17.67	1.33%	2.94	89.6	>78	>200	0.302	C	4	Poor
91C	Woodburn silt loam, 8 to 15 percent slopes	Service Area 3	5.62	0.42%	2.94	89.6	>78	>200	0.302	C	12	Poor
92F	Xerochrepts and Haploxerolls, very steep	Service Area 3	47.87	3.60%	4.5	137.2	>78	>200	0.827	B	40	Poor
93E	Xerochrepts-Rock outcrop complex, moderately steep	Service Area 3	1.81	0.14%	>6.5	>200	9.8	25	1.100	C	15	Poor
2225A	Huberly silt loam, 0 to 3 percent slopes	Service Area 3	2.30	0.17%	0.72	21.9	>78	>200	0.015	C/D	1	Poor
W	Water	Service Area 3	0.05	0.00%	--	--	>78	>200	--	---	0	--

Notes

[1] AOI is Area of Interest

[2] Hydrologic soil groups are as follows:

A = Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

B = Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

C = Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

D = Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas.

cm = centimeters
ft = feet or foot
hr = hour
in = inches
K_{sat} = saturated soil hydraulic conductivity

Figures

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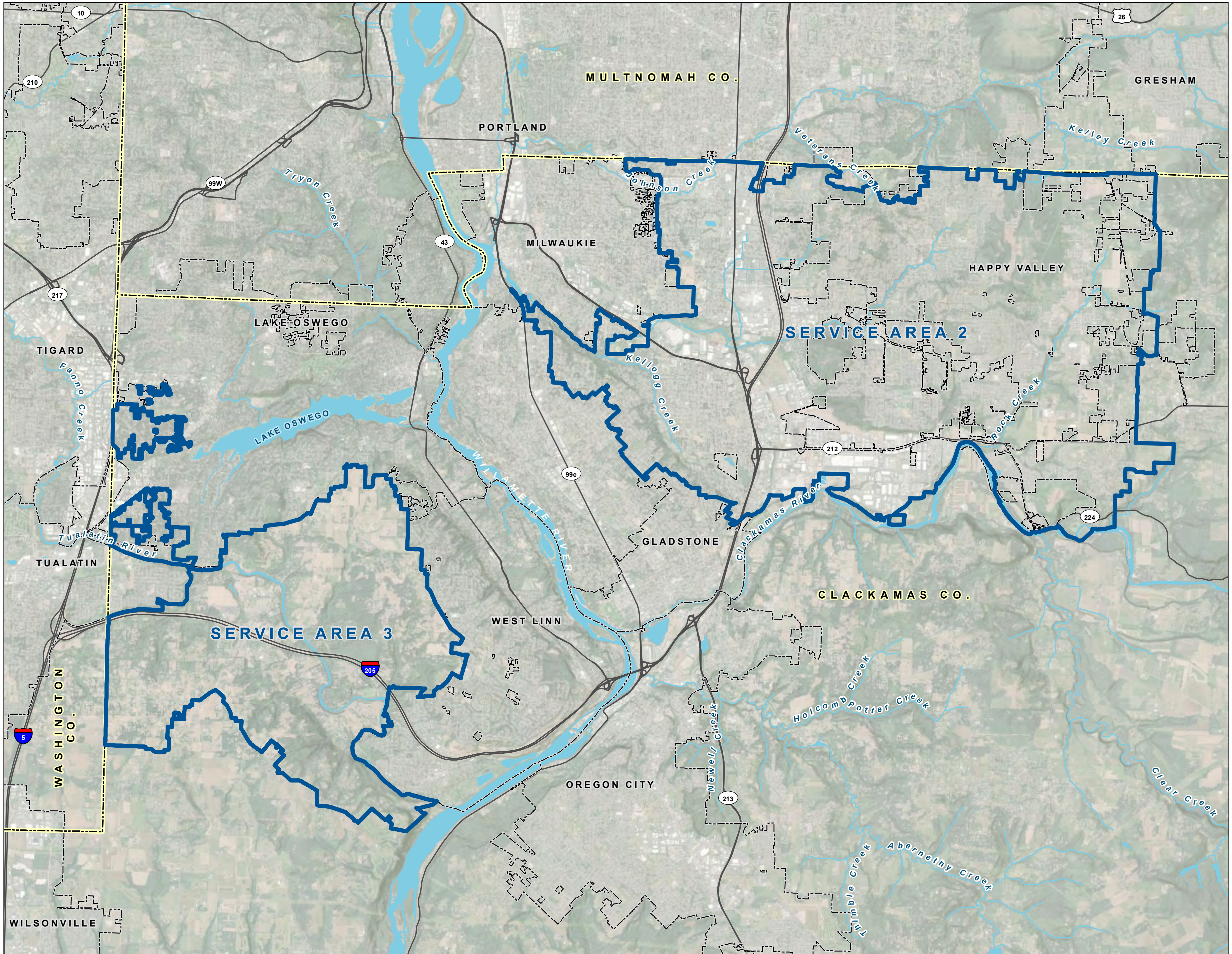

FIGURE 1

Overview Map

Clackamas WES Service
Areas 2 and 3

LEGEND

Study Area

All Other Features

County Boundary

City Boundary

Major Road

Watercourse

Waterbody

N

0 3,300 6,600 9,900
Feet

Date: April 8, 2022
Data Sources: USGS, BLM, OGIC, METRO 2020

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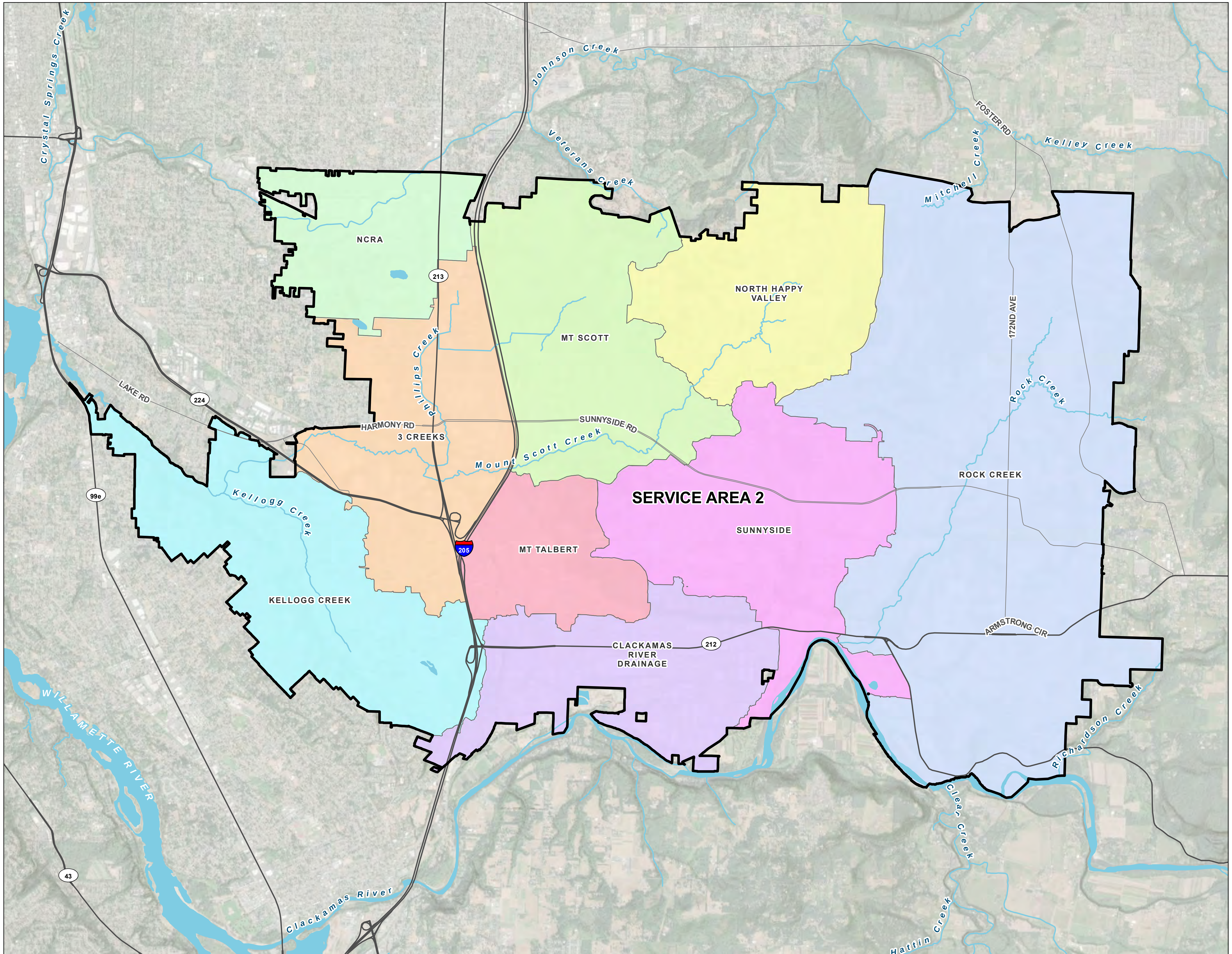

FIGURE 2

Location Map

Clackamas WES Service Areas 2 and 3

LEGEND

Sewer District

- 3 Creeks
- Clackamas River Drainage
- Kellogg Creek
- Mt Scott
- Mt Talbert
- NCRA
- North Happy Valley
- Rock Creek
- Sunnyside

All Other Features

- Study Area
- Major Road
- Watercourse
- Waterbody

N

0 2,000 4,000 6,000
Feet

Date: April 8, 2022
Data Sources: USGS, BLM, OGIC, METRO 2020

GSI Water Solutions, Inc.

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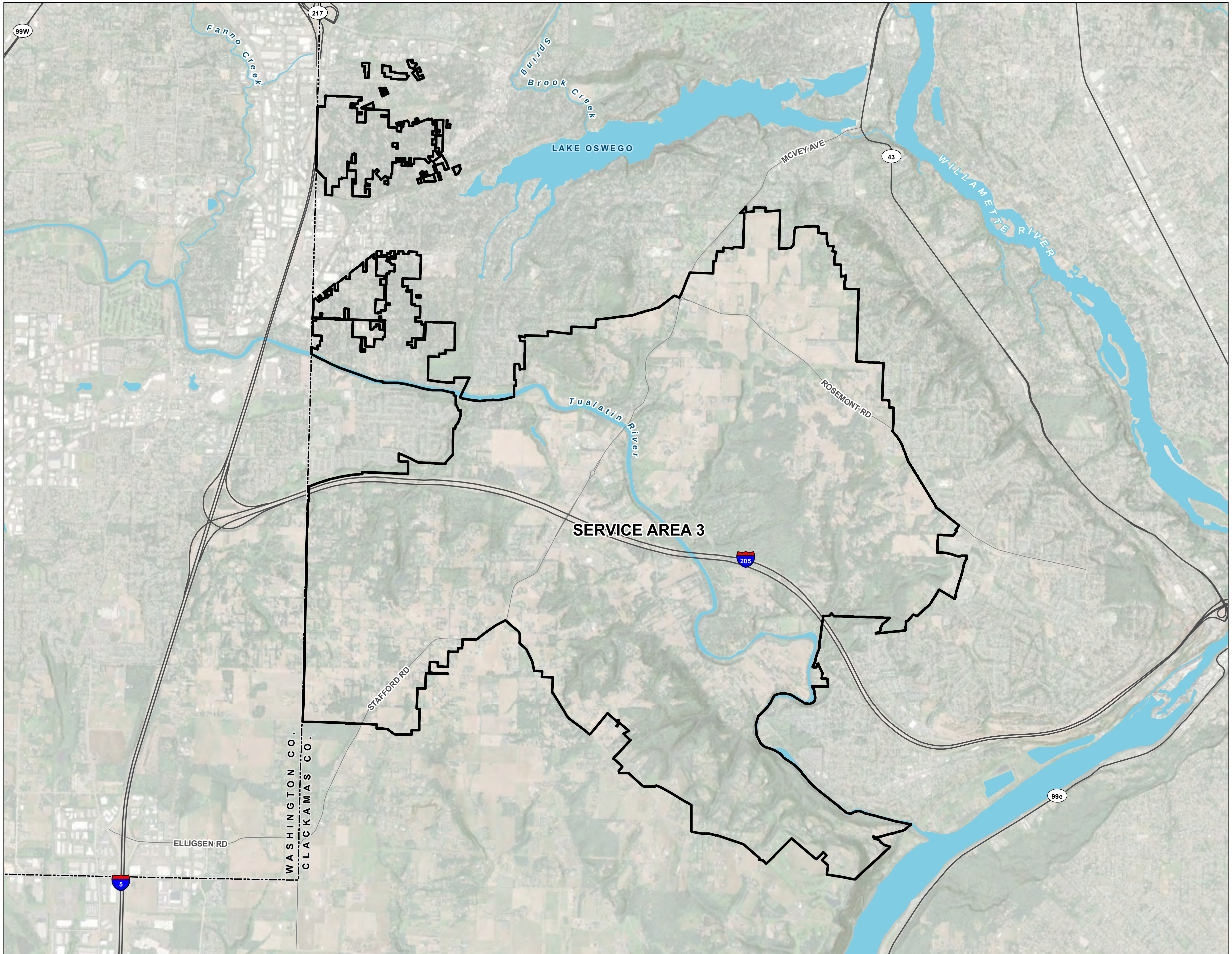

FIGURE 3

Location Map

Clackamas WES Service Areas 2 and 3

LEGEND

Study Area

All Other Features

County Boundary

Major Road

Watercourse

Waterbody

N

0 1,800 3,600 5,400

Feet

GSI Water Solutions, Inc.

Date: April 8, 2022
Data Sources: USGS, BLM, OGIC, METRO 2020

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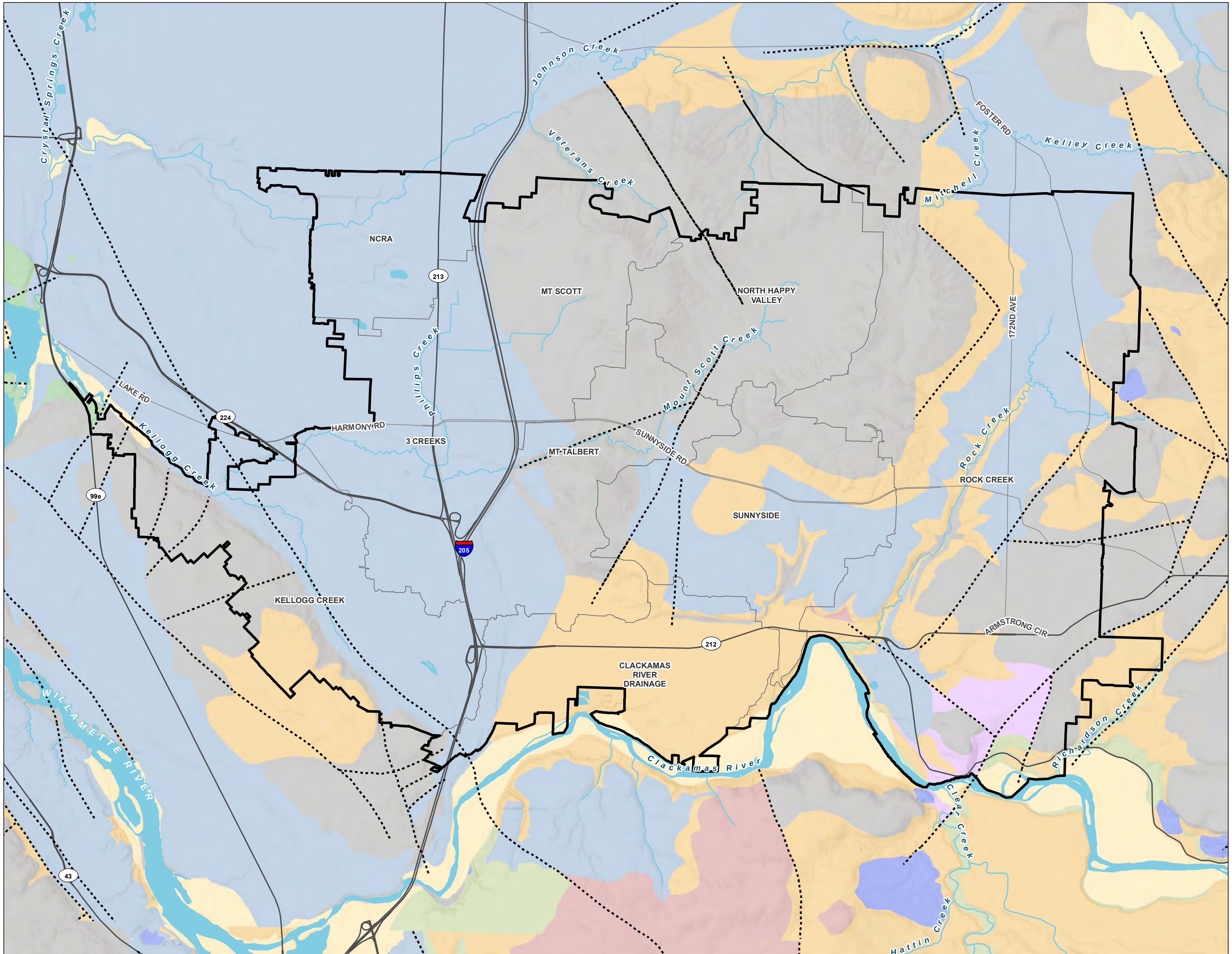

FIGURE 4

Surficial Geology

Clackamas WES Service Areas 2 and 3

LEGEND

Geology

- Fault
- Fold
- Quaternary Landslide Deposits
- Quaternary Alluvium
- Catastrophic Flood Deposits
- Quaternary Terrace Deposits
- Troutdale Formation
- Volcaniclastic Rock
- Boring Lava
- Columbia River Basalt
- Basalt of Waverly Heights

All Other Features

- Study Area
- Sewer District Boundary
- Major Road
- Watercourse
- Waterbody

N

0 2,000 4,000 6,000
Feet

GSI Water Solutions, Inc.

Date: July 15, 2016
Data Sources: OWRD, METRO, USGS, NRCS

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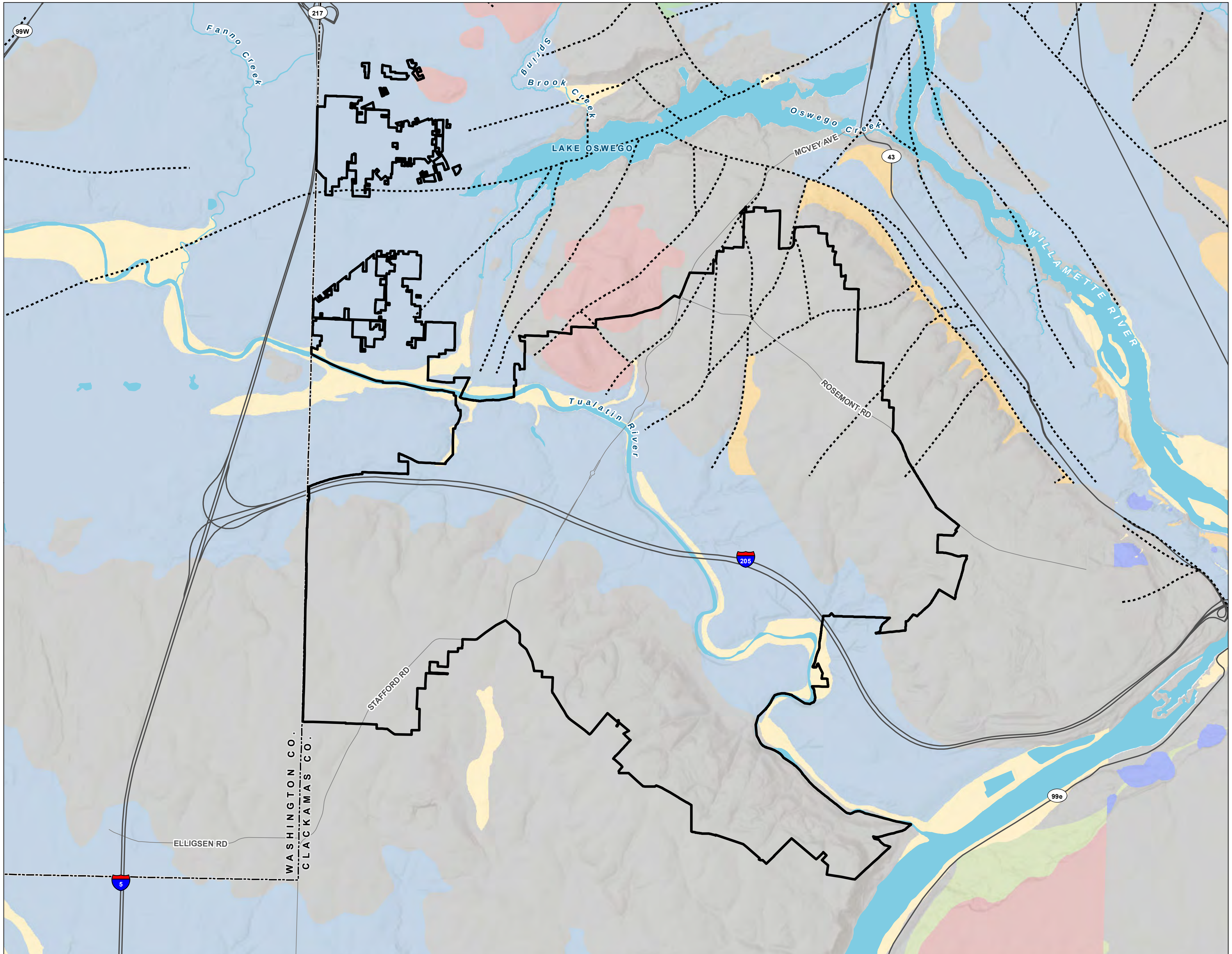


FIGURE 5

Surficial Geology

Clackamas WES Service Areas 2 and 3

LEGEND

Geology

- Fault
- Fold
- Quaternary Landslide Deposits
- Quaternary Alluvium
- Catastrophic Flood Deposits
- Quaternary Terrace Deposits
- Troutdale Formation
- Boring Lava
- Columbia River Basalt
- Basalt of Waverly Heights

All Other Features

- Study Area
- County Boundary
- Major Road
- Watercourse
- Waterbody

N

0 1,800 3,600 5,400
Feet

Date: April 8, 2022
Data Sources: USGS, BLM, OGIC, COP Imagery Taken Summer 2018.

GSI Water Solutions, Inc.

Document Path: Y:\0655_Otak\Source_Figures\002_WES_HV_StormSystem\Figure5_Geology.mxd, npalmer

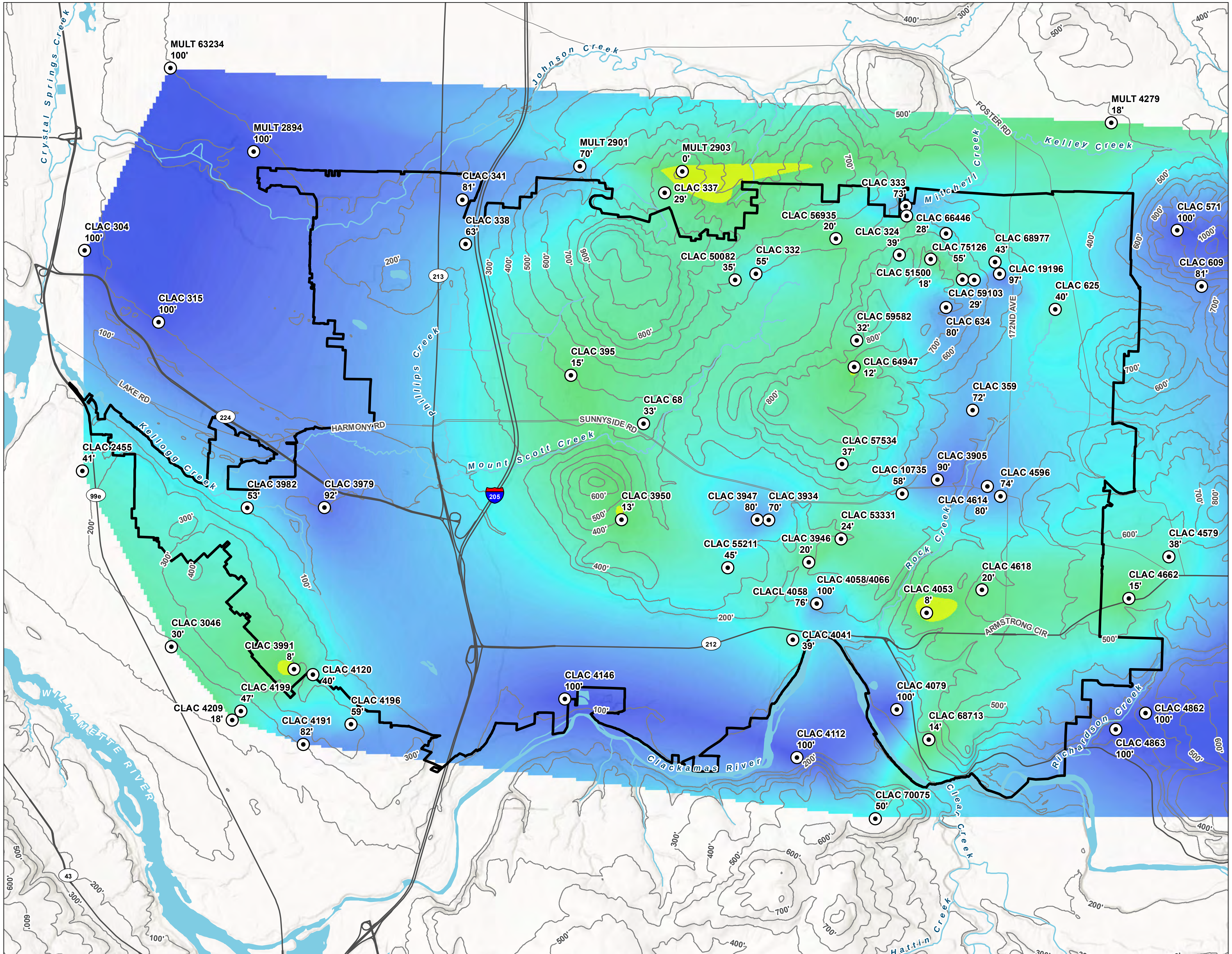


FIGURE 6

Depth to Bedrock

Clackamas WES Service Areas 2 and 3

LEGEND

- Well
- Surface Elevation Contour (100')
- Depth to Bedrock Less Than 15'

Depth to Bedrock (ft bgs)

0'

100'

All Other Features

- Study Area
- Major Road
- Watercourse
- Waterbody

N

0 2,000 4,000 6,000

Feet

Date: July 15, 2016

Data Sources: OWRD, METRO, USGS, NRCS

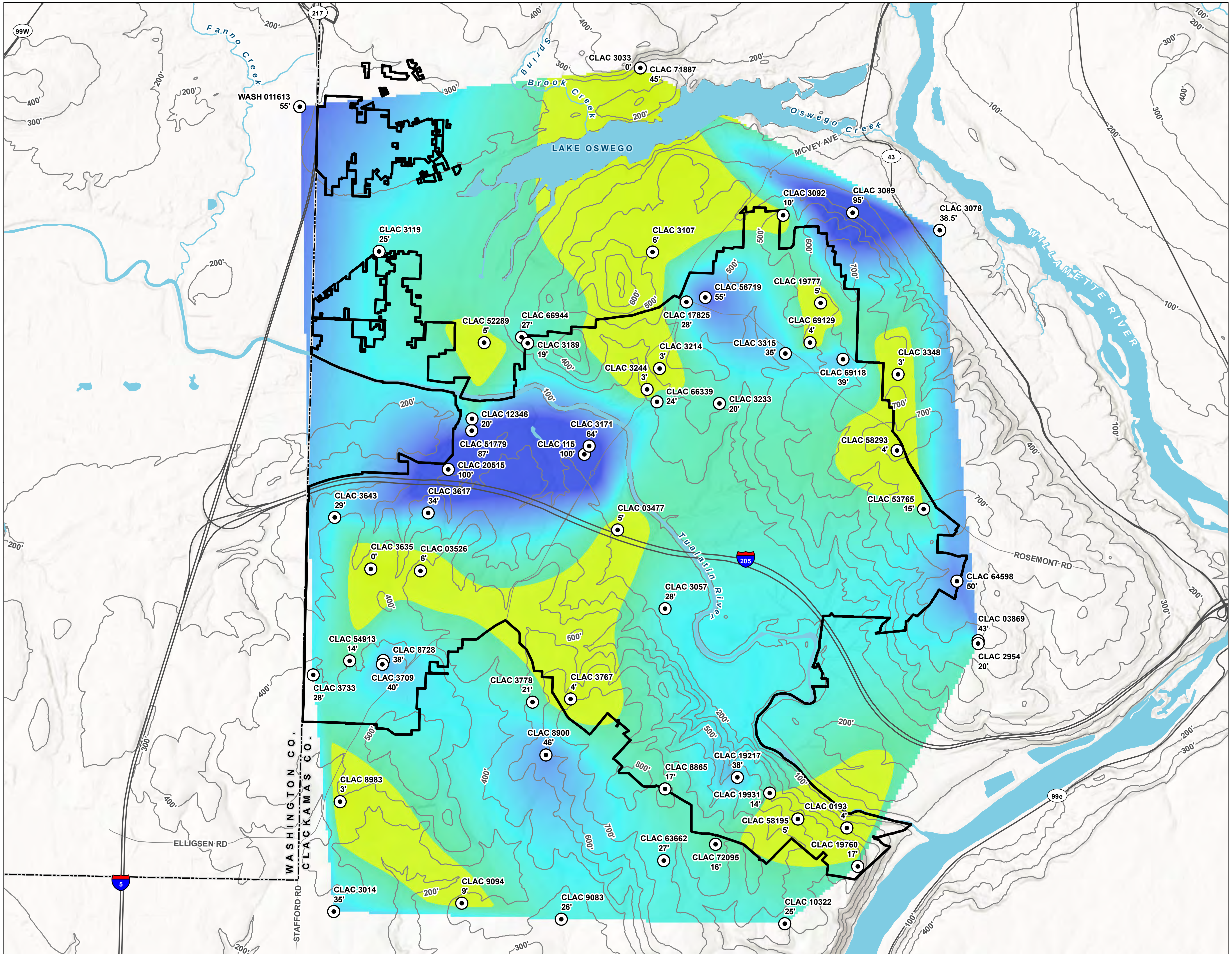
GSI Water Solutions, Inc.

Document Path: Y:\0655_Otak\Source_Figures\002_WES_HV_StormSystem\Figure6_Depth_to_Bedrock.mxd

FIGURE 7

Depth to Bedrock

Clackamas WES Service Areas 2 and 3



LEGEND

- Well
- Surface Elevation Contour (100')
- Depth to Bedrock Less Than 15' (ft bgs)

Depth to Bedrock (ft bgs)

0'

100'

All Other Features

- Study Area
- County Boundary
- Major Road
- Watercourse
- Waterbody

NOTE

bgs : below ground surface

N

0 1,800 3,600 5,400

Feet

Date: April 8, 2022

Data Sources: USGS, BLM, OGIC, OWRD

GSI Water Solutions, Inc.

Document Path: Y:\0655_Otak\Source_Figures\002_WES_HV_StormSystem\Figure7_Depth_to_Bedrock.mxd, npalmer

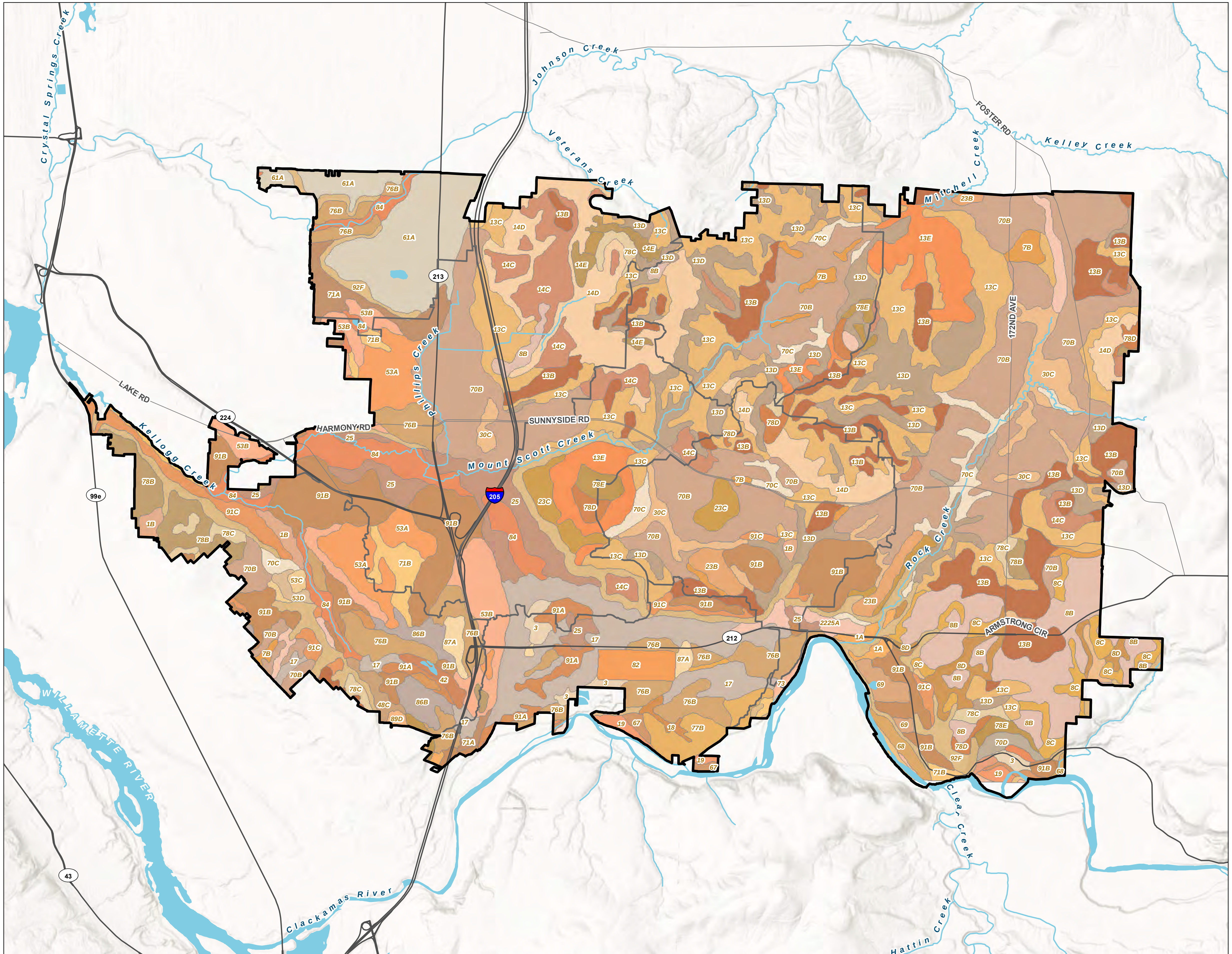


FIGURE 8

Clackamas Area Soil Groups

Clackamas WES Service
Areas 2 and 3

LEGEND

Soil Type

All Other Features

Study Area

Sewer District Boundary

Major Road

Watercourse

Waterbody

N

0 2,000 4,000 6,000
Feet

GSI Water Solutions, Inc.

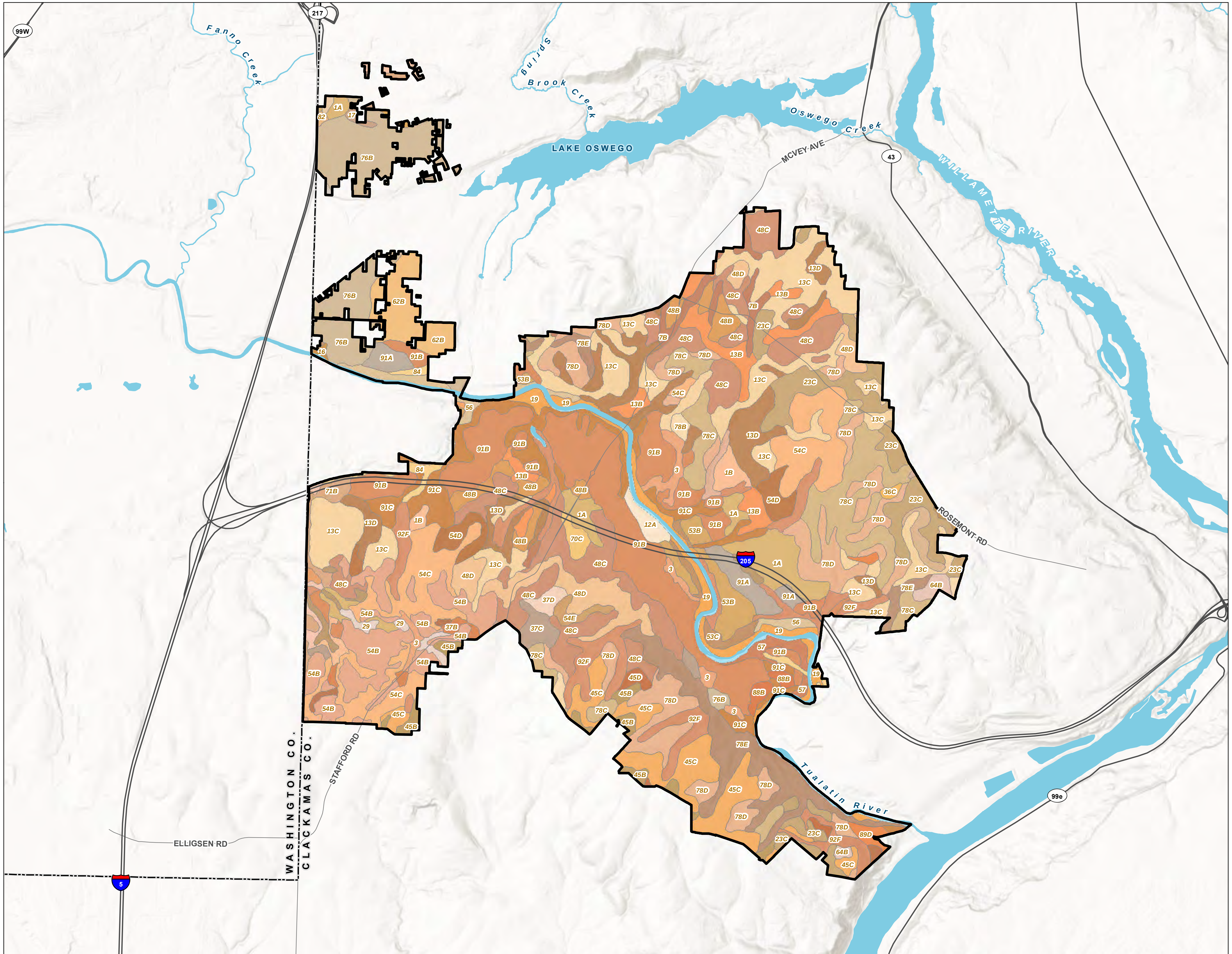
Date: July 15, 2016
Data Sources: OWRD, METRO, USGS, NRCS,
Air Photo Summer 2018 COP

Document Path: Y:\0655_Otak\Source_Figures\002_WES_HV_StormSystem\Figure8_Soil_Groups.mxd

FIGURE 9

NRCS Soil Groups

Clackamas WES Service
Areas 2 and 3



LEGEND

- Soil Type

All Other Features

- Study Area
- County Boundary
- Major Road
- Watercourse
- Waterbody

N

0 1,800 3,600 5,400
Feet

Date: April 8, 2022
Data Sources: USGS, BLM, OGIC, NRCS

GSI Water Solutions, Inc.

Document Path: Y:\0655_Otak\Source_Figures\002_WES_HV_StormSystem\Figure9_Soil_Groups.mxd, npalmer

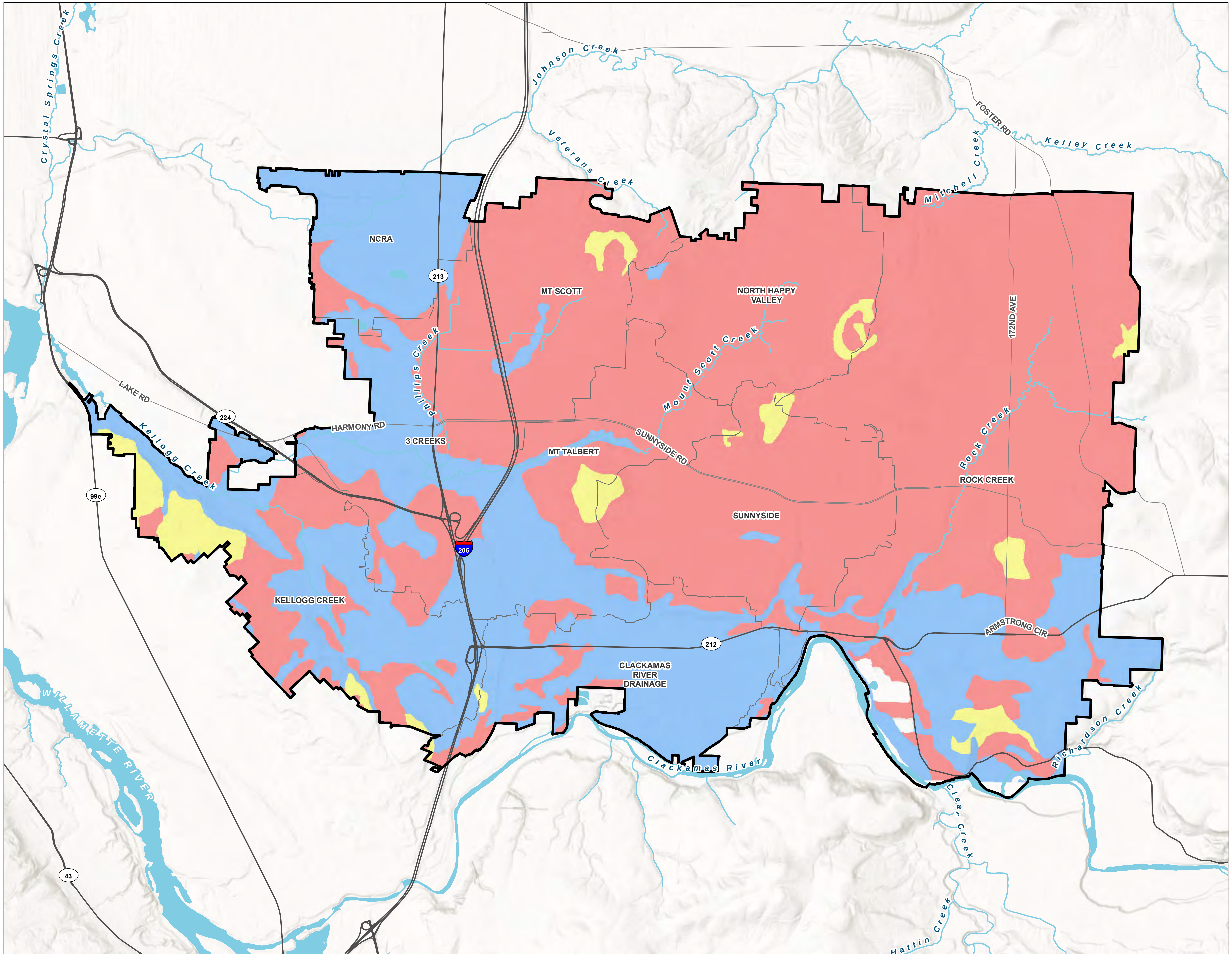


FIGURE 10

Depth to Restrictive Layer

Clackamas WES Service Areas 2 and 3

LEGEND

Depth to Restrictive Layer

- 0 - 100 cm (0 - 3.3 ft)
- 100 - 200 cm (3.3 - 6.5 ft)
- >200 cm (>6.5 ft)

All Other Features

- Study Area
- Sewer District Boundary
- Major Road
- Watercourse
- Waterbody

N

0 2,000 4,000 6,000
Feet

Date: July 15, 2016
Data Sources: OWRD, METRO, USGS, NRCS

GSI Water Solutions, Inc.

Document Path: Y:\0655_Otak\Source_Figures\002_WES_HV_StormSystem\Figure10_Depth_to_Restrictive_Layer.mxd

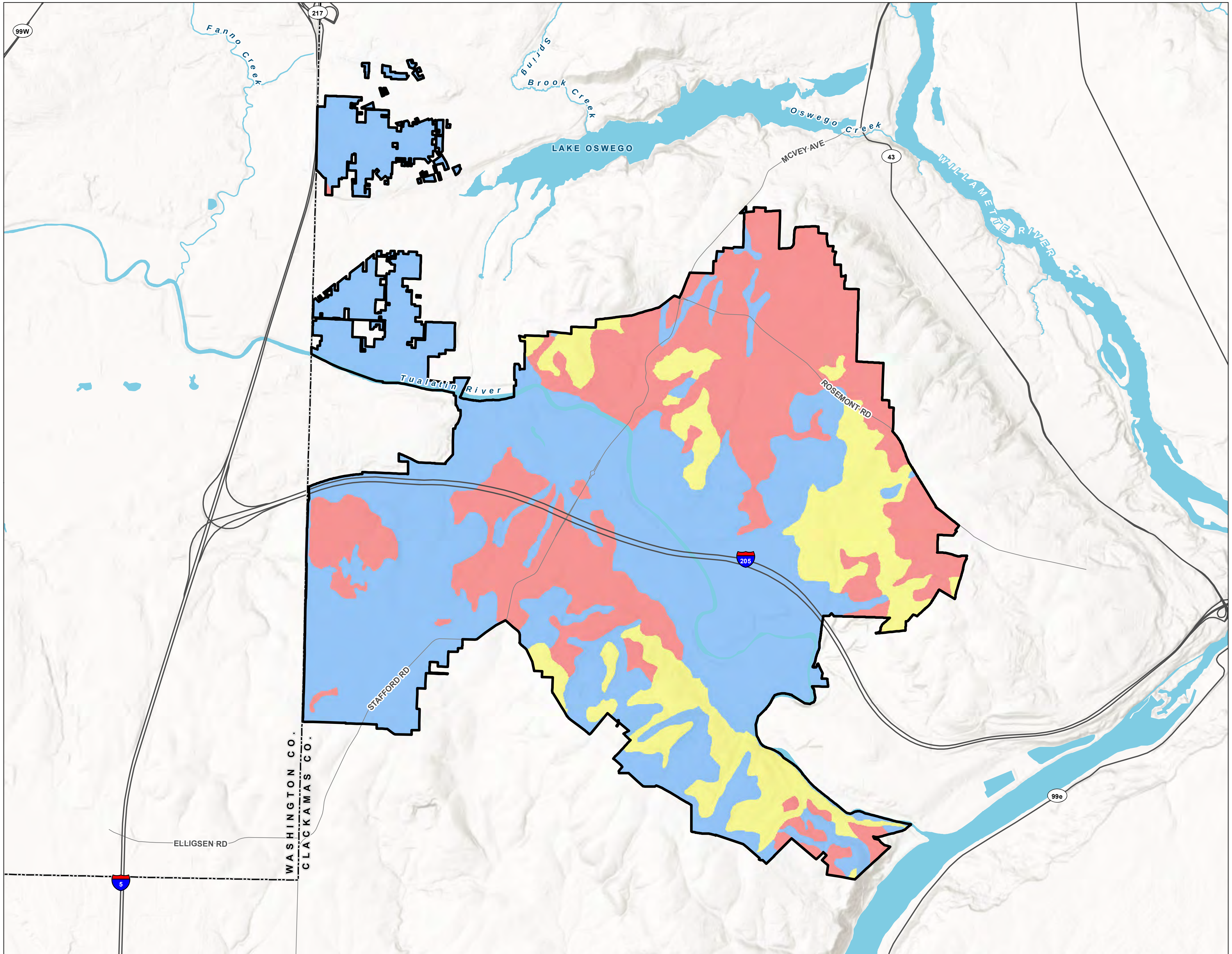


FIGURE 11

Depth to Restrictive Layer

Clackamas WES Service Areas 2 and 3

LEGEND

Depth to Restrictive Layer

- 0 - 100 cm (>40 in)
- 100 - 200 cm (40 - 78 in)
- >200 cm (>78in)

All Other Features

- Study Area
- County Boundary
- Major Road
- Watercourse
- Waterbody

N

0 1,800 3,600 5,400
Feet

GSI Water Solutions, Inc.

Date: April 8, 2022
Data Sources: USGS, BLM, OGIC, NRCS

Document Path: Y:\0655_Otak\Source_Figures\002_WES_HV_StormSystem\Figure11_Depth_to_Restrictive_Layer.mxd, npalmer

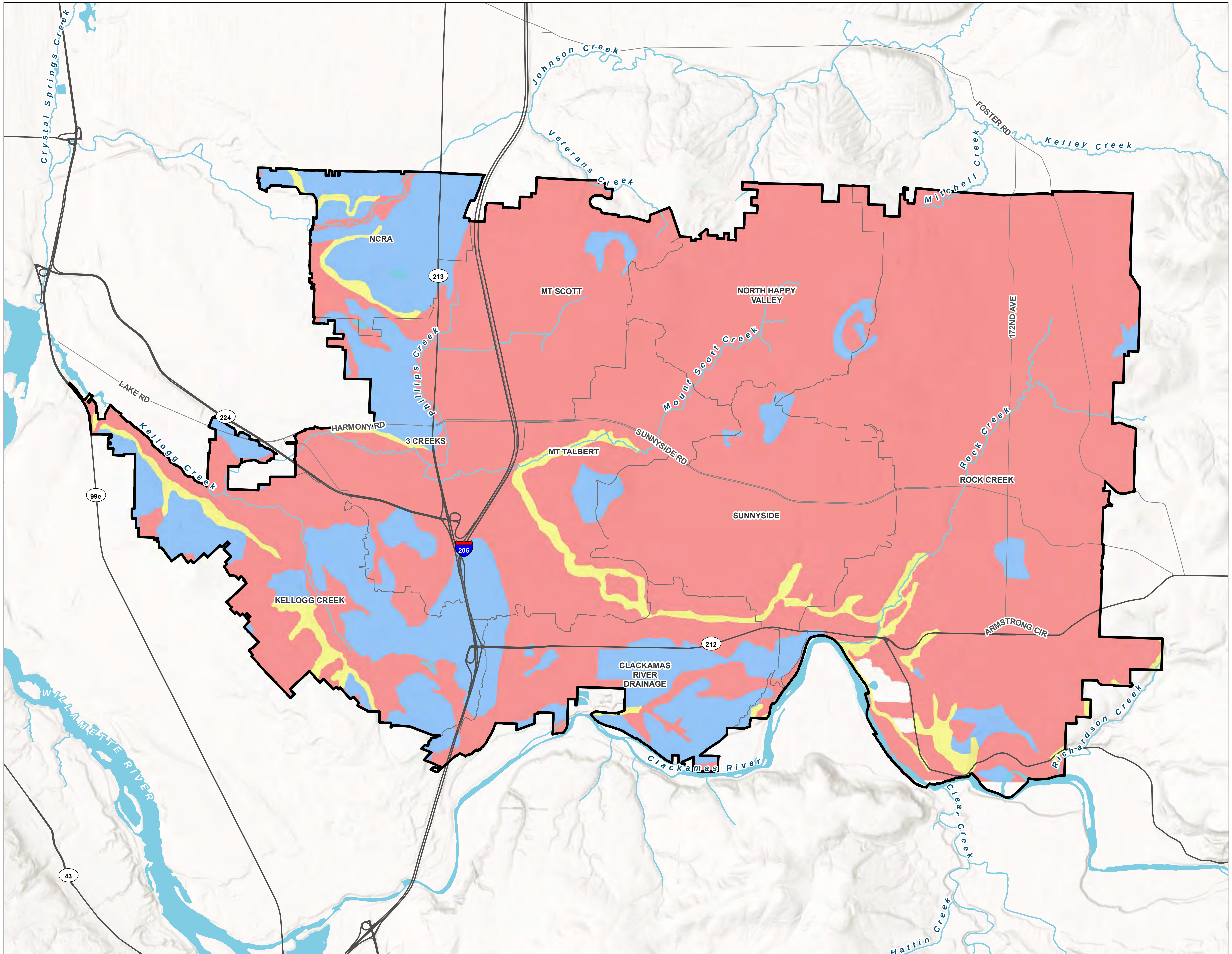


FIGURE 12

Depth to Shallow Water Table From NRCS Soil Data

Clackamas WES Service Areas 2 and 3

LEGEND

Depth to Water Table

- 0 - 100 cm (0 - 3.3 ft)
- 100 - 200 cm (3.3 - 6.5 ft)
- >200 cm (>6.5ft)

All Other Features

- Study Area
- Sewer District Boundary
- Major Road
- Watercourse
- Waterbody

N

0 2,000 4,000 6,000
Feet

Date: July 15, 2016
Data Sources: OWRD, METRO, USGS, NRCS

GSI Water Solutions, Inc.

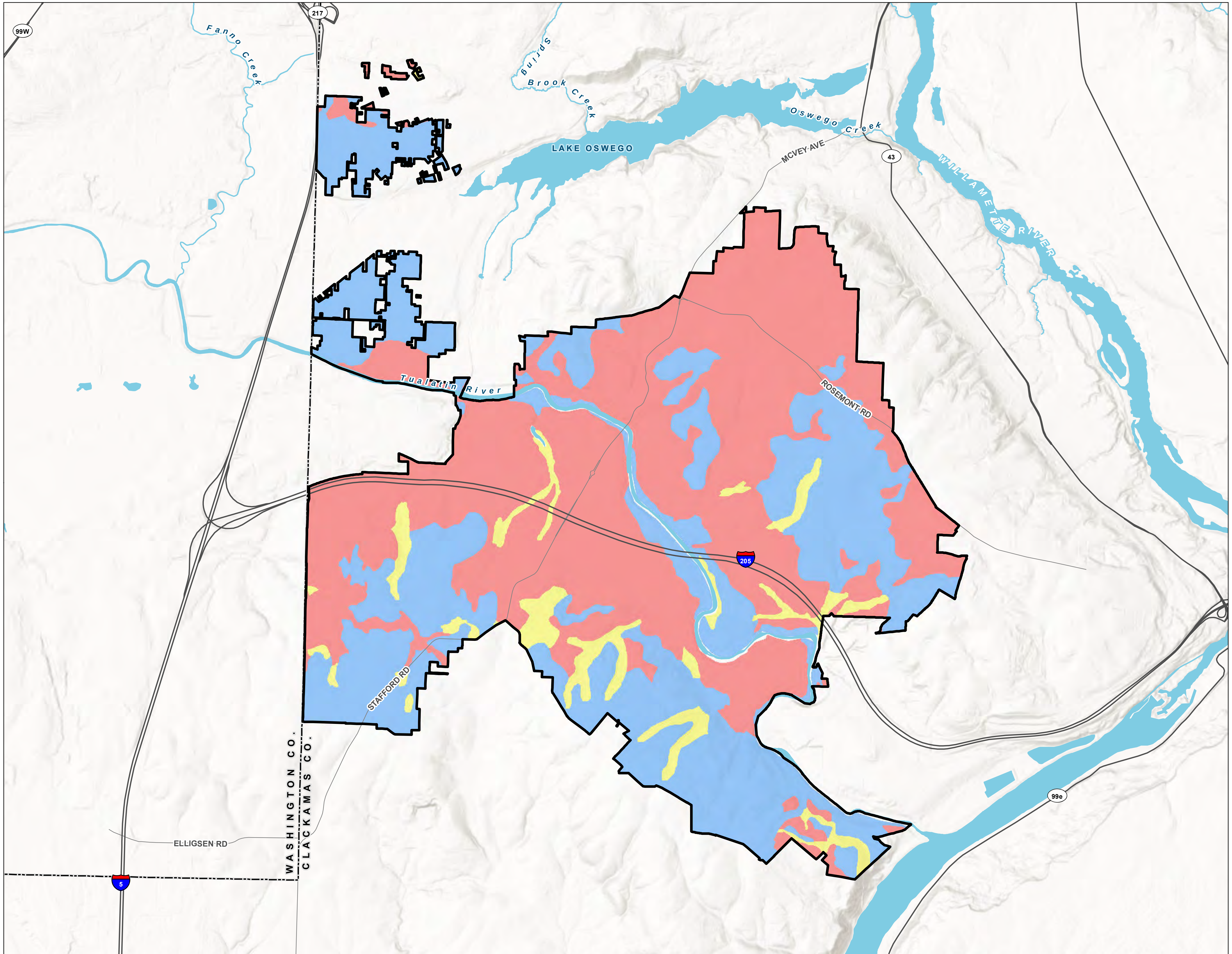


FIGURE 13

Depth to Shallow Water Table From NRCS Soil Data

Clackamas WES Service Areas 2 and 3

LEGEND

Depth to Water Table

- 0 - 100 cm (>40 in)
- 100 - 200 cm (40 - 78 in)
- >200 cm (>78 in)

All Other Features

- Study Area
- County Boundary
- Major Road
- Watercourse
- Waterbody

N

0 1,800 3,600 5,400
Feet

Date: April 8, 2022
Data Sources: USGS, BLM, OGIC, NRCS.

GSI Water Solutions, Inc.

Document Path: Y:\0655_Otak\Source_Figures\002_WES_HV_StormSystem\Figure13_Depth_to_Water_Table.mxd, npalmer

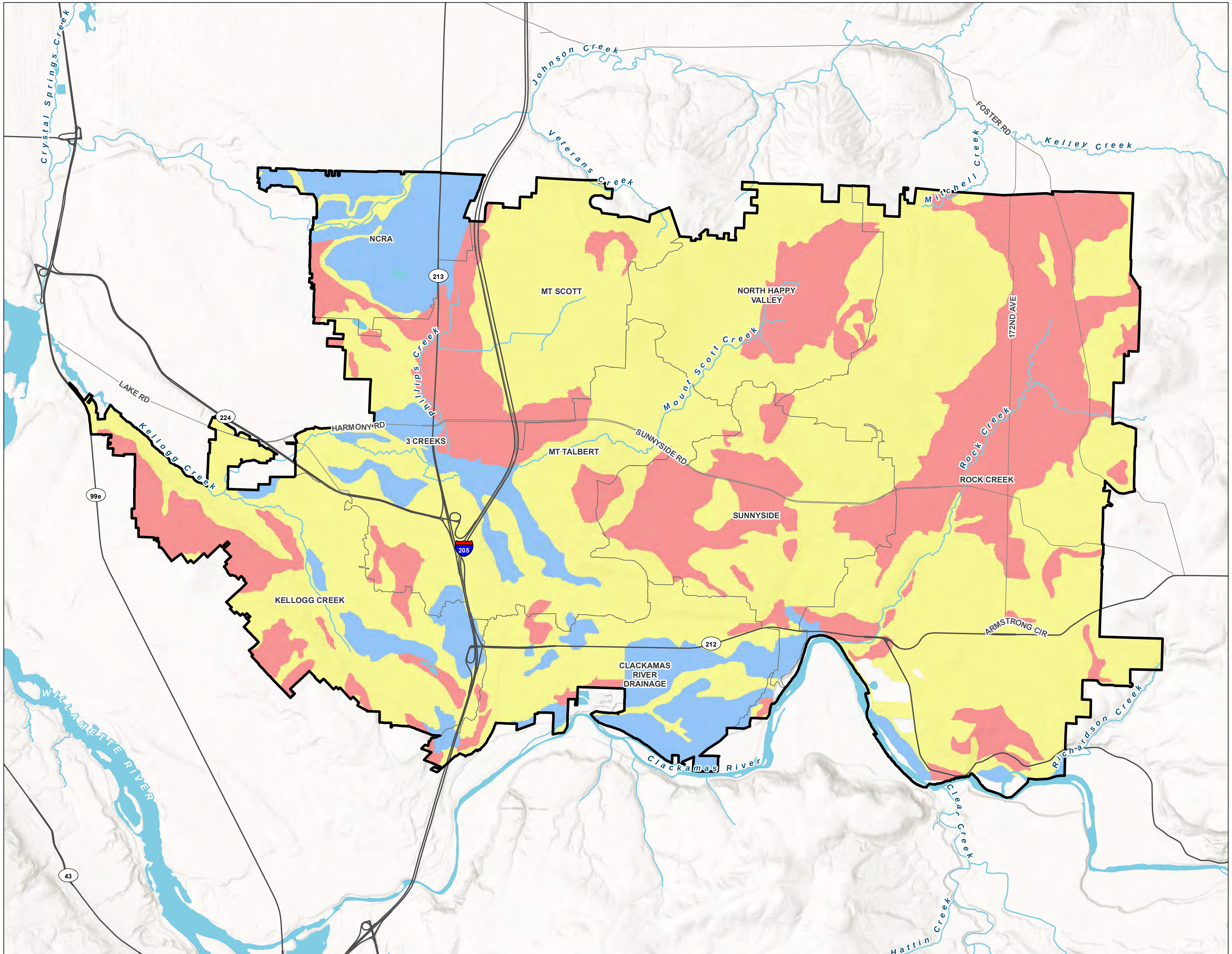


FIGURE 14

Saturated Hydraulic Conductivity

Clackamas WES Service Areas 2 and 3

LEGEND

Ksat Rating, in/hr

- 0 - 0.5
- 0.5 - 2
- >2

All Other Features

- Study Area
- Sewer District Boundary
- Major Road
- Watercourse
- Waterbody

N

0 2,000 4,000 6,000
Feet

GSI Water Solutions, Inc.

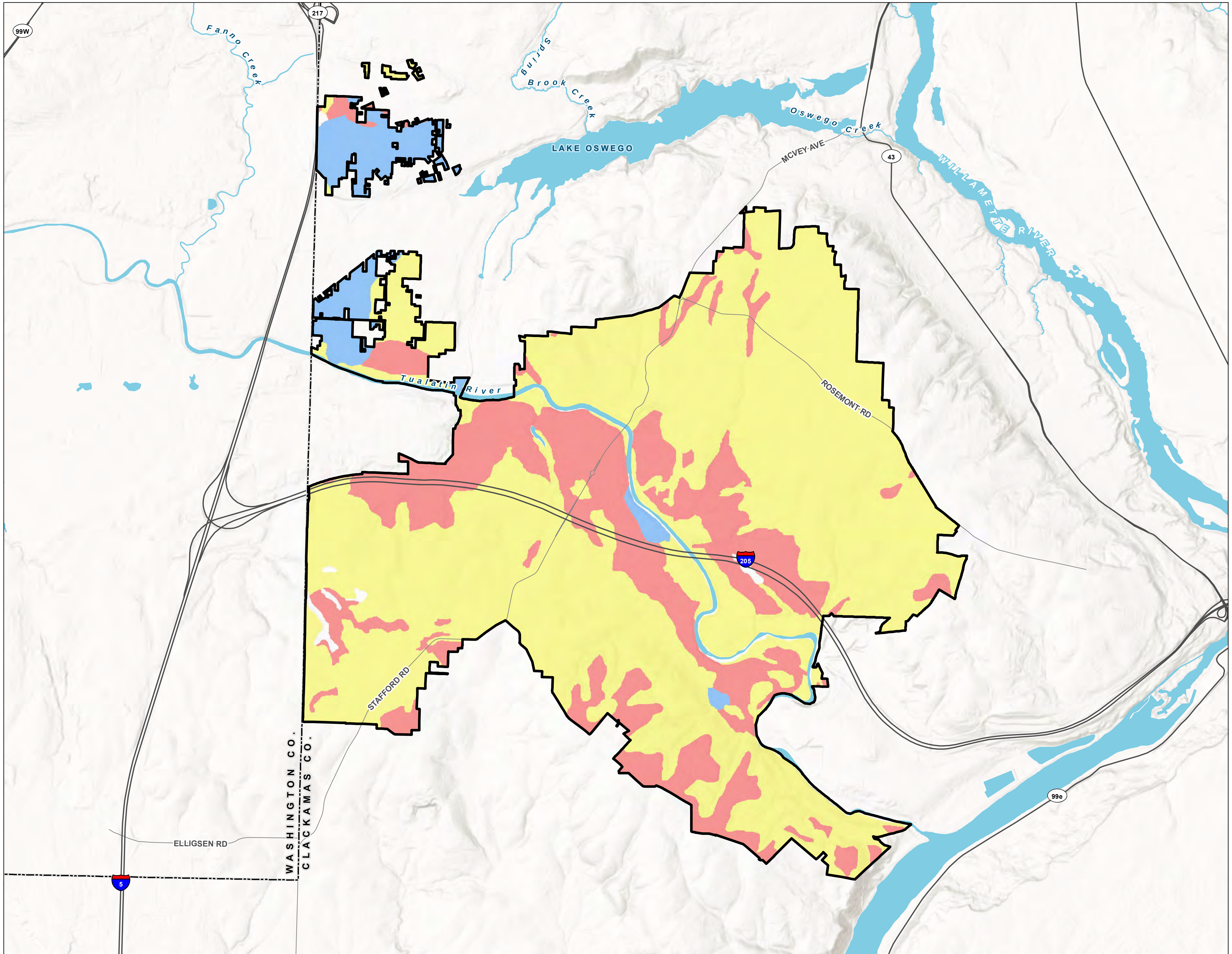
Date: July 15, 2016
Data Sources: OWRD, METRO, USGS, NRCS

Document Path: Y:\0655_Otak\Source_Figures\002_WES_HV_StormSystem\Figure14_Sat_Hydro_Conductivity.mxd

FIGURE 15

Saturated Hydraulic Conductivity

Clackamas WES Service Areas 2 and 3



LEGEND

Ksat Rating, in/hr

- 0 - 0.5
- 0.5 - 2
- >2

All Other Features

- Study Area
- County Boundary
- Major Road
- Watercourse
- Waterbody

N

0 1,800 3,600 5,400
Feet

Date: April 8, 2022
Data Sources: USGS, BLM, OGIC, NRCS.

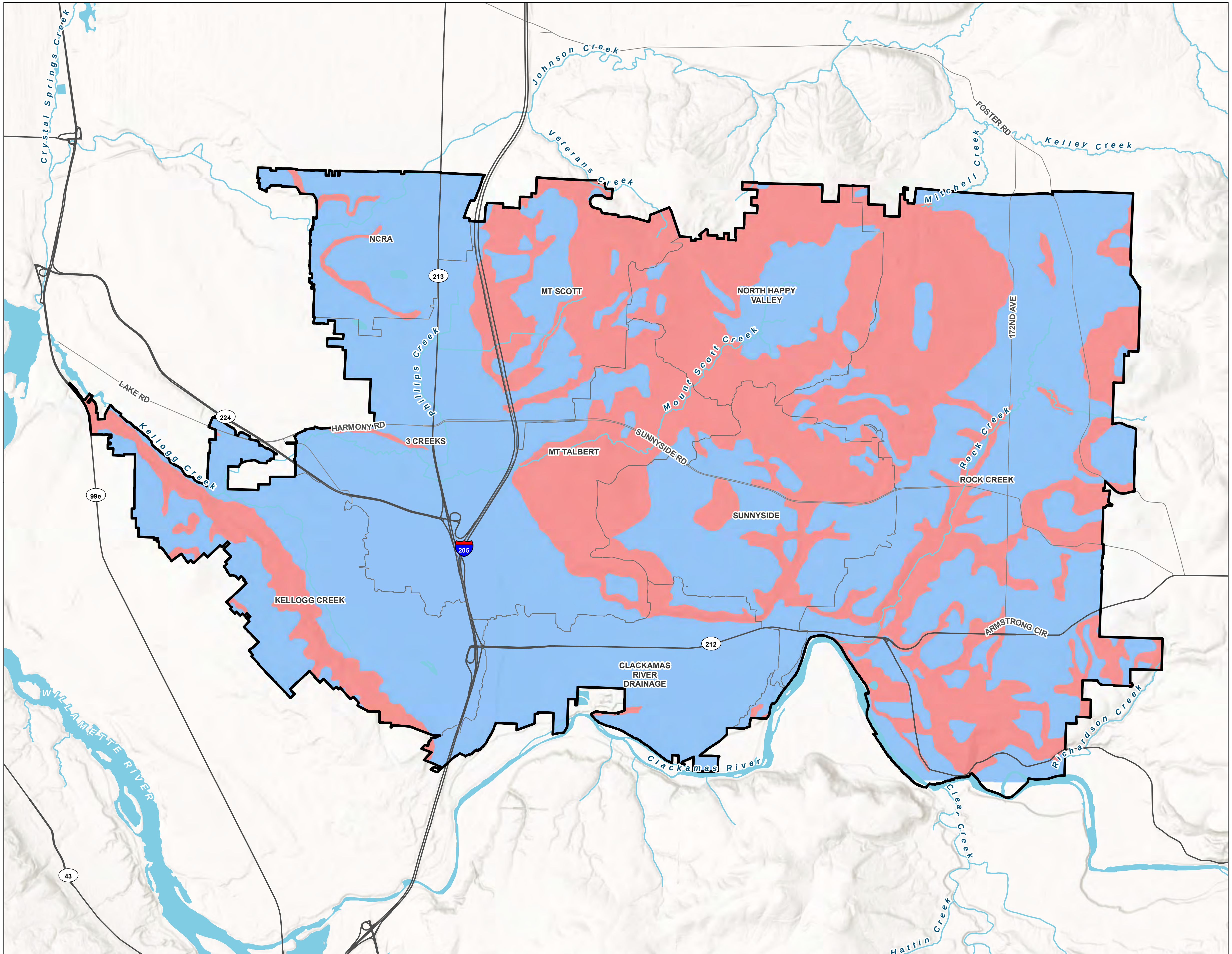
GSI Water Solutions, Inc.

Document Path: Y:\0655_Otak\Source_Figures\002_WES_HV_StormSystem\Figure15_Sat_Hydro_Conductivity.mxd, npalmer

FIGURE 16

Ground Slope

Clackamas WES Service Areas 2 and 3



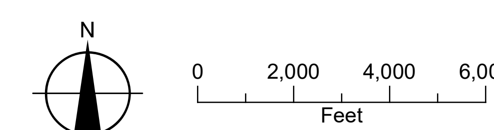
LEGEND

Slope, %

- 0 - 10
- >10

All Other Features

- Study Area
- Sewer District Boundary
- Major Road
- Watercourse
- Waterbody



Date: July 15, 2016
Data Sources: OWRD, METRO, USGS, NRCS

GSI Water Solutions, Inc.

Document Path: Y:\0655_Otak\Source_Figures\002_WES_HV_StormSystem\Figure16_Ground_Slope.mxd

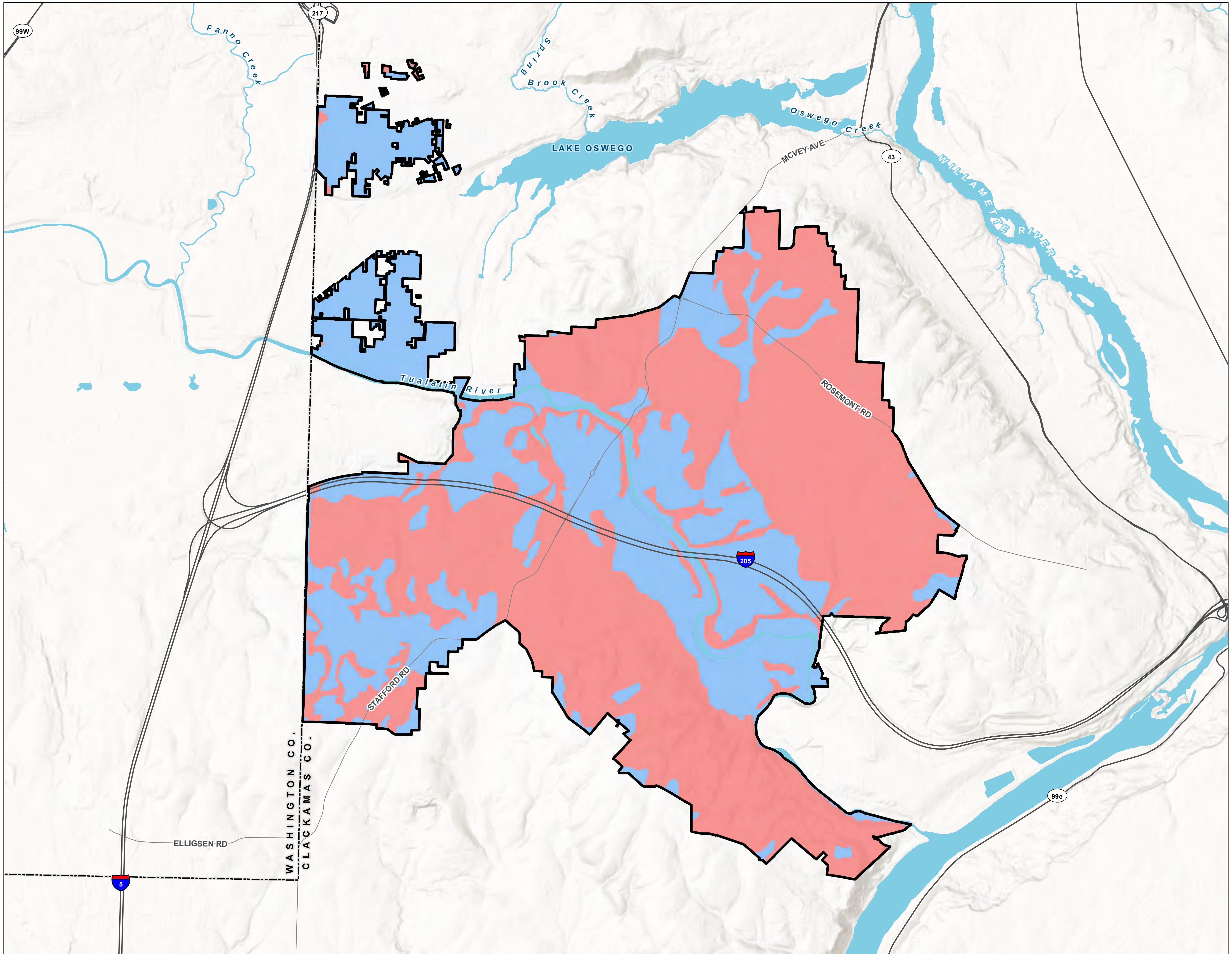


FIGURE 17

Ground Slope

Clackamas WES Service Areas 2 and 3

LEGEND

Slope, %

- 0 - 10
- >10

All Other Features

- Study Area
- County Boundary
- Major Road
- Watercourse
- Waterbody

N

0 1,800 3,600 5,400

Feet

Date: April 8, 2022

Data Sources: USGS, BLM, OGIC, NRCS.

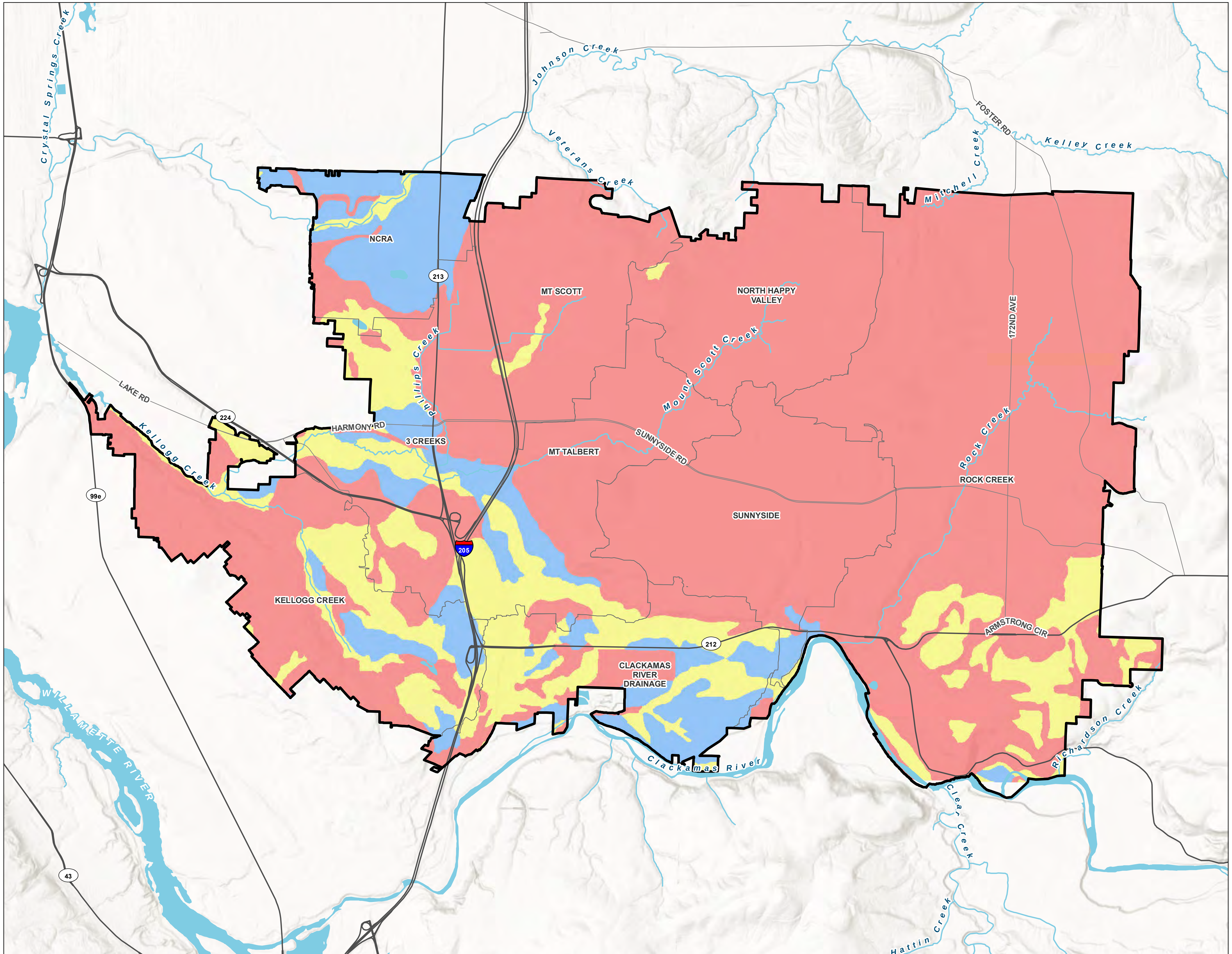
GSI Water Solutions, Inc.

Document Path: Y:\0655_Otak\Source_Figures\002_WES_HV_StormSystem\Figure17_Ground_Slope.mxd, npalmer

FIGURE 18

Infiltration Potential

Clackamas WES Service
Areas 2 and 3



LEGEND

Infiltration Rating

- Poor
- Moderate
- Good

All Other Features

- Study Area
- Sewer District Boundary
- Major Road
- Watercourse
- Waterbody

N

0 2,000 4,000 6,000
Feet

GSI Water Solutions, Inc.

Date: July 15, 2016
Data Sources: OWRD, METRO, USGS, NRCS

Document Path: Y:\0655_Otak\Source_Figures\002_WES_HV_StormSystem\Figure18_Infiltration_Potential.mxd

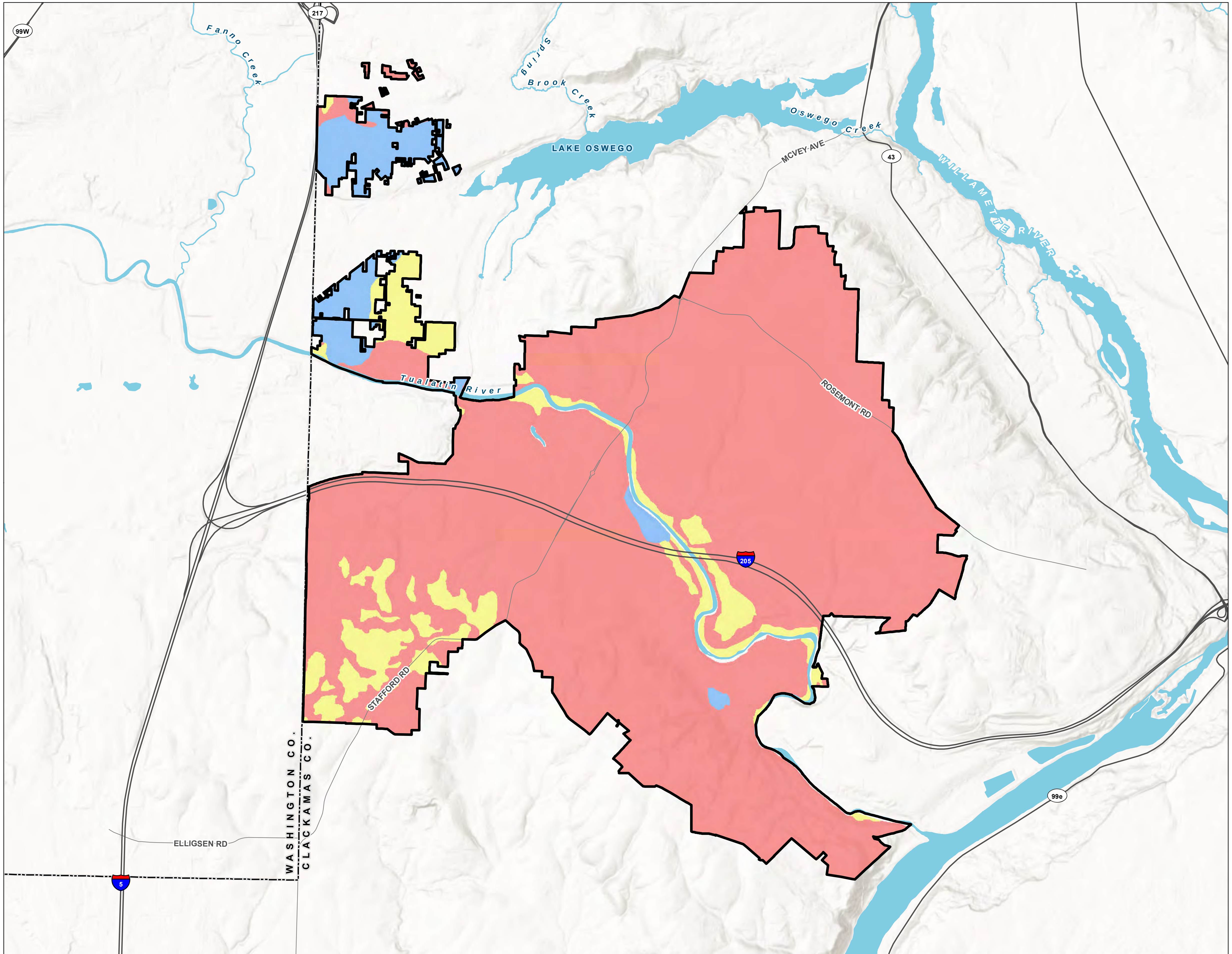


FIGURE 19

Infiltration Potential

Clackamas WES Service Areas 2 and 3

LEGEND

Infiltration Rating

- Poor
- Moderate
- Good

All Other Features

- Study Area
- County Boundary
- Major Road
- Watercourse
- Waterbody

N

0 1,800 3,600 5,400

Feet

GSI Water Solutions, Inc.

Date: April 8, 2022
Data Sources: USGS, BLM, OGIC, NRCS.

Document Path: Y:\0655_Otak\Source_Figures\002_WES_HV_StormSystem\Figure19_Infiltration_Potential.mxd, npalmer

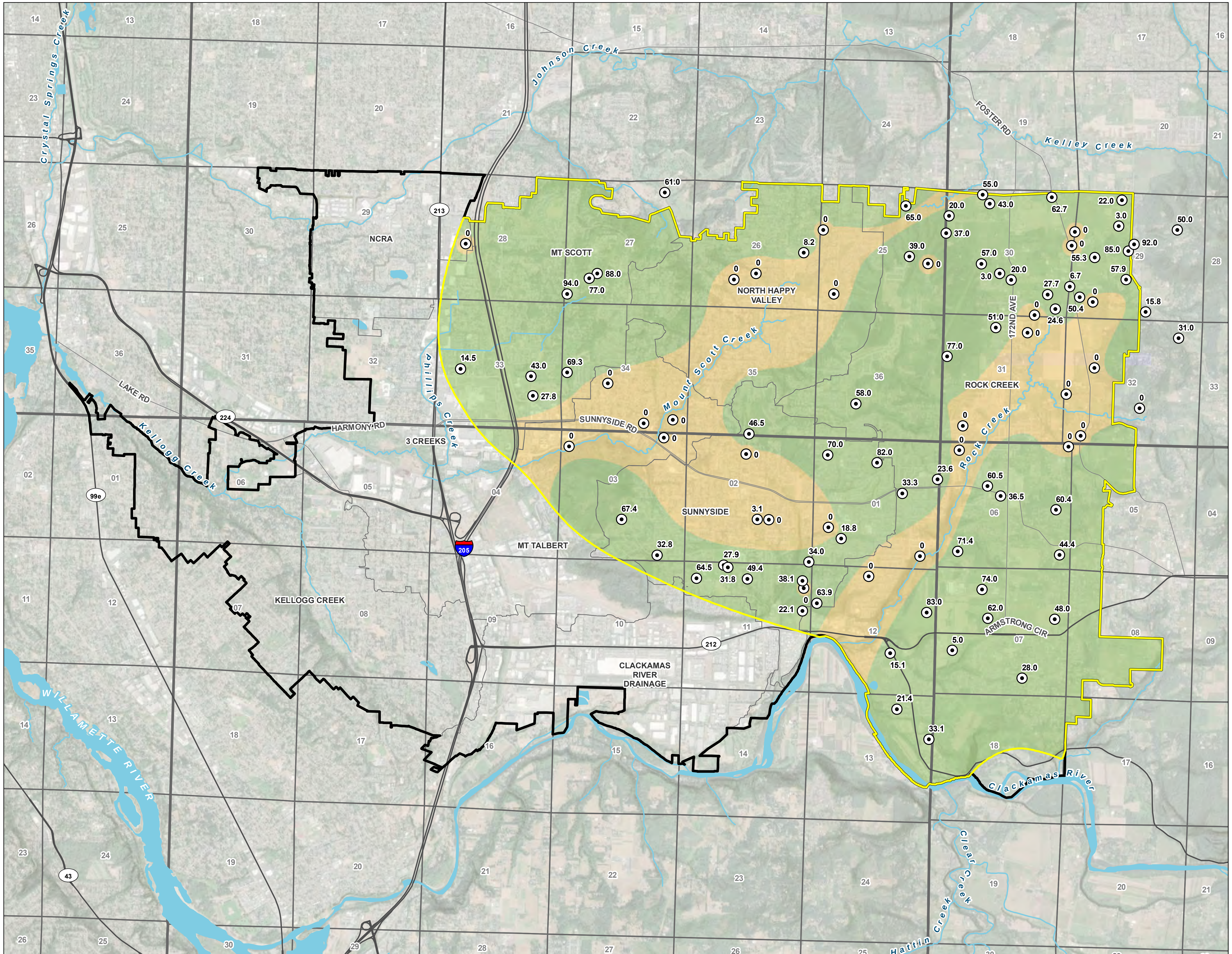


FIGURE 20

Sub-Silt Infiltration Potential

Clackamas WES Service Areas 2 and 3

LEGEND

- Well, Values are the Thickness (feet) of Unsaturated Gravel within 100 feet of Ground Surface
- Sub-Silt Infiltration Study Area
- Infiltration, Feasible
- Infiltration, Not Feasible

All Other Features

- Study Area
- Sewer District Boundary
- Major Road
- Watercourse
- Waterbody

N

0 2,000 4,000 6,000
Feet

Date: 6/21/2022
Data Sources: OWRD, METRO, USGS, NRCS

GSI Water Solutions, Inc.

Document Path: Y:\0655_Otak\Source_Figures\002_WES_HV_StormSystem\Figure20_SubSilt_Infiltration.mxd

Appendix B

Study Area Detail Maps

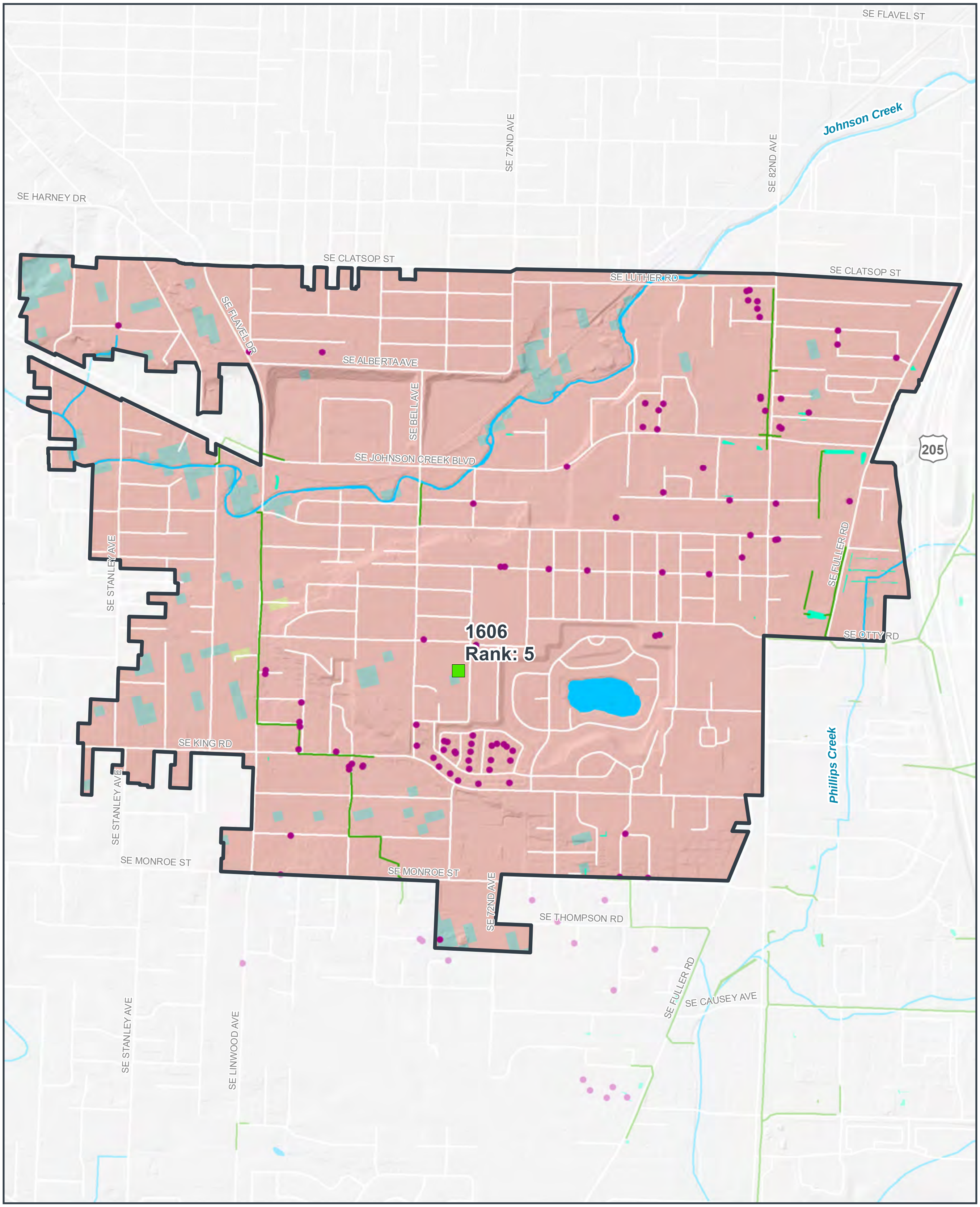


FIGURE B-1

NCRA
STUDY AREA

WES STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY, OR

Study Area
Stream/Waterbody
Dry Well
Storm Pipe (24"+)
Storm Facility

Land Use
Developed
Forest/Open Space
Pasture
Storm System Projects

DATE: 12/22/2020

0 — 1,400 ft

CLACKAMAS WATER ENVIRONMENT SERVICES

Otak

L:\PROJECT\19100\19109\CADD\GIS\MXDS\MASTER PLAN REPORT MAPS\FIG_STUDYAREA_NCRA.MXD

NOTE: THIS DATA IS NOT A SURVEY AND IS MEANT FOR PLANNING PURPOSES ONLY. DATA IS PROVIDED BY ESRI, WES, AND METRO RLIS.

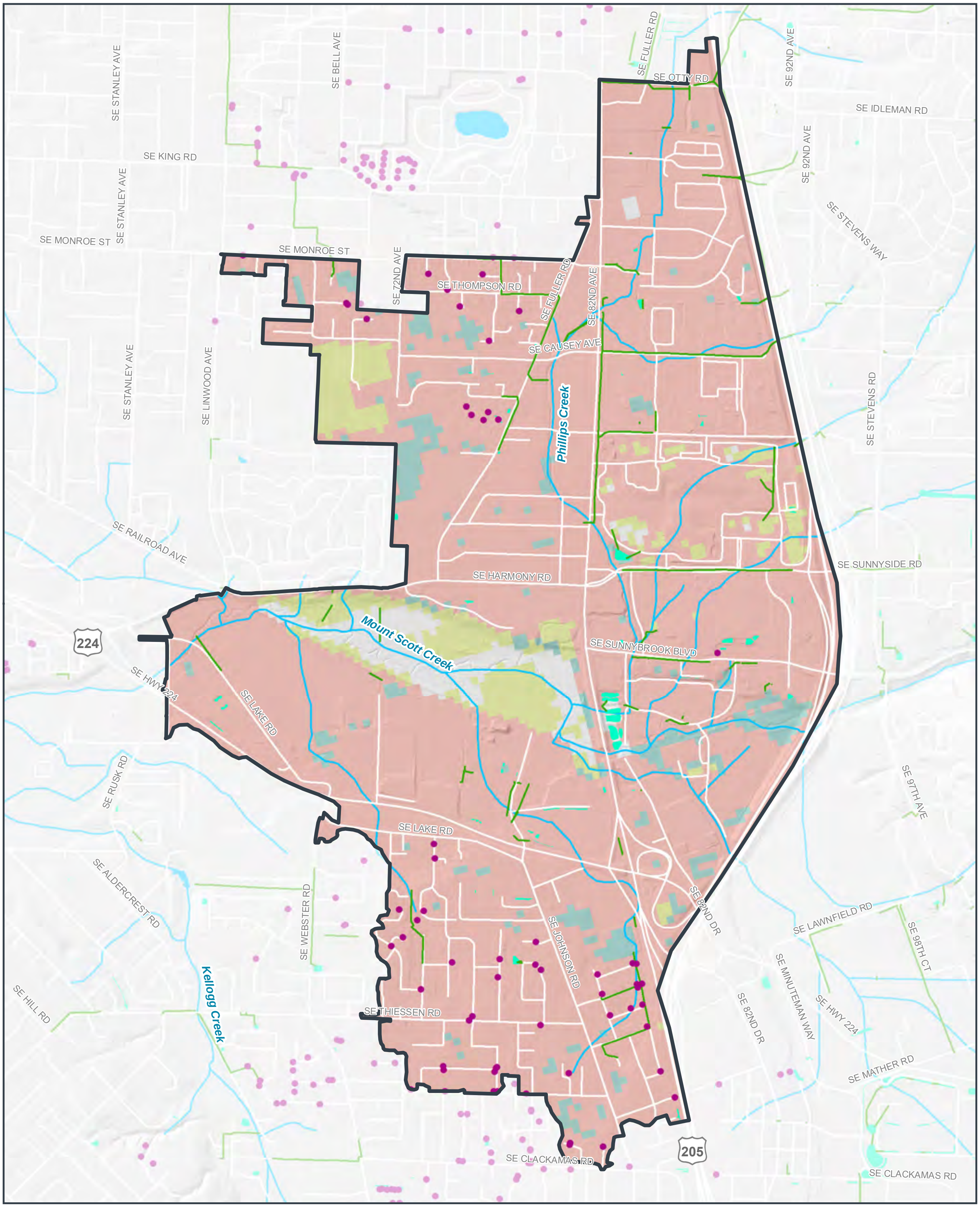


FIGURE B-2

THREE CREEKS STUDY AREA

WES STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY, OR

Study Area
Stream/Waterbody
Dry Well
Storm Pipe (24"+)
Storm Facility

Land Use
Developed
Forest/Open Space
Pasture

DATE: 12/22/2020

ft
0 1,900

CLACKAMAS WATER ENVIRONMENT SERVICES

Otak

L:\PROJECT\19100\19109\CADD\GIS\MXDS\MASTER PLAN REPORT MAPS\FIG_STUDYAREA_3CREEKS.MXD

NOTE: THIS DATA IS NOT A SURVEY AND IS MEANT FOR PLANNING PURPOSES ONLY. DATA IS PROVIDED BY ESRI, WES, AND METRO RLIS.

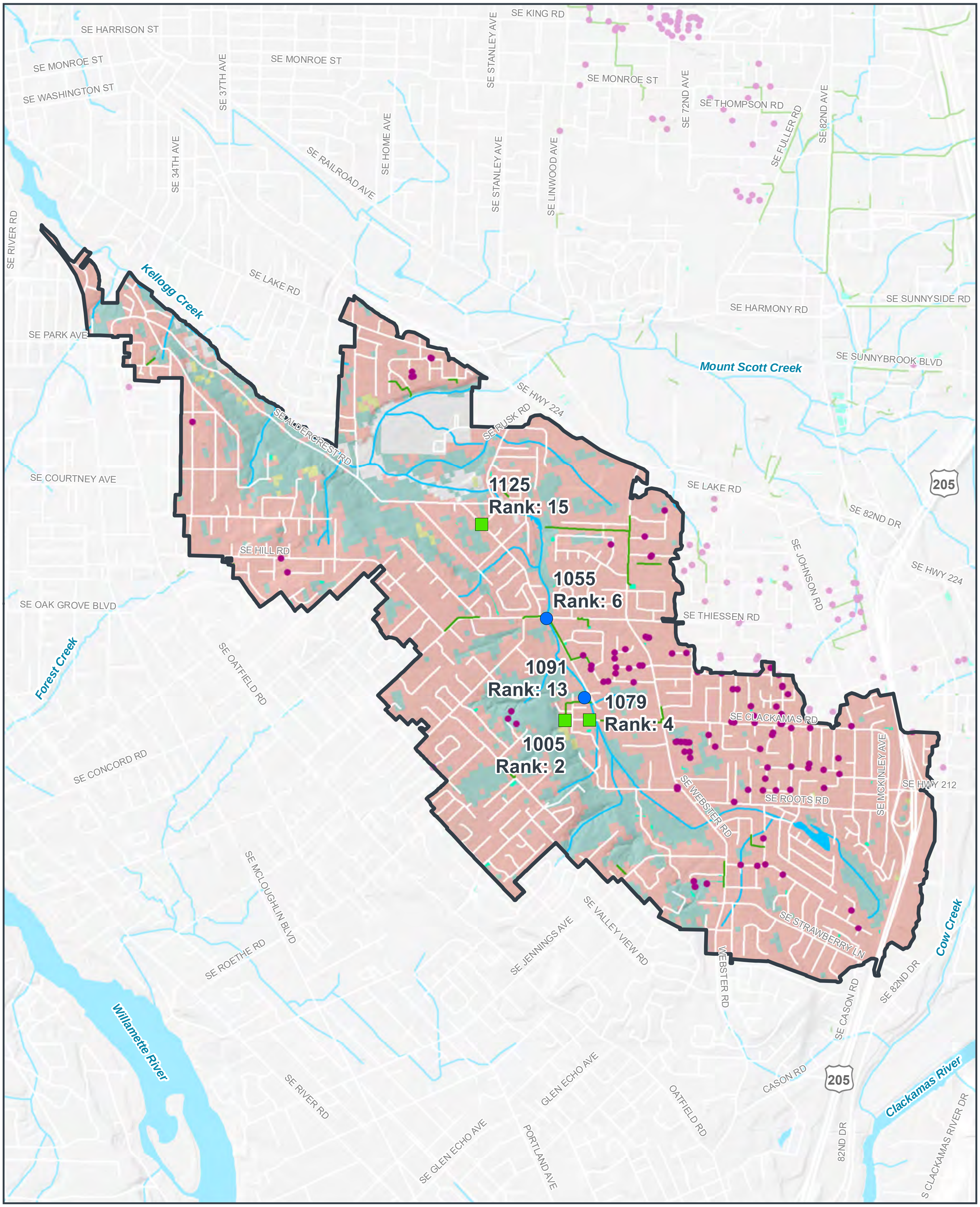


FIGURE B-3

KELLOGG CREEK STUDY AREA

WES STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY, OR

Study Area
Stream/Waterbody
Dry Well
Storm Pipe (24"+)
Storm Facility

Land Use
Developed
Forest/Open Space
Pasture
Storm System Projects
Culvert/In-Stream Projects

DATE: 12/22/2020

ft
0 2,700

CLACKAMAS WATER ENVIRONMENT SERVICES

Otak

L:\PROJECT\19100\19109\CADD\GIS\MXDS\MASTER PLAN REPORT MAPS\FIG_STUDYAREA_KELLOGG.MXD

NOTE: THIS DATA IS NOT A SURVEY AND IS MEANT FOR PLANNING PURPOSES ONLY. DATA IS PROVIDED BY ESRI, WES, AND METRO RLIS.

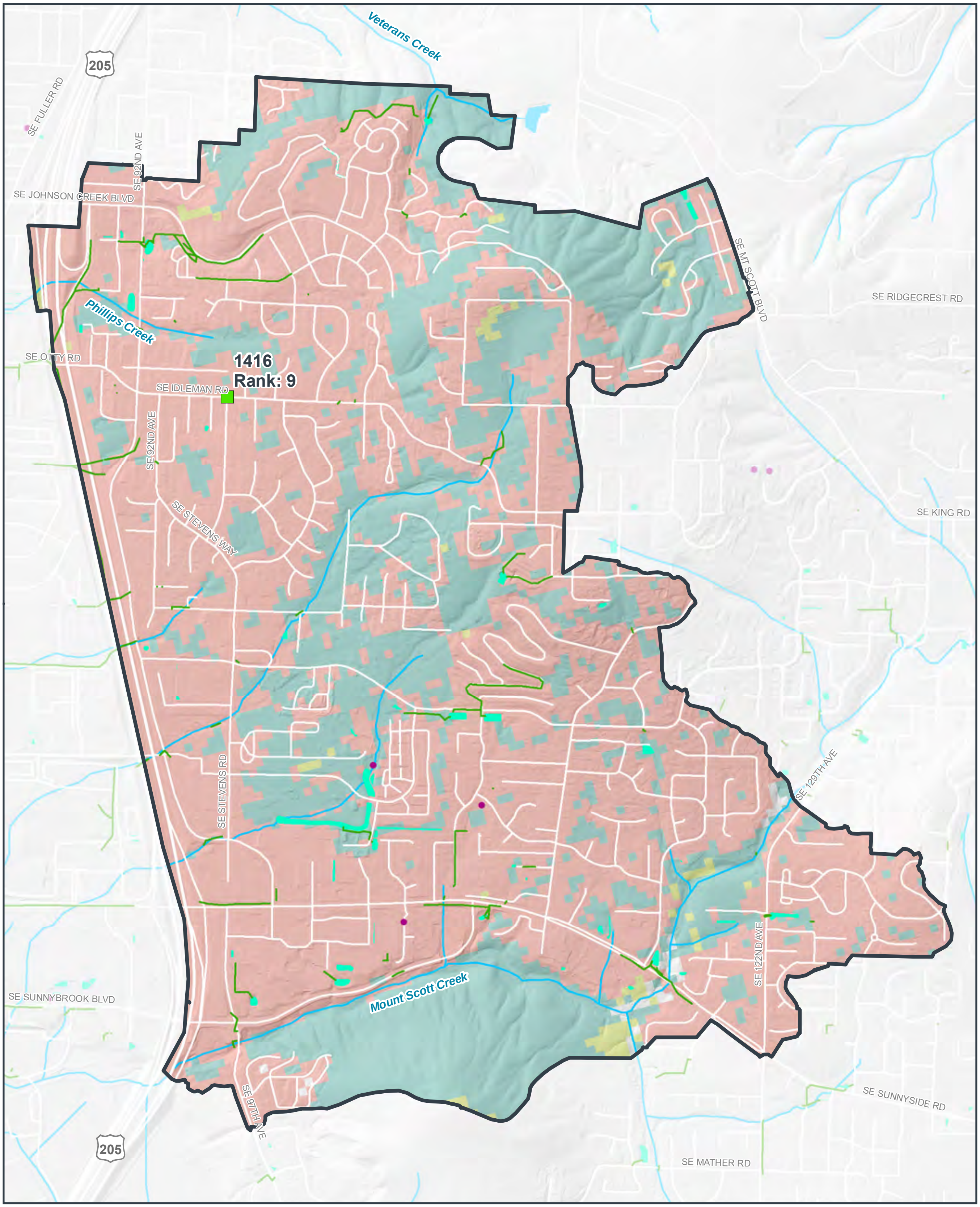


FIGURE B-4

MT. SCOTT STUDY AREA

WES STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY, OR

Study Area
Stream/Waterbody
Dry Well
Storm Pipe (24"+)
Storm Facility

Land Use
Developed
Forest/Open Space
Pasture
Storm System Project

DATE: 12/22/2020

0 — 1,700 ft

CLACKAMAS WATER ENVIRONMENT SERVICES

Otak

L:\PROJECT\19100\19109\CADD\GIS\MXDS\MASTER PLAN REPORT MAPS\FIG_STUDYAREA_MTSCOTT.MXD

NOTE: THIS DATA IS NOT A SURVEY AND IS MEANT FOR PLANNING PURPOSES ONLY. DATA IS PROVIDED BY ESRI, WES, AND METRO RLIS.

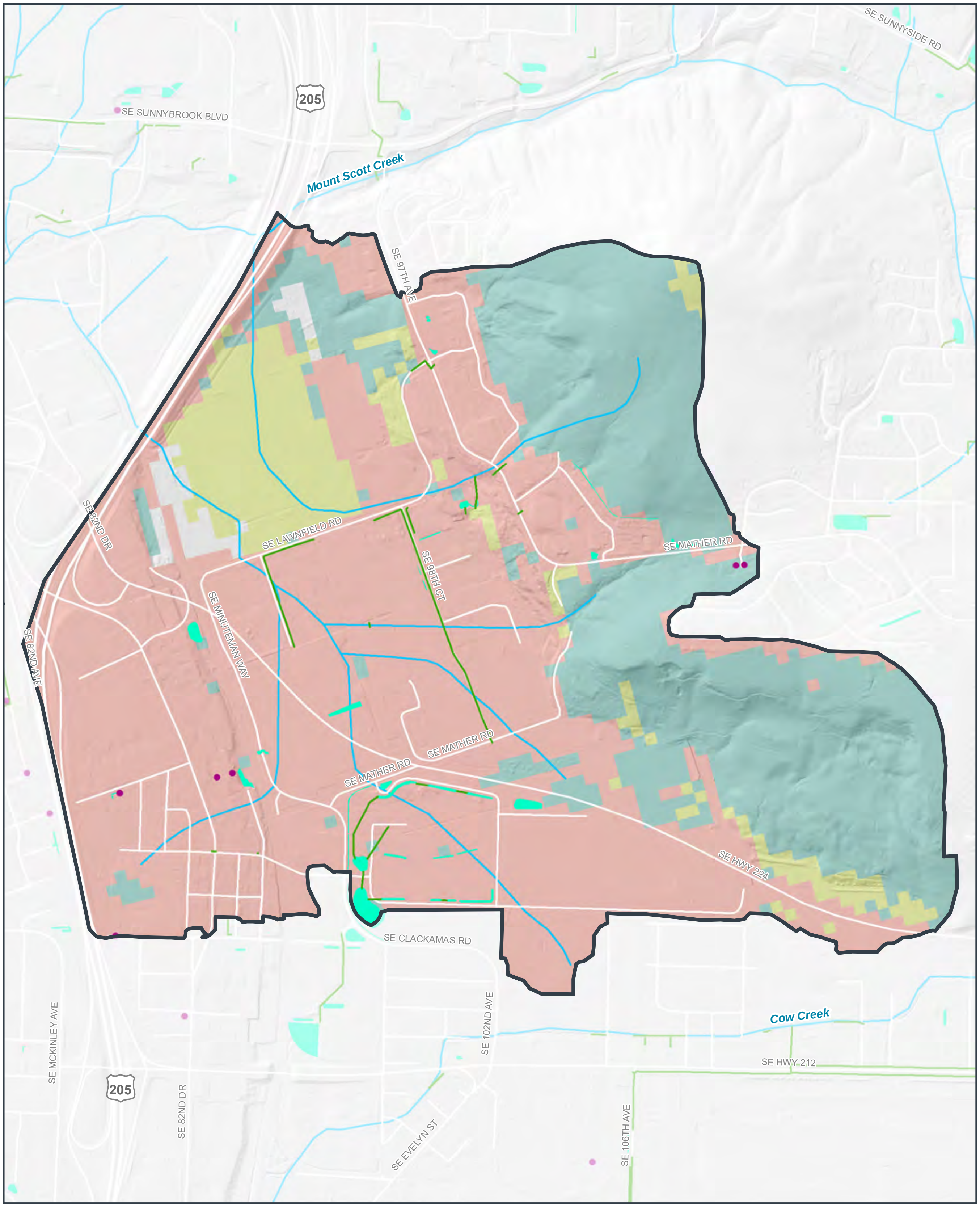


FIGURE B-5

MT. TALBERT STUDY AREA

WES STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY, OR

- Study Area
- Stream/Waterbody
- Dry Well
- Storm Pipe (24"+)
- Storm Facility

Land Use

- Developed
- Forest/Open Space
- Pasture

DATE: 12/22/2020

0 1,200 ft

CLACKAMAS WATER ENVIRONMENT SERVICES

Otak

L:\PROJECT\19100\19109\CADD\GIS\MXDS\MASTER PLAN REPORT MAPS\FIG_STUDYAREA_MTTALBERT.MXD

NOTE: THIS DATA IS NOT A SURVEY AND IS MEANT FOR PLANNING PURPOSES ONLY. DATA IS PROVIDED BY ESRI, WES, AND METRO RLIS.

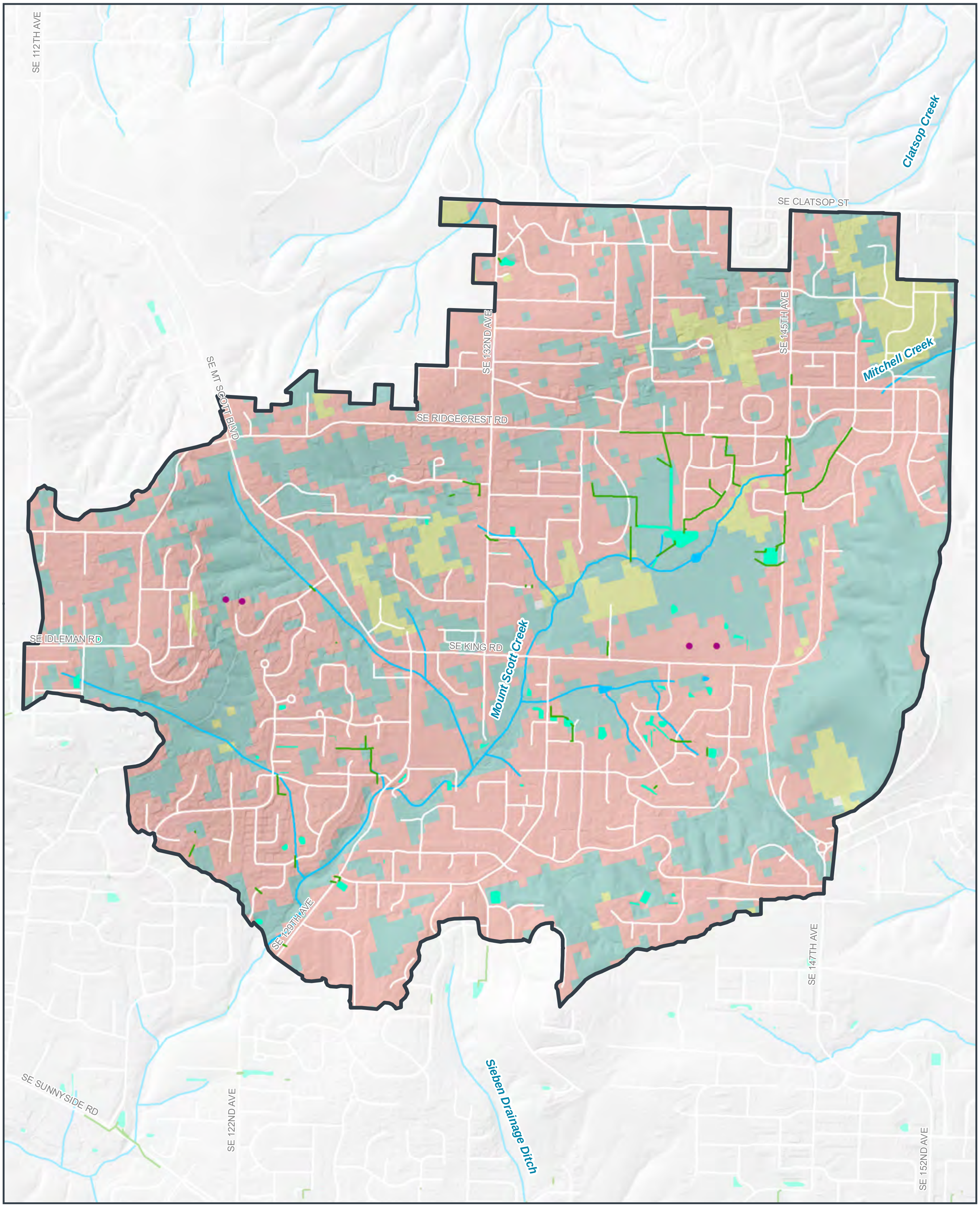


FIGURE B-6

NORTH HAPPY VALLEY STUDY AREA

WES STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY, OR

Study Area
Stream/Waterbody
Dry Well
Storm Pipe (24"+)
Storm Facility

Land Use
Developed
Forest/Open Space
Pasture

DATE: 12/22/2020

0 1,600 ft

CLACKAMAS WATER ENVIRONMENT SERVICES

Otak

L:\PROJECT\19100\19109\CADD\GIS\MXDS\MASTER PLAN REPORT MAPS\FIG_STUDYAREA_NORTHHV.MXD

NOTE: THIS DATA IS NOT A SURVEY AND IS MEANT FOR PLANNING PURPOSES ONLY. DATA IS PROVIDED BY ESRI, WES, AND METRO RLIS.

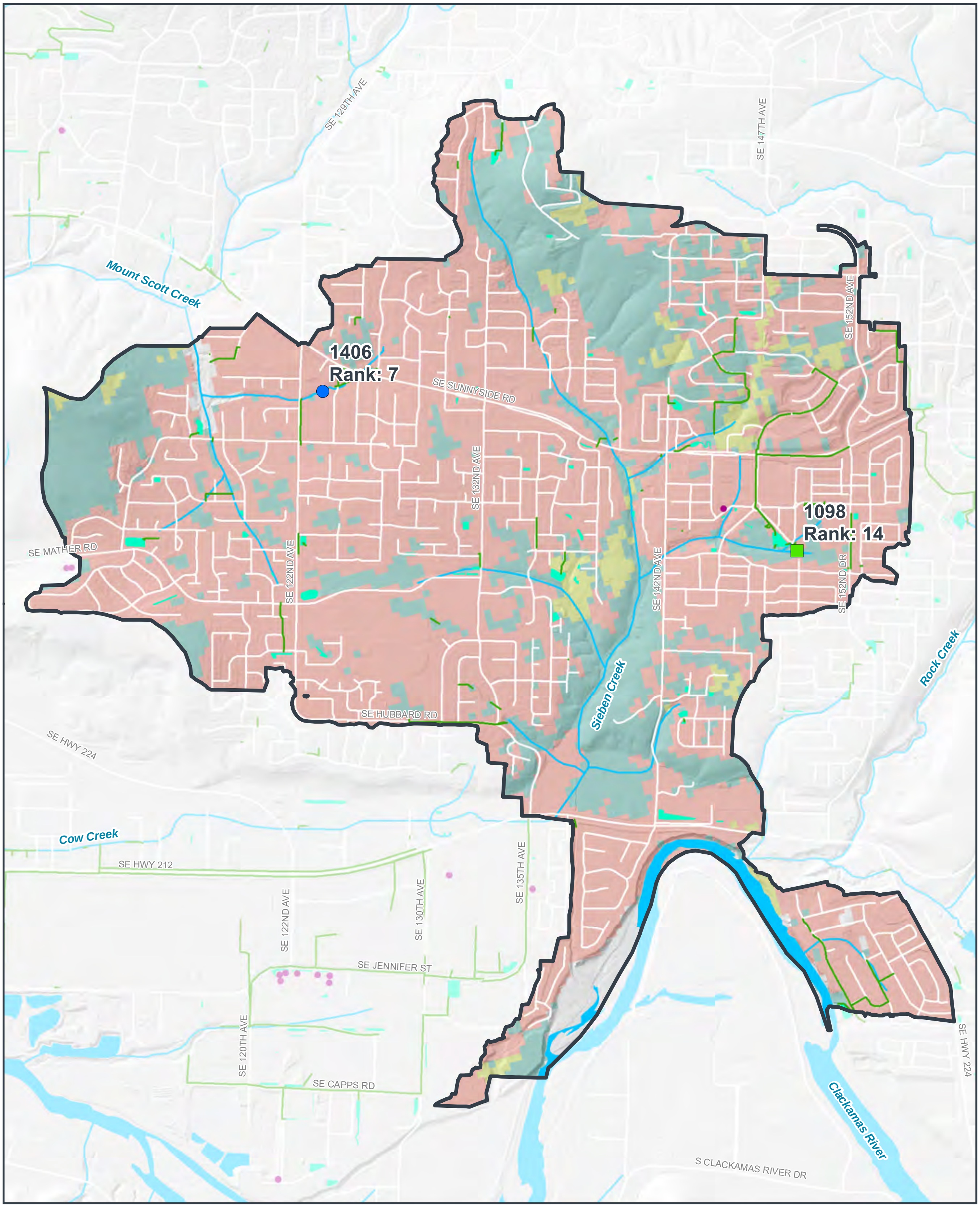


FIGURE B-7

SUNNYSIDE STUDY AREA

WES STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY, OR

Study Area
Stream/Waterbody
Dry Well
Storm Pipe (24"+)
Storm Facility

Land Use
Developed
Forest/Open Space
Pasture
Storm System Projects
Culvert/In-Stream Projects

DATE: 12/22/2020

0 2,000 ft

CLACKAMAS WATER ENVIRONMENT SERVICES

Otak

L:\PROJECT\19100\19109\CADD\GIS\MXDS\MASTER PLAN REPORT MAPS\FIG_STUDYAREA_SUNNYSIDE.MXD

NOTE: THIS DATA IS NOT A SURVEY AND IS MEANT FOR PLANNING PURPOSES ONLY. DATA IS PROVIDED BY ESRI, WES, AND METRO RLIS.

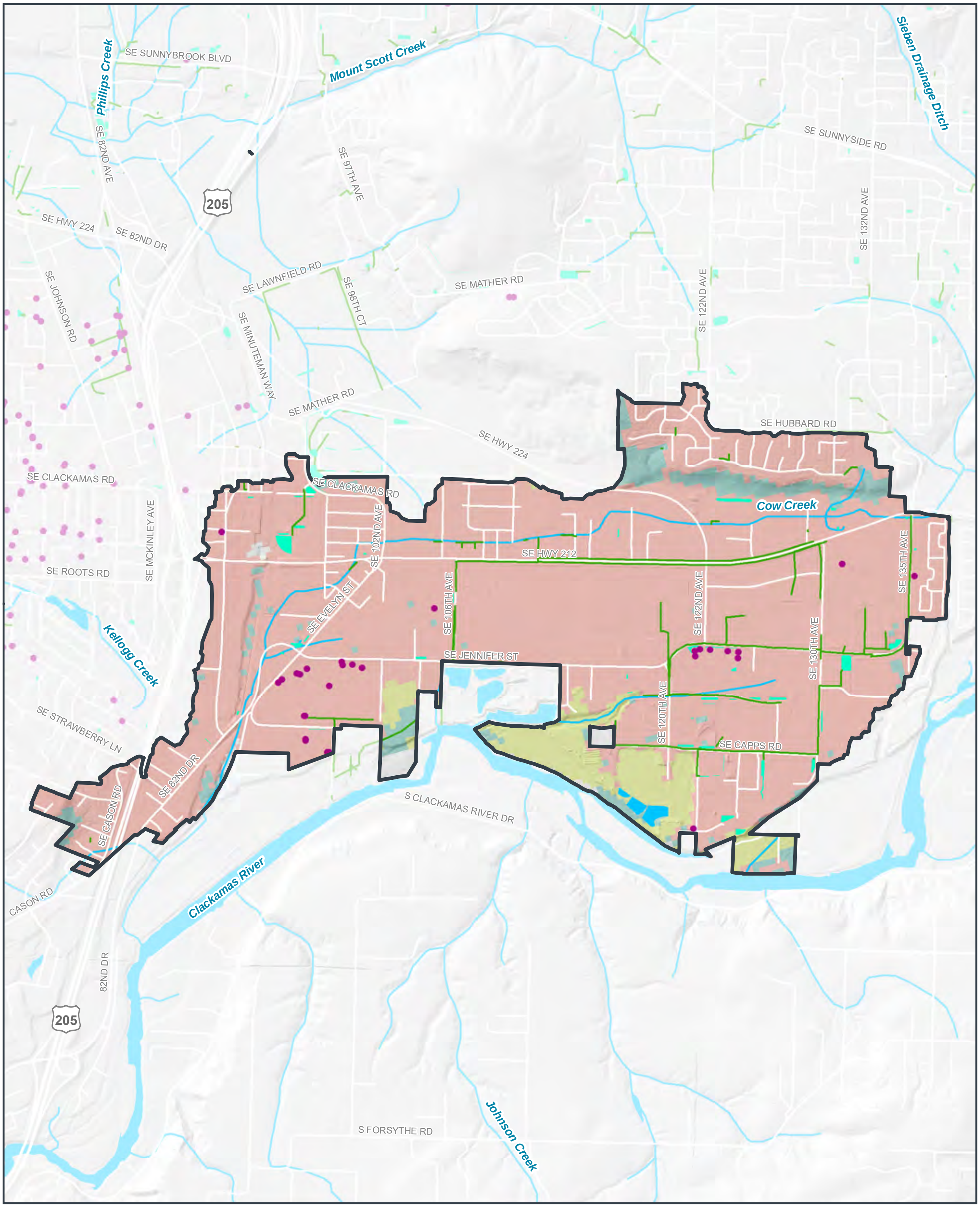


FIGURE B-8

CLACKAMAS RIVER STUDY AREA

WES STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY, OR

- Study Area
- Stream/Waterbody
- Dry Well
- Storm Pipe (24"+)
- Storm Facility

Land Use

- Developed
- Forest/Open Space
- Pasture

DATE: 12/22/2020

0 — 2,300 ft

CLACKAMAS WATER ENVIRONMENT SERVICES

Otak

L:\PROJECT\19100\19109\CADD\GIS\MXDS\MASTER PLAN REPORT MAPS\FIG_STUDYAREA_CLACKAMAS.MXD

NOTE: THIS DATA IS NOT A SURVEY AND IS MEANT FOR PLANNING PURPOSES ONLY. DATA IS PROVIDED BY ESRI, WES, AND METRO RLIS.

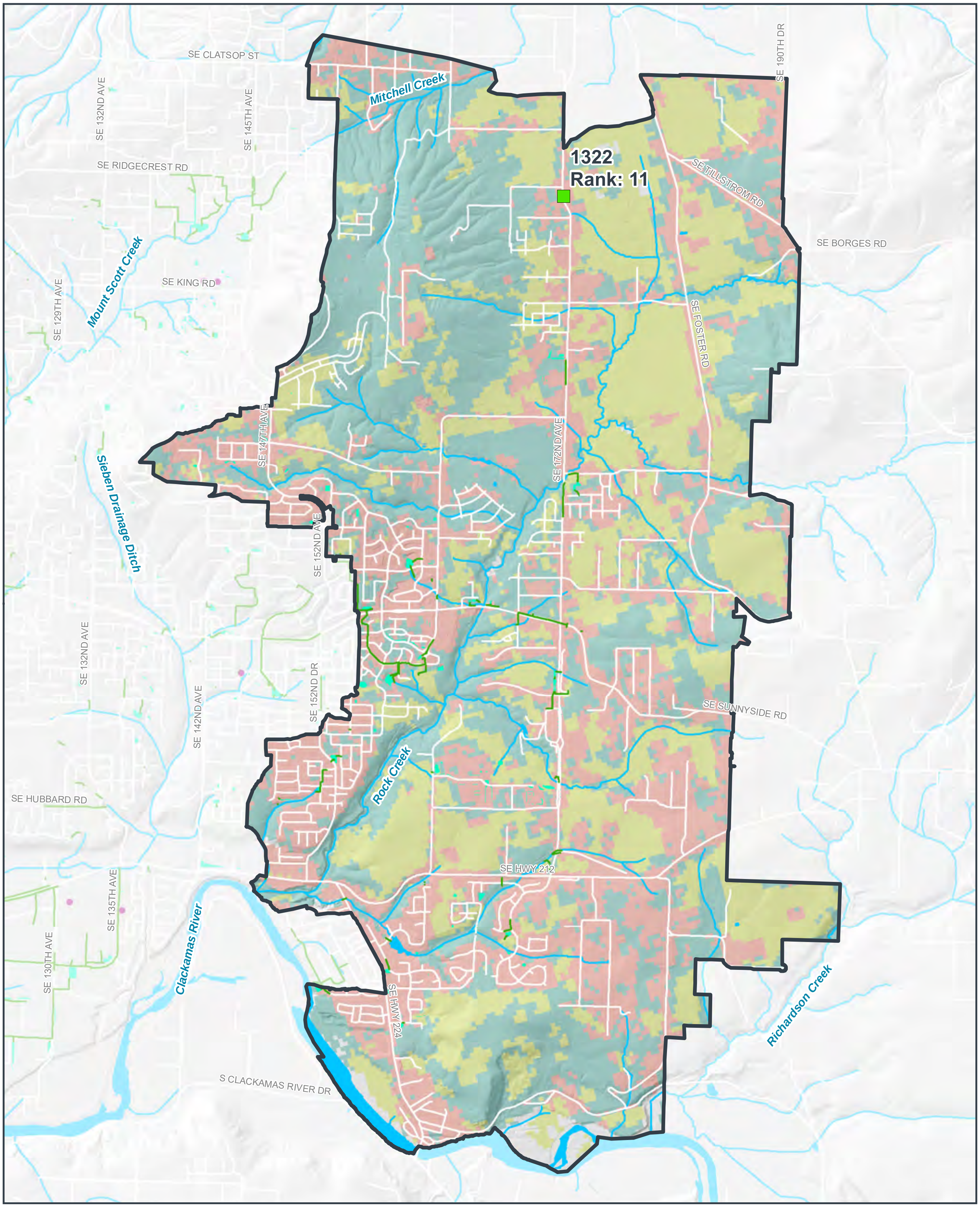


FIGURE B-9

ROCK CREEK STUDY AREA

WES STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY, OR

Study Area
Stream/Waterbody
Dry Well
Storm Pipe (24"+)
Storm Facility

Land Use
Developed
Forest/Open Space
Pasture
Storm System Projects

DATE: 12/22/2020

0 3,200 ft

CLACKAMAS WATER ENVIRONMENT SERVICES

Otak

L:\PROJECT\19100\19109\CADD\GIS\MXDS\MASTER PLAN REPORT MAPS\FIG_STUDYAREA_ROCKCREEK.MXD

NOTE: THIS DATA IS NOT A SURVEY AND IS MEANT FOR PLANNING PURPOSES ONLY. DATA IS PROVIDED BY ESRI, WES, AND METRO RLIS.

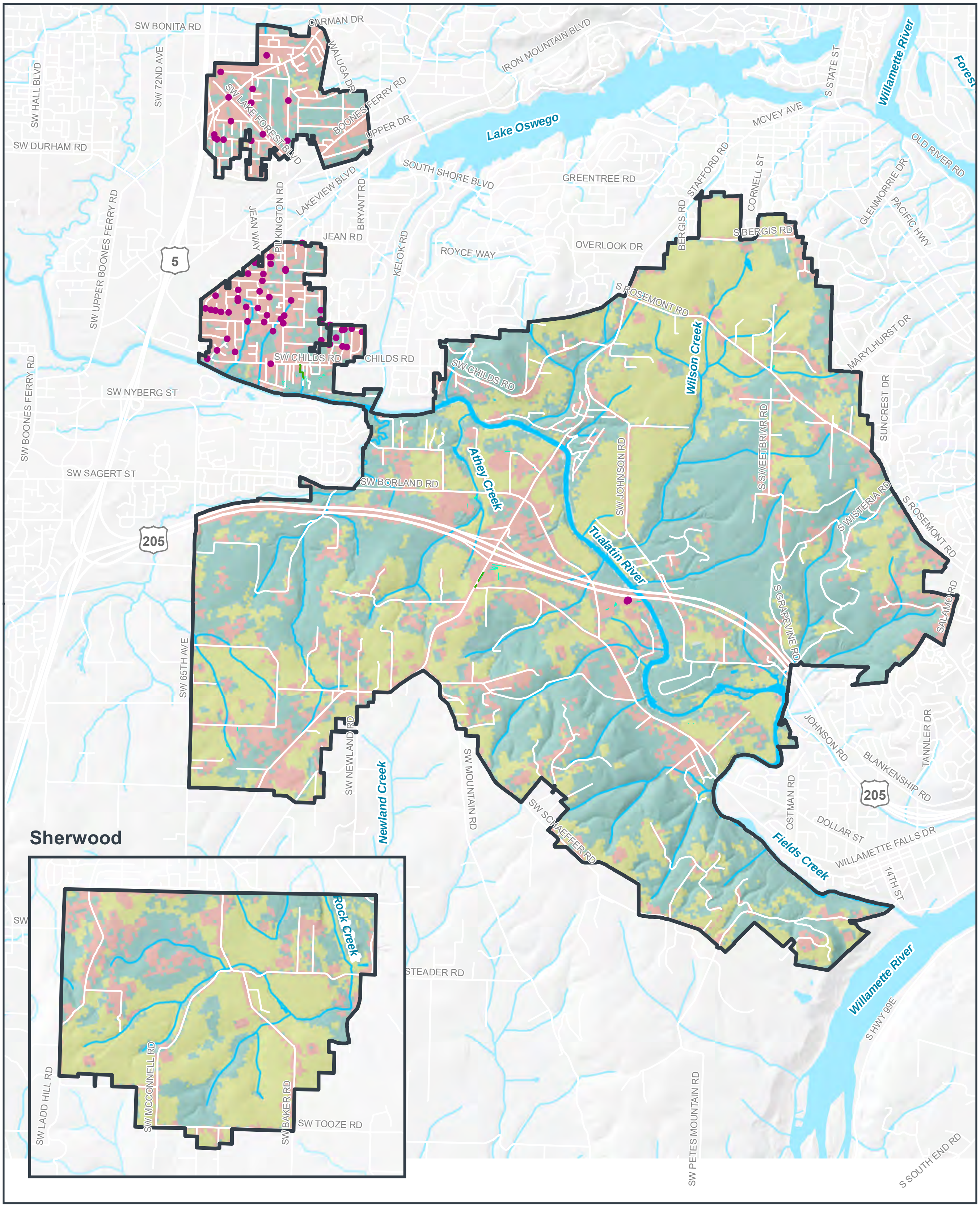


FIGURE B-10

SWMACC STUDY AREA

WES STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY, OR

- Study Area
- Stream/Waterbody
- Dry Well
- Storm Facility
- Storm Pipe (24"+)

Land Use

- Developed
- Forest/Open Space
- Pasture

DATE: 12/22/2020

0 4,500 ft

CLACKAMAS WATER ENVIRONMENT SERVICES

Otak

L:\PROJECT\19100\19109\CADD\GIS\MXDS\MASTER PLAN REPORT MAPS\FIG_STUDYAREA_SWMACC.MXD

NOTE: THIS DATA IS NOT A SURVEY AND IS MEANT FOR PLANNING PURPOSES ONLY. DATA IS PROVIDED BY ESRI, WES, AND METRO RLIS.

Appendix C

WES Stormwater Master Plan Model Review

Technical Memorandum

To:	Leah Johanson, Clackamas Water Environment Services
From:	Gary Wolff, PE, D.WRE, CFM Doug Beyerlein, PE, D.WRE Joshua Owens, PE Leah Bensching, EI Teresa Huntsinger, EI
Copies:	Trista Kobluskie; Kevin Timmins, PE; File
Date:	February 11, 2021
Subject:	WES Storm System Master Plan Model Review
Project No.:	19109

Introduction

Otak, Inc. is working with Clackamas Water Environment Services (WES) on a Storm System Master Plan (SSMP).

This Technical Memorandum documents a review of the existing hydrologic and hydraulic models within the WES service area that are available for use in developing SSMP recommendations or capital improvement projects (CIPs). The files of four different models were reviewed:

1. HSPF Hydrologic Model/WES-RTS
2. HEC-HMS Hydrologic Model
3. XP-SWMM Hydrologic/Hydraulic Model
4. HEC-RAS Hydraulic Model

Three of the four models were developed by Pacific Water Resources, Inc. (PWR) for the *Clackamas County Service District No. 1 Surface Water Management Program Master Plan* (Shaun Pigott Associates, et al., 2006) (2006 SWMPMP). The fourth model was developed by URS Corp. for two basins within Clackamas County Service District No. 1 (CCSD#1) for a study unrelated to the 2006 SWMPMP. Under the current organization of WES, CCSD#1 corresponds to WES Service Area No. 2. No models were reviewed within the Surface Water Management Agency of Clackamas County, which corresponds to WES Service Area No. 3.

Each model was reviewed to assess its usefulness in the context of the SSMP. Recommendations were made to improve the utility of each model. After review, none of the models were used to identify any potential CIPs for the SSMP.

HSPF Hydrologic Model and WES-RTS

Hydrologic Simulation Program-Fortran (HSPF) is a physically-based continuous hydrologic model that includes all processes in the hydrologic cycle.

The HSPF model for CCSD#1 was developed by PWR for the 2006 SWMPMP and documented in "Technical Memorandum No. 6, HSPF Model Development and Calibration" (PWR, 2005a). The model covered all of the contemporaneous boundary of CCSD#1 (12,000 acres) as well as contemporaneous expansion areas to the east

(13,000 acres). Basins modeled include Kellogg Creek, Mt. Scott Creek, Phillips Creek, Deer Creek, Sieben Creek, Cow Creek, Rock Creek, Richardson Creek, Noyer Creek, and Sunshine Creek.

The model was set up using a single precipitation time series between 1973-1979.

PWR used the HSPF model to create a simplified continuous modeling analysis tool called WES-RTS, or Water Environment Services – Runoff Time Series model. WES-RTS was developed as a spreadsheet program and was based on the concept of the King County Runoff Time Series (KCRTS) from King County, Washington. It was set up to size stormwater ponds for project sites smaller than 640 acres (1 square mile). WES-RTS uses pre-computed HSPF runoff data stored in the spreadsheet and does not run HSPF to generate results. It appears that WES-RTS has not been updated since 2005 and is not currently used by WES as a sizing methodology for stormwater ponds.

WES-RTS and its supporting HSPF input files include the following four pervious land cover categories:

- Agricultural – Forest
- Urban Lawns – Gardens
- Urban Bare – Vacant Ground
- Wetlands (and Hydrologic ‘D’ Soils)

WES-RTS also has one impervious land cover category:

- Impervious Surface (Roofs, Pavement, and Open Water)

Each of the pervious land cover categories assumes a fixed slope and hydrologic soil group. The impervious land cover category assumes a storage depth of 0.1 inches and slope of 0.01.

At the time of completion, available flow data for streams in CCSD#1 was not adequate to calibrate the model. Instead, the model was calibrated using gages in the Tualatin Valley watershed where development patterns, soils and other model inputs were considered representative of CCSD#1. The 2006 SWMPMP suggested an update to the HSPF model development and calibration study be completed when the flow gages within WES had adequate data for calibration. However, the HSPF model and WES-RTS have not been updated since they were created in 2005.

Value for Master Plan and Recommendations

The CCSD#1 HSPF model and WES-RTS do not provide useful support for SSMP analyses.

The two models are outdated and less robust than models currently used in the region. Programs such as these that use pre-simulated HSPF data are no longer necessary because users have the computing power to run HSPF calculations. King County no longer uses its similar model, KCRTS. The simplified land cover type options in the 2006 HSPF model and WES-RTS are limiting and do not compare with the many land cover type options available in more recent HSPF models that are used in the Pacific Northwest. More accurate models in use regionally include the Western Washington Hydraulic Model (WWHM) and the Tualatin River Urban Stormwater Tool (TRUST 2019), which run HSPF calculations and allow the selection of numerous land cover parameters, including soil type, vegetation type, and slopes. In addition, each of these models was calibrated with local stream gage data, and run hydrologic simulaitons based upon extended periods(over 40 years) of precipitation records.

WES’ proposed draft stormwater standards were reviewed to determine if WES-RTS would be useful. The proposed standards will require a flow duration-based design for flow control facilities. A hydrologic/hydraulic analytical model capable of performing a continuous simulation of flow rates from local long-term rainfall data must be used to determine the peak flow rates, recurrence intervals, and flow durations. WES-RTS is not capable of meeting this requirement. WES has developed another simplified model that is capable of sizing facilities to meet a flow duration matching requirement in Clackamas County watersheds – the WES BMP Sizing Tool. The Tool was not reviewed for this study.

Although an updated and calibrated HSPF model would be beneficial for final design of CIPs proposed in the SSMP, use of an HSPF model is not necessary for the schematic level design of the CIPs. The proposed stormwater standards will be incorporated in the CIPs using the BMP Sizing Tool.

HEC-HMS Hydrologic Model

HEC-HMS stands for the Hydrologic Engineering Center Hydrologic Modeling System, and the model is published by the US Army Corps of Engineers (USACE). HEC-HMS is used to perform hydrologic modeling of watersheds.

The HEC-HMS model was developed by PWR for the 2006 SWMPMP and documented in "Technical Memorandum No. 4, HEC-HMS Model Development, Calibration, Modeled Scenarios and Peak Flow Estimates" (PWR, 2005b).

The model was built in version 2.2.2. and includes all of the contemporaneous boundary of CCSD#1 (12,000 acres) as well as expansion areas to the east that are relatively undeveloped (13,000 acres). Basins modeled include Kellogg Creek, Mt. Scott Creek, Phillips Creek, Deer Creek, Sieben Creek, Cow Creek, Rock Creek, Richardson Creek, Noyer Creek and Sunshine Creek. The HEC-HMS model was used to determine peak flows for CCSD #1 and the WES expansion area and to assess effectiveness at the watershed scale of the suite of existing site-scale detention facilities and to simulate application of Low Impact Development (LID) BMPs.

The HEC-HMS modeling effort was focused on the creeks but also included limited hydrologic input data for a small number of CIPs and existing facility retrofits. The model was set up with five different basin area extents: 1) all basins, 2) a pilot basin, 3) the pilot basin with Upper Mt. Scott, 4) retrofit of four existing regional facilities, and 5) three CIPs to construct regional detention ponds in the expansion area. The pilot basin is a section of the Mt. Scott basin, and it was used to evaluate success of the contemporaneous WES polices in achieving their goals and to evaluate new management methods and their implementation criteria. The WES expansion area included Rock, Richardson, Noyer and Sunshine Creeks. The retrofit of four existing regional facilities included Happy Valley Park Pond A, Happy Valley Park Pond B, Sunnyside Village South Pond, and Burgundy Rose Detention Pond. The three CIP regional detention facilities in the expansion area included SE 162nd Ave, South 172nd Ave, and North 172nd Ave (all located between SE Sunnyside Road and Highway 212). The basins were run with high and low initial soil moisture conditions, and the results showed that high initial soil moisture conditions were more accurate for winter peak flows. Each iteration of the model was run with existing and future land cover.

HEC-HMS uses the soil moisture accounting (SMA) method for runoff and the Muskingum Cunge method for storage routing. SMA is a linear reservoir method intended for use as a continuous simulation model. It accounts for storage in surface flow, soil, and ground water. It uses accounting units to define land cover characteristics through simplified channel reaches, and it uses ponds to define larger storage areas. Nine user-defined parameters based on land use and soil type were used:

- Urban
- Dry
- LID
- Forested (Type B, C, and D soils)
- Rural (Type B, C, and D soils)

Within each accounting unit, storage capacity and initial storage is defined for two ground water layers, the canopy, the surface, and soil layers. Impervious area was determined using light detection and ranging (LiDAR) and was defined as a percent of the total basin area.

Gaging records for the study area were limited, dating back only to 2001. Due to the limited meteorological inputs and stream flow gaging, HEC-HMS was set up as a single event model. PWR developed a 72-hour "typical" design storm to replace the 24-hour design storm most commonly used in a single event model. The 72-hour storm consisted of a small storm event and a large storm event separated by a 6-hour dry period. The second peak embedded a 24-hour rainfall depth and the total for the entire storm was equal to 1.6 times that found in the 24-hour depth. The small storm within the 72-hour storm simulated wet conditions that commonly precede large storm events in the Pacific Northwest. More details on the 72-hour storm are found in PWR's "Technical Memorandum No. 2: Developing Rainfall Design Storms for Modeling Hydrology" (PWR, 2004).

The model was calibrated based on stream flow gages in upper Kellogg Creek and Philips Creek for a single 72-hour storm from December 11, 2003 to December 20, 2003. Given the limited time series data available, the calibration was not as robust as desired for providing quality results.

Value for Master Plan and Recommendations

The HEC-HMS model provides limited utility for SSMP analyses.

None of the three regional detention ponds or the four retrofits of existing facilities identified in the 2006 SWMPMP have been included as CIPs in the SSMP. The HEC-HMS creek flow data could be used for a CIP design that replaces an existing culvert crossing. The creek flow data is also included in the HEC-RAS model, described below.

A robust calibration effort could improve the accuracy of the HEC-HMS model. There were not sufficient data to perform a full calibration on the model. Streamflow data was only available from 2001 to 2005 and did not include an extreme flood event. For the model to provide accurate and useful storm event data, the calibration would need to be updated with gage data that includes larger flood event. In addition, the calibration should be expanded beyond a single sub-basin. CCSD#1 covers a wide range of land use, soil, and terrain, so one sub-basin may not adequately represent all basins in the district.

The model uses soil moisture accounting (SMA) to calculate runoff. SMA is best for continuous flow, however, it is used here for an event-based analysis. It is recommended that the runoff method be updated with an event-based flow method or the analysis should be changed to a continuous flow simulation. Many jurisdictions in Oregon and Washington are moving towards continuous simulation requirements for stormwater infrastructure design because it has been shown to better reflect changes to hydrology over a period of time and the design of stormwater best management practices to mitigate for hydrologic changes.

HEC-RAS Model

HEC-RAS stands for Hydrologic Engineering Center River Analysis System, and the model is published by the US Army Corps of Engineers (USACE). HEC-RAS is used to perform flow and sediment transport calculations in rivers and streams.

The HEC-RAS model was developed by PWR for the 2006 SWMPMP and documented in "Technical Memorandum No. 7, Conversion and Evaluation of Existing FEMA FIS Models" (PWR, 2006). Its purpose was to provide a basis for prediction of flood levels and mapping the Special Flood Hazard Area (SFHA) on the modeled streams in CCSD#1.

The HEC-RAS model was a compilation of earlier hydraulic models developed for the Effective Flood Insurance Study (Effective FIS) for streams in Clackamas County. All of these models are very old, and most date to the early 1980's. They were developed in the USACE HEC-2 program, the predecessor to HEC-RAS. PWR converted the original HEC-2 models to run using the HEC-RAS software and combined the models of the different stream reaches into one interconnected model. Two versions of the model are available, one in the original NGVD29 vertical datum and another with the model elevations converted to the NAVD88 vertical datum.

The model includes the following stream reaches in CCSD#1:

- Upper Kellogg Creek from about 1,000 feet upstream of SE Webster Road to the confluence with Mt. Scott Creek.
- Lower Kellogg Creek from the confluence with Mt. Scott Creek to Highway 99E.
- Mt. Scott Creek from about 450 feet upstream of I-205 to the confluence with Kellogg Creek.
- Phillips Creek from about 50 feet upstream of SE Causey Avenue to the confluence with Mt. Scott Creek.
- Deer Creek from about 50 feet upstream of I-205 to the confluence with Mt. Scott Creek.

At the time of the PWR modeling effort, over 25 years of watershed changes had occurred, and the original FIS models no longer reflected current watershed conditions or flood risk. Therefore, as part of their review and conversion of the models to HEC-RAS, PWR changed the model to reflect updated modeling standards, available information, and field observations.

Model revisions were made by PWR based on field observations and available information at the time with no detailed survey data. The revisions were considered approximate based on judgement and field data and were not considered "best available information" for updating the Effective FIS models. As such the Effective FIS models were not updated at the time and have not been updated since. Model revisions are itemized for each creek, below.

Upper Kellogg Creek
The Effective FIS model for Upper Kellogg Creek is based on an HEC-RAS model developed in 2000 by Harper, Houf, Righellis, Inc. and therefore is based on data newer than the other stream reaches. Based on a field review, PWR concluded that the model data substantially matched conditions in 2006, and therefore no model changes were made to this reach.

Lower Kellogg Creek
The crossing at Kuhn Road Bridge was updated to reflect field observations.

Mt. Scott Creek
The following changes were made for this reach:

- The model of the railroad bridge at River Mile (RM) 11.15 was updated to reflect the two piers instead of one.
- The North Clackamas Regional Flood Control Facility (FCF) was not included in the Effective FIS model and was added by PWR. It should be noted that inclusion of the structure increased local 100-year flood elevations by over four feet and would have significant implications for the mapped floodplain in this area if this model were used by USACE for Effective FIS modeling.
- Channel straightening and other geometry improvements upstream of SE 82nd Avenue as reflected in surveys conducted around 1993 to support the design of the FCF were added to the model.
- The crossing at SE 84th Avenue did not exist at the time of the Effective FIS and was added to the model based on current (1993) conditions.

Phillips Creek
The following changes were made for this reach:

- The culverts at SE 84th Avenue were updated to reflect improvements since the Effective FIS modeling.
- A private bridge at a Costco parking lot did not exist at the time of the Effective FIS and was added to the model.
- The culvert at SE Sunnyside Road was updated to reflect an upgrade since the Effective FIS modeling.

Deer Creek
No changes were made for this reach.

Value for Master Plan and Recommendations

Because of the significant land cover and stream changes since the models were created and last updated, the HEC-RAS model provides limited utility for SSMP analyses. The information could be used for a CIP design that replaces an existing culvert crossing.

Any CIPs developed in CCSD#1 for the current SSMP that involve construction within the limits of the Special Flood Hazard Area will require a floodplain development permit, and the HEC-RAS model would need to be updated in the project vicinity to reflect current conditions. Model update would require local survey data to reflect current conditions and possibly changes to the hydrology to reflect current watershed conditions. Project cost estimates should reflect the cost of these studies, where required.

XP-SWMM Model

XP-SWMM is a proprietary hydraulic and hydrology model based on the Environmental Protection Agency's Storm Water Management Model (SWMM) that is published by Innovyze.

The XP-SWMM Model of Richardson and Rock Creeks was developed by URS Corp. in 2000. Its purpose was to model the capacity of structures such as culverts at road crossings. The model simulated existing and future 25-year, 50-year, and 100-year flows in the two creeks and their tributaries, using Soil Conservation Service (SCS) Type 1A 24-hour design storms. Each stream reach link had a natural channel cross-section shape with Manning's roughness coefficients defined for the channel and left and right banks, plus upstream and downstream elevations, average longitudinal slope, and length. Reach lengths ranged from 15 to 3,877 feet. Culverts at roadway crossings were represented by pipes with given diameters, slopes, roughness, and invert elevations. Nodes on either end of roadway culverts represented culvert inlets and outlets, including spill crest elevations. The model included four ponds ranging in size from 0.2 to 2.6 acres. An AutoCAD basemap drawing provided context for how the XP-SWMM nodes and links related to the geographic locations of roads and streams.

The hydrology was modeled using the Green-Ampt method, which calculates surface ponding, infiltration, and runoff based on soil characteristics and evapotranspiration rates. The model included subbasin areas, Manning's roughness coefficients for overland flow, and existing and future impervious area percentages. Subbasin areas ranged from 14 acres to 473 acres. Under future conditions, subbasin area imperviousness increased by 3 to 48 percent, depending on the basin. Additional research would be needed to determine to what extent the future land use conditions forecast in 2000 are consistent with current conditions.

Output reports from the model identified structures that were deficient during each design storm. The output report indicated that one structure on the Rock Creek mainstem (Borges-12) was deficient during the existing 25-year storm, and eight structures on tributaries to Rock Creek were deficient during the 25-year storm under future conditions.

Value for Master Plan and Recommendations

The model is 20 years old, and its land use information would need to be updated with current data to improve its accuracy. None of the structures identified as deficient in the XP-SWMM model are CIPs for the current SSMP.

References

Pacific Water Resources, Inc., 2004. Technical Memorandum No. 2, Developing Rainfall Design Storms for Modeling Hydrology, Clackamas County Service District No. 1, Surface Water Management Program Master Plan, December 2004.

Pacific Water Resources, Inc., 2005a. Technical Memorandum No. 6, HSPF Model Development and Calibration, Clackamas County Service District No. 1, Surface Water Management Program Master Plan, September 30, 2005.

Pacific Water Resources, Inc., 2005b. Technical Memorandum No. 4, HEC-HMS Model Development, Calibration, Modeled Scenarios and Peak Flow Estimates, Clackamas County Service District No. 1, Surface Water Management Program Master Plan, July 18, 2005.

Pacific Water Resources, Inc., 2006. Technical Memorandum No. 7, Conversion and Evaluation of Existing FEMA FIS Models, Clackamas County Service District No. 1, Surface Water Management Program Master Plan, April 26, 2006.

Shaun Pigott Associates, LLC, Pacific Water Resources, Inc., GeoSyntec Consultants, Donovan Enterprises, Inc., Norton Arnold & Company, 2006. Clackamas County Service District No. 1, Surface Water Management Program Master Plan, April 2006.

Otak, Inc., 2020. Hydrologic Calibration for TRUST 2019 with the U.S. EPA Hydrologic Simulation Program – FORTRAN (HSPF) Draft, January 16, 2020.

Appendix D

WES and Happy Valley Storm System Master Plan Review of Existing Data

Otak

Technical Memorandum

To:	Leah Johanson, Water Environment Services
From:	Leah Bensching, EIT
Copies:	Kevin Timmins, Trista Kobluskie, File
Date:	March 23, 2020
Subject:	WES and Happy Valley Storm System Master Plan Review of Existing Data
Project No.:	19109

Introduction

The purpose of this memorandum is to document the discovery phase of the Water Environment Services (WES) and City of Happy Valley Storm System Master Plan (SSMP). This memorandum summarizes the review of available information as well as the process for summarizing useful information about problems and solutions to be carried forward in development of the recommendations for the SSMP. The planning area for the Storm System Mast Plan includes the storm sewer utility areas in the WES service district, which contains City of Happy Valley, unincorporated urban Clackamas County in the vicinity of Happy Valley, the Pleasant Valley-North Carver planning area, unincorporated Clackamas County in the WES Service Area 2 and the City of Rivergrove. A map of the planning area boundary is found in Exhibit D.

Review of Existing Information

The discovery phase began with a review of existing information pertaining to the stormwater infrastructure and stream systems within the planning area. This information includes stormwater reports and stormwater infrastructure plans as well as community plans, master plans and needs analysis studies. Exhibit A contains a comprehensive list of documents provided by the client and reviewed by Otak staff.

The existing information review was supplemented by meetings with City of Happy Valley and WES staff to collect additional background knowledge and discuss known issue locations for the stormwater infrastructure and stream corridors in the planning area. Additionally, potential project ideas were discussed with City of Happy Valley and WES staff. These discovery meetings with city staff took place on 9/12/2019, 10/2/2019 and 10/30/2019.

Collect and Categorize Issues

The information about issues in the storm system collected during the discovery phase was compiled and classified in an ESRI geodatabase. The geodatabase was composed of a collection of geographic points that identify the location of known issues. The schema for the geodatabase and numbering conventions are in Exhibit B.

Identifying known issues was the first step in the process of studying the storm system and developing solutions. Each known issue was given a unique identification number in the geodatabase. Additional fields provided descriptive information about the issue, such as the full name of the issue, the study area basin in which the issue is located, a long description of the nature of the issue, as well as a field for any supplemental notes from site visits. A group of fields were included to indicate if the known issue was primarily related to water quality, water quantity, erosion, or maintenance. Table 1 shows the number of issues that fall into each category. Some fall into multiple categories.

Table 1—Number of known issues within each category

Type of Issue	Count
Quality	70
Quantity	132
Erosion	26
Maintenance	47

To further describe some of the known issues, 60 sites were selected for field visits with approval from WES. Sites were selected when more information was needed to develop a proposed solution. During field visits, site conditions and potential solutions were documented using the ESRI Collector App. A memo outlining field work will be developed and submitted at a later date.

Solutions

For most known issues, a solution will be proposed. A solution could be a large capital project or a program.

Known issues that are candidates for large capital improvement projects are given a unique potential project identification number (PPID). The potential project list will be studied and further developed in a subsequent planning step. An attribute field for "no action" was created for instances in which the site visit or another source of information determined that no additional action was warranted for a known issue. The final list of potential projects will be rated and ranked to select CIPs.

Programs are groups of similar small and medium projects that are tackled gradually over time with fixed yearly funding. Most of the known issues will be grouped into programs that will enable the WES staff to address stormwater needs that require attention but do not rise to the scale or priority level of a capital project. Some programs have already been defined in the WES 2018-2023 Capital Improvement Plan. In addition to these, Otak will propose to develop a handful of new programs to address common problems among the known issues. Known issues that are program candidates will be identified in the Known Issues Geodatabase by a text field called "Program" and by a numeric field called "Program ID."

A complete list of known issues in the geodatabase is provided in Exhibit C. A map of the known issues is provided in the Known Issues Atlas in Exhibit D.

Collect and Map Supporting Data

To support the known issue identification and solutions analysis, various supporting data were collected and mapped.

Planning Area

The planning area includes WES Service Stormwater Service Area, North Clackamas Revitalization Area and City of Happy Valley future development in Pleasant Valley North Carver. The planning area shapefile also includes a delineation of areas outside of the WES service district. A map of the planning area is in Exhibit D.

Basin Delineation

Basin delineation from a previous Storm System Master Plan was reviewed and revised to incorporate storm system conveyance changes. Only minor changes to the existing basin delineation were found.

Study Areas

Study areas were determined by a combination of watershed basin boundaries and built features. Table 2 defines land cover characteristics of each study area as well as primary water bodies. Detailed land use maps of each study area can be found in Exhibit D.

Table 2—Study area land cover characteristics and water bodies

Study Area	Water Bodies	Characteristics
Kellogg Creek	Kellogg Creek	Mostly low intensity development with scattered areas of medium and high intensity development and forest.
Three Creeks	Mt. Scott Creek, Philips Creek, Deer Creek	Varies from low to high intensity development with wetland where the three creeks intersect. Also contains significant sections of open space and pasture.
Sunnyside	Sieben drainage ditch, bordered by Clackamas River to the south	A variety of developed land intensities with scattered forested land and wetland near the Clackamas River.
Clackamas River Drainage	Cow Creek	Majority high and medium intensity development.
Mt. Scott	Mt. Scott Creek	Primarily low intensity development with sections of forest scattered throughout.
Rock Creek	Rock Creek, bordered by Clackamas River to the south.	Mix of low intensity development, developed open space, pasture and forest. Wetland on southern edge near the Clackamas river
North Clackamas Revitalization Area	Johnson Creek	Mostly medium and high intensity development. Some low intensity development.
Mt. Talbert	Tributaries of Mt. Scott Creek	Large forested areas on eastern side. Primarily heavy and medium intensity development elsewhere with a section of pasture.
North Happy Valley	Mt. Scott Creek	Majority low intensity development and open space with patches of forest and pasture.
SWMACC	Tualatin River, Athey Creek, Wilson Creek	A mix of pasture and forest with scattered areas of low intensity development and developed open space.

Exhibit A

SSMP Data Inventory

Otak

WES and Happy Valley SSMP Data Inventory
3/18/2020

Title	Published	Author	Received From
2006 Surface Water Management Master Plan	Apr-06	Shaun Pigott, Pacific Water Resources, GeoSyntec	WES
2018-2019 Fiscal Year Budget Report (WES)		WES	WES
3_Scanned_sheets_from_August_2000	11/20/2019	Clackamas County	WES
5 Year Transportation CIP (2017-2022)		WES	WES
Aldrige Road Comprehensive Plan Development Study	5/11/2016	ASK engineering & Foresty LLC	City of Happy Valley
As-builts-additional files	n/a	Clackamas County	WES
Carver: Opportunities & Constraints			City of Happy Valley
CIP Clackamas County Service District No. 1 and WES. 2017 to 2022	1/1/2017	WES	WES
CIP Clackamas County Service District No. 1 and WES. 2018 to 2023			WES
City of Happy Valley Land Use Zoning	11/20/2018	City of Happy Valley	City of Happy Valley
City of Happy Valley Staff Report to the Planning Commission	1/27/2009	Catherin L. Daw	City of Happy Valley
City of Happy Valley Town Center Plan Land Use Designation	10/25/2018		City of Happy Valley
Clackamas County and Happy Valley Planning Areas	3/15/2018	City of Happy Valley	City of Happy Valley
Clackamas County Service District No. 1 Surface Water Management Program Master Plan	4/1/2006	Shaun Pigott Associates LLC & others	WES
Clackamas Regional Center Area Design Plan & Sunnyside Corridor Community Plan	11/4/2008		WES
Combined Landowner Maps	5/9/2018		WES
Current CIP List		WES	WES
DetentionPondRetrofiltAssessment2011			WES
Draft UpperKellogg_BasinAssessment_comments	5/21/2019	WES	WES
Drainage Problem Areas Table	n/a	n/a	WES
East Happy Valley Comprehensive Plan	10/25/2018		City of Happy Valley
Field Retrofit Guide	8/22/2011	CDM	WES
Floodplain Restoration Assessment	7/18/2017	Wetlands Conservancy	WES
Happy Valley SDC and TIF Revenue Projections	11/13/2018	Tiberius Solutions	WES
Happy Valley Town Center Existing Conditions Report	5/24/2011		City of Happy Valley
Happy Valley Transportation System Plan	12/1/2017		City of Happy Valley
Happy Valley Urban Area Renovation Plan	5/28/2019	Happy Valley	Happy Valley
Happy Valley Urban Renewal Area		City of Happy Valley	WES
Happy Valley Urban Renewal Area		City of Happy Valley	WES
Lamphier St As Builts		Clackamas County DTD	WES
Land Owner Access Request	5/7/2008	WES	WES
Land Owner Access Request	6/14/2008	WES	WES
Land Owner Survey Permissions Jan2019	1/7/2019	WES	WES
Land Use Assumptions	10/17/2019		
Landowner Outreach Form	11/27/2018	WES	WES
Landowner Permission Form Final	12/12/2018	WES	WES
North Clackamas Revitalization Area Plan	4/27/2006	Otak	WES
Philips Creek WES Retrofit Strategy & Fee In-Lieu Study	11/20/2013	Cardno	WES
Photos by Andrew Swanson	n/a	Andrew Swanson	WES

WES and Happy Valley SSMP Data Inventory
3/18/2020

Title	Published	Author	Received From
Pleasant Valley North Carver Comperhensive Plan Memo			City of Happy Valley
Pleasant Valley North Carver Comprehensive Plan Boundary Map			City of Happy Valley
Pleasant Valley North Carver Project Management Plan	7/13/2018		City of Happy Valley
Pleasant Valley North Carver: Existing Conditions			City of Happy Valley
Presentation Example	n/a	Clackamas County	WES
Problem Drainage Areas 2018		Clackamas County DTD	WES
Proposed North Clackamas Revitalization Area Design Plan	5/25/2006	Clackamas County Development Agency	WES
PVNC Bikeway and Trails		Angelo Planning	Angelo Planning
PVNC Bikeway and Trails		Angelo Planning	Angelo Planning
PVNC Refined Plan - Land Use		Angelo Planning	Angelo Planning
PVNC Refined Street Network		Angelo Planning	Angelo Planning
Report on the North Clackamas Revitalization Plan	5/25/2006	North Clackamas Urban Renewal Agency	WES
Rock Creek Area Land Use Plan	4/17/2011		City of Happy Valley
Rock Creek Regional Stormwater Facility Siting Analysis: Clackamas County, OR		Marjorie Wolfe	WES
Rock Creek Watershed Action Plan	6/2/2009	Brown And Caldwell	WES
Sanitary Risk Analysis	9/25/2019	Jacobs	WES
SOLIDS Study Area			WES
Storm Hot Spots		WES	WES
Storm water asset work orders			WES
Stormwater Drainage Issues Summary	working	WES	WES
Stormwater Facility Retrofit and Performance Optimization Program	4/20/2011	CDM	WES
Subdivision Map	8/1/2018	City of Happy Valley	City of Happy Valley
Sunnyside Village Green Clackamas County Service District NA. 1 Water Environment Services, Clackamas County Oregon	8/17/2016	Otak	WES
System Wide Assesmment	5/24/2018	WES	WES
TechMemo 011707	3/6/2018	Interfluve	WES
Technical Memoradum on Modeling and Field Visit for Upper Kellogg Creek	5/28/2014	Jim Harper	WES
Understanding and Approach	5/8/2017	WES	WES
Upper Kellogg Creek Basin Assessment	6/1/2019	Inter-Fluve	WES
Upper Kellogg Creek Basin Plan (budget)	5/8/2017	WES	WES
Water Environment Services Agreement	10/2/2007	WES	WES
Watershed Action Plan Kellog-Mt. Scott Watershed	6/1/2009	Brown And Caldwell	WES
WES Capital Improvement Plan (2018-2023)		WES	WES
WES Service Areas		WES	WES
Willamette River Waterhsed Total Maximum Daily Load Implementation Plan	1/7/2011	WES	WES

Exhibit B

GBD Schema

WES and Happy Valley SSMP Known Issue Geodatabase Schema
3/18/2020

Feature			**Attributes**								
Known Issue Point		Field	UNIQUEID	FullName	BASIN	Quality	Quantity	Erosion	Maint	Source	LongDesc
Dataset	Existing Conditions	Alias	*Unique Identification*	*Full Name*	*Study Area Basin*	*Water Quality Issue*	*Flooding Issue*	*Erosion Issue*	*Maintainability Issue*	*Source*	*Long description*
Featur Class	KnonIssue_P	Format	Long Int	Text, 100	Text, 50	Short Int	Short Int	Short Int	Short Int	Text, 50	Text, 8000
Geometry	point	Content	a unique four digit number for known issue point, 1XXX	full name of the issue	Study Area Basin location for the Known Issue	1 for yes or 0 for no regarding water quality issue	1 for yes or 0 for no regarding water quantity issue	1 for yes or 0 for no regarding erosion issue	1 for yes or 0 for no regarding maintenance issue	Category of source (i.e. interview, previous study, existing data)	A long description of the issue and the nature of the issue.

Unique ID Key	**Number Series**	**Count**
WES CIP and Storm Hot Spot Lists	000's, 100's	143
Happy Valley	300's	24
WES Maintenance Staff	400's	16
DTD Meeting	500's	14
Field Work/Other	600's	5

WES and Happy Valley SSMP Known Issue Geodatabase Schema
3/18/2020

Feature			**Attributes**									
Known Issue Point		Field	UNIQUEID	SiteVisitNotes	CreatedBy	OrigDate	UpdateBy	LastUpdate	ProbSource	OwnerComme	MaintComm
Dataset	Existing Conditions	Alias	*Unique Identification*	*SiteVisitNotes*	*Created by*	*Date of origin*	*Updated by*	*Last updated*	*Problem Source*	*Ownership Issue Comment*	*Maintenance Issue Comment*
Featur Class	KnonIssue_P	Format	Long Int	Text, 5000	Text, 50	Date	Text, 50	Date	Text, 255	Text, 255	Text, 254
Geometry	point	Content	a unique four digit number for known issue point, 1XXX	Any pertinent notes from site visits	"Otak, Inc."	XX/XX/XXXX	Person/Agency who updated	XX/XX/XXXX	A long description of the source and underlying causes of the issue.	A long description of ownership issues associated with the issue.	A long description of maintenance issues associated with the issue.

WES and Happy Valley SSMP Known Issue Geodatabase Schema
3/18/2020

Feature			**Attributes**								
Known Issue Point		Field	UNIQUEID	SafetyComm	Program	ProgramID	PP_ID	CIP_ID	No_Action	Site_Visit	Study_Area
Dataset	Existing Conditions	Alias	*Unique Identification*	*Safety Issue Comment*	*Program*	*Program ID*	*Potential Project ID*	*CIP ID*	*No Action*	*Site_Visit*	*Study_Area*
Featur Class	KnonIssue_P	Format	Long Int	Text, 254	Text, 254	Short Int	Short Int	Short Int	Text, 50	Text, 50	Text, 254
Geometry	point	Content	a unique four digit number for known issue point, 1XXX	A long description of safety issues associated with the issue.	Name of the Stormwater Program, if applicable	Stormwater Program ID Number, if applicable (see below)	Unique ID Number for Potential Projects point, 41XX; 80XX for existing CIPs; 81XX for scored projects.	ID Number for CIP Projects	1 for no further action on a Potential Project	"Site Visit" if a field visit was performed, blank if not	Name of the study area the point is located in.

Exhibit C

Known Issues

Otak

UNIQUE ID	Full Name	Long Description	Site Visit Notes	Quality	Quantity	Erosion	Maintenance	Source	Maintenance Comment	Study_Area
0	Commerce Park Milwaukie	Chronic drainage issue. WES is currently working on a solution to the problem.		0	0	0	0	WES CIP List		3 Creeks
1	William Otty/Cougar Manhole Repair	The flow is coming from two different directions. The manhole needs repair. A new trash grate is needed on the inlet. Access to the hatch has been removed. There is an open manhole and weird hydraulics in the manhole. Plan: Capacity assessment on storm line.		0	1	0	1	WES Storm Hotspot	FIXED	North Happy Valley
2	SE Kimberly Ct Ditch Inlet	Drainage debris plugs up the ditch inlet		0	0	0	1	WES Storm Hotspot		North Happy Valley
3	SE 147th Ave	Debris plugs up the inlets and outlets. WES or City placed rip-rap in the "big hole"	System switches back and forth between open and closed conveyance. Clogging occurs at inlets. Road lacks curb and gutter, homes are built downhill from road. Ditch alongside road has been filled in by homeowners to create parking area.	0	0	0	1	WES Storm Hotspot		North Happy Valley
4	Grate structure piles up with debris and rock from creek. Ditch inlet gets plugged with debris	The grate structure fills up with debris and rock from the creek. The ditch inlet gets plugged with debris.		0	0	0	1	WES Storm Hotspot		Kellogg Creek
5	SE Wildlife Estates Dr ditch Inlet	The ditch inlet grate structure gets clogged with debris and rock from the creek. Worst case known related to ID 91 (house that floods regularly). Have gotten recommendations for building a berm and raising the road. Entire Oliver Crest Court floods. Suggested a box culvert option to replace steel pipe.	There's a lot of sediment washing from steep slopes and uncontrolled runoff. Maintence removes lot of sediment (12, 5 CY trucks two years ago). The ditch inlet structure could also be improved.	0	1	1	1	WES Storm Hotspot		Kellogg Creek
6	Inlet at failed stairway	There was a catastrophic stairway failure 3-4 years ago. There is a large elevation gain to get access. The grate gets plugged and water is blocked by a build-up at the fences and backyards. Water flows from the new NE subdivision to open drainage, then enters the inlet at the top of stairs and flows through a pipe through the cul-de-sac, then outfalls at the bottom of the hill. Would need as-built for new subdivision for access. There is likely a sanitary line in the area. Potential solution: Secondary inlets to create redundancy and easier maintenance. Definitely need better equipment access.	Inlet grate is at a location at the top of gravel stairs that is very difficult to access. There have been major flooding problems when previous upstream construction work caused the inlet grate to clog with sediment and debris, washing down the hill onto the street. Now WES clears the inlet more regularly, since it is on the hotspot list.	0	1	0	1	WES Storm Hotspot	Large elevation gain to get access. 60" inlet. Washed out the stairs. Headwater. Make easier to maintain and create redundancy.	Sunnyside
7	Inlet swIN-007687	Same as 6. Inlets get plugged with debris		0	1	0	1	WES Storm Hotspot	Fences and backyards.	Sunnyside
8	Inlet swIN-007677	Same as 6. Inlets get plugged with debris	Regular maintenance of ditch inlet is required. On hotspot list.	0	1	0	1	WES Storm Hotspot	Fences and backyards.	Sunnyside
9	Catch basins PC33A-134 and PC33A-135	Same as 6. Catch basins on hillside (PC33A-134 and PC33A-135) get plugged with leaves and water floods downstream yards at the end of cul-de-sac on 95th.		0	1	0	1	WES Storm Hotspot		Mt Scott
10	Inlet swIN-007924	Inlet gets plugged with debris		0	0	0	1	WES Storm Hotspot		Sunnyside

UNIQUE ID	Full Name	Long Description	Site Visit Notes	Quality	Quantity	Erosion	Maintenance	Source	Maintenance Comment	Study_Area
11	Inlet at SE Marisa Ct	Inlet gets plugged with debris	House is lower than the road elevation. When CB inlets get clogged with debris, the house floods.	0	0	0	1	WES Storm Hotspot		Sunnyside
12	Pond outlet gets plugged and there is a very vocal customer next door	There is an erosion issue at SE Orchard Lane. The pond outlet gets plugged and there are complaints from nearby neighbors. ODOT was supposed to fix this.		0	0	1	1	WES Storm Hotspot		Sunnyside
13	Mabel Ave A	Open drainage is silting in the transition area from the steep to low-gradient run-off. The run-off gains momentum on the hill and water goes into the bowl and backs up to Clackamas Road. The inlets and outlets get plugged and silted in. They need to be dug out (usually) yearly.		0	0	1	1	WES Storm Hotspot		Kellogg Creek
14	Mabel Ave B (Autumn hill Open Space)	The run-off gains momentum on hill and has to get dug out. Water goes into the bowl and backs up to Clackamas Road. They suspect nutria may be there. Headwaters in Johnson City. Inlets and outlets get plugged and silted in. They need to be dug out (usually) yearly	There's a lot of sediment washing from steep slopes and uncontrolled runoff. Solution requires stream improvements to prevent incising and sedimentation. #14 hasn't had any issues since new home was constructed and driveway paved.	0	0	1	1	WES Storm Hotspot		Kellogg Creek
15	Happy Valley Wetland Park Pond	Problems associated with NOs. 23, 24, 26 and 16 drain to pond at No. 15. There is a clogged outlet and in high flows it backs up the system into the right of way. It was cleared in 2017 but it has since filled up with cattails. The pond was retrofitted with the Opti system to provide real time control of the outlet structure and maximize detention. These are expensive and difficult to clean out ~$300k each. The control structure of the pond was overwhelmed in recent storms, removing manhole covers into the road (flood location at SE Purple Finch Drive and 145th Avenue). OPTI will likely fix this. No CIP needed.	Regional pond with OptiRTC. Cattails get overgrown and die when pond fills with water, creating debris that can clog outlet. Opti technology is not responsive enough to flashy storm events. Pond has overflowed to wetland.	0	0	0	1	WES Storm Hotspot		North Happy Valley
16	Road flooding due to Happy Valley Wetland Park Pond	The same as #23 but with less impact. It can get plugged or water backs up out of structure from the pond and floods roadway.		0	0	0	1	WES Storm Hotspot		North Happy Valley
17	Spring Mountain storm line root removal	See KI 66. Possible slip line projects, previously flooded a house due to tree roots. Old storm systems were built by home owners mostly in the 60's and 70's. West of 205 homes are from the 60's and 70's; it's flatter so it has fewer issues even though its older. East of I-205 is the new Happy Valley storm system, flashy and high relief: not flat. Roots in pipes. Needs to be rehabbed. The pipes in the worst condition are west of Sunnyside Road between I-205 and 122nd.		0	0	0	1	WES Storm Hotspot	Smaller pipe, can be cut. Floods houses because of roots.	Mt Scott
18	Highland Summit Pond Rehab	The outlet plugs up and the pond needs to be cleaned out.		0	0	0	1	WES Storm Hotspot		Sunnyside
19	Inlet swIN-008963	The catch basin backs up during high flow.		0	1	0	1	WES Storm Hotspot		Sunnyside

UNIQUE ID	Full Name	Long Description	Site Visit Notes	Quality	Quantity	Erosion	Maintenance	Source	Maintenance Comment	Study_Area
20	SE 142nd Inlet	The inlet gets plugged with debris.		0	0	0	1	WES Storm Hotspot		Rock Creek
21	Mountain Gate Road	The pipe is not big enough and water runs down the road to the 3rd house on the right (16" inlet and 12" outfall.) The catch basin should be a manhole and the catch basin lid blows off (capacity issue). Beavers downstream are slowing the entire drainage.	Upstream channel is incising. Ditch inlet clogs with debris. During high flows it overtops banks and flows into the road. Manhole lid used to blow off because it had flow control orifice in it, which has been removed. Downstream ditch along backyards has berm that looks likely to fail.	0	1	0	0	WES Storm Hotspot		North Happy Valley
22	King Road Culvert	There is excessive debris in creek bed. The culvert plugs up and the nearby catch basin backs up and floods the road.	Undersized culvert crossing. Water backs up but rarely overtops road. Heavy vegetation on upstream end clogs culvert inlet. Low gradient at downstream end, as well as beaver activity.	0	1	0	0	WES Storm Hotspot		North Happy Valley
23	Drainage swale behind Emerald Loop	Drainage swale plugs up with vegetation. Inlets plug up as well. Property owners removed cattle fence and resolved problem. Solution: Cleaning out the ponds has reduced flooding. Also put in a ditch at the park and wetland to help mitigate.	Open channel conveyance behind three houses gets clogged with vegetation, sometimes floods. Small culvert under road. Pipes (#006732) shown in GIS do not appear to exist.	0	0	0	0	WES Storm Hotspot		North Happy Valley
24	Emerald Loop drainage swale	Same as #23. Swale over tops banks and sheet flows to sidewalk. Drainage swale plugs up with vegetation. Inlets plug up as well	Open channel conveyance gets overgrown and requires frequent maintenance at ditch inlet. Floods if clogged, crossing over Ridgecrest Road.	0	0	0	0	WES Storm Hotspot		North Happy Valley
25	SE Hillcrest Rd Ditch Inlet	The ditch inlet plugs up and floods the road and nearby properties.		0	0	0	1	WES Storm Hotspot		Mt Scott
26	Springs in Monterra Private Park	Same as #23. The Park area is full of springs. The cut-off ditch fills with sediment and floods backyards.	Saturated soils. Difficult to even mow the muddy lawn. Groundwater in park drains downhill to backyards. Ditch inlet collects water at one end, but does not protect all backyards.	0	1	1	0	WES Storm Hotspot		North Happy Valley
27	Otty Road	Lacking adequate drainage system on entire road. There are steep slopes and no curbs. The culverts and inlets plug which results in inlet bypass during high flows.		0	1	0	0	WES Storm Hotspot		Mt Scott
28	130th/135th Ave Outfall/Stormwater Treatment Facility	Large outfall water quality retrofit. Similar to Carli Creek project.		1	0	0	0	WES CIP List		Clackamas River Drainage
29	Addington Place Detention Pond Retrofit	Built in 1997. (Two ponds in Subdivision Retrofit), Water Quality and hydrology improvement		1	1	0	0	WES CIP List		Rock Creek
30	Regency View Inlet Structure Replacement	Need to replace the inlet structures. The catch basin drains off of the hillside. Flash floods occur on 137th. The storm system needs something more substantial than a ditch inlet. Easement thru 3-4 houses; all inlets plugged; went over road; caused sinkholes.		0	0	0	0	WES CIP List		Sunnyside
31	Burlington Coat Factory New WQ Facility	New Water Quality Facility. Described in Retrofit Strategy & Fee In-Lieu Study (Cardno 2013)		1	0	0	0	WES CIP List		3 Creeks

UNIQUE ID	Full Name	Long Description	Site Visit Notes	Quality	Quantity	Erosion	Maintenance	Source	Maintenance Comment	Study_Area
32	Thiessen Heights Detention Pond Retrofit	Built in 1996. Private Property?	Basketball court has been constructed over pond area. What is remaining are two ditch inlets that do not appear to provide any flow control.	1	1	0	0	WES CIP List		Kellogg Creek
33	Jannsen Gardens Detention Pond Retrofit	Built in 1997		1	1	0	0	WES CIP List		3 Creeks
34	Sky High Ct. Storm line Root Removal	Tree roots are blocking the water flow in pipes off of McNary and Oak above Oatfield. Pipe connecting two developments; tree in yard; cut roots in pipe several times. Needs to be lined.		0	0	0	1	WES CIP List		Kellogg Creek
35	Cardinal View Detention Pond Retrofit	Built in 2008		1	1	0	0	WES CIP List		Kellogg Creek
36	Happy Valley Sub Regional Pond A Opti Installation	OptiRTC Technology Retrofit		1	1	0	0	WES CIP List		North Happy Valley
37	Happy Valley Sub Regional Pond B Opti Installation	Overgrown trees and excess vegetation is clogging the pond, which is not functional. SOLUTION: The pond needs to be completely cleared out to remove vegetation and replanted/seeded with a more appropriate mix. Plan: Hire contractor for clean out and revegetation. OptiRTC is to be installed.		1	1	0	0	WES CIP List		North Happy Valley
38	Scott Creek Estates Detention Pond Retrofit	Built in 1997, WQ and hydrology improvement	Old pond needs maintenance and possible retrofit. Inlet is buried but still seems to function. WES staff will investigate whether decomposing paper is evidence of cross connection.	1	1	0	0	WES CIP List		North Happy Valley
39	Rivergrove City Park New Vegetated Swale	If we can't get a swale in here, we might be able to install a below-ground stormwater treatment unit, although this storm sewer system is quite shallow, so this may not be feasible. This is a proposed MS4 project.		1	0	0	0	WES CIP List		SWMACC
40	Oregon Trail Estates Detention Pond Retrofit	Built in 1995, hydrology improvement		1	1	0	0	WES CIP List		Sunnyside
41	Public Safety Center New Detention Pond	Install/add a detention pond at this potential location. Construction of new extended dry detention pond north of Public Safety Center.		1	1	0	0	WES CIP List		3 Creeks
42	SE 106th Avenue Storm System Completion	Incomplete project, the lower piece was built. Need an access/easement from Clackamas River Water to connect the pipes near Robert Avenue.		1	1	0	0	WES CIP List		Clackamas River Drainage
43	Cody Estates Detention Pond Retrofit	WQ and hydrology improvements		1	1	0	0	WES CIP List		North Happy Valley
44	Mt. Scott Creek Oak Bluff Reach Restoration	A restoration concept plan was completed by ESA. The project is planned for property not owned by the district. A grant was obtained to complete the project. Plan: Waiting on easements. Have a concept plan. Entire site not yet an asset, need Conservation Easement		0	0	0	0	WES CIP List	.	3 Creeks
45	Daffodil Flats Detention Pond Retrofit	Built in 2005. HOA, WQ and hydrology improvements		1	1	0	0	WES CIP List		Kellogg Creek
46	Dew Point Detention Pond Retrofit	Built in 2005. HOA, WQ and hydrology improvements		1	1	0	0	WES CIP List		Kellogg Creek

UNIQUE ID	Full Name	Long Description	Site Visit Notes	Quality	Quantity	Erosion	Maintenance	Source	Maintenance Comment	Study_Area
47	Fields Creek Stabilization	Easement needed this is private ownership. Location is on Bosky Dell Nursery property and does not currently have property owner support, so not a definite project at all.		0	0	1	0	WES CIP List		SWMACC
48	Ross Center Control Structure Retrofit	WQ		1	0	0	0	WES CIP List		3 Creeks
49	Drainage: Farrin_Rosewood_Drywell	Three drywells. 25', 20' and 10' deep. 20' drywell intersects with groundwater. Not near MS4. Not easy to fix.		0	1	0	0	WES CIP List		SWMACC
50	Forton Detention Pond Retrofit	Re-route the open channel flow around the pond; the pond is located in property owners' driveway; fills with debris and plugs pond. Re-route road runoff around facility. Road runoff is too much for the facility.	Upstream open channel is connected to the pond. The pond has no flow control structures and provides limited water quality treatment. The outlet of the pond clogs with debris and the pond is overwhelmed by the upstream flows. Pond is like a pit in the middle of the driveway.	0	1	0	0	WES CIP List		Mt Scott
51	Drainage Repair - Emerald Loop	Multiple Property Owners* Conveyance repair/retrofit. Drainage that is filled in and flooding backyards. Wetland. Full condition assessment of the problems needed. ** Conservation Easement: What is allowed in this easement from the HOA?		1	1	0	0	WES CIP List		North Happy Valley
52	Clackamas Town Center Detention Pond Retrofit	Control Structure Retrofit	Large stormwater facility that serves Clackamas Town Center. A 30" and 48" pipe outfall into this pond. This pond most likely only provides detention and not providing water quality treatment. Overgrown with trees and bushes. Steep side slopes. Pond is likely undersized for the basin area contributing.	1	1	0	0	WES CIP List		3 Creeks
53	Eagle Landing Detention Pond Retrofit	Built in 2003		1	1	0	0	WES CIP List		Mt Scott
54	Idleman & 92nd Root removal	10211 SE 100th Drive. Tree roots in structures and inadequate drainage in the area. There are several bottlenecks and it is under-drained for the amount of water coming off of the hill.		0	0	0	1	WES CIP List		Mt Scott
55	SE Thiessen Rd Culvert Replacement	Nearby beaver dams up to 20 ft. tall (On private property). Water tries to make a right turn but is blocked, so it floods. Even farther north, see 13 and 14. Road department is upgrading the failing road.	Culvert is causing backwater. Some erosion is occurring at the downstream end. Unverified beaver dam downstream could also be causing backwater.	0	1	0	0	WES CIP List	Beaver dams (15-20') blocking. Culvert is failing.	Kellogg Creek
56	Greenbrier Detention Pond Retrofit	Built in 2004. HOA		1	1	0	0	WES CIP List		Kellogg Creek
57	Rivergrove Tualatin River Riparian Enhancement	(65th & Childs)		0	0	1	0	WES CIP List		SWMACC
58	Happy Valley Heights Detention Pond Retrofit			1	1	0	0	WES CIP List	Project completed (per Leah J. 3/20/2020 mtg.)	North Happy Valley

UNIQUE ID	Full Name	Long Description	Site Visit Notes	Quality	Quantity	Erosion	Maintenance	Source	Maintenance Comment	Study_Area
59	Aldercrest Circle Detention Pond Retrofit	Built in 1999 - two ponds.	WES had no issues to report on this facility. The pond was recently retrofitted to create a depression at the outlet and inlet and they added BES soil media. It appears that the pond has a high infiltration rate since they have not seen ponding water in the facility since it was retrofitted.	1	1	0	0	WES CIP List		Kellogg Creek
60	Highland View Estates Detention Pond Retrofit			1	1	0	0	WES CIP List		North Happy Valley
61	Highland Summit Detention Pond Retrofit	Water Quality Retrofit and Downstream Conveyance. Look at outlet structure and downstream conveyance. Surging downstream.		1	1	0	0	WES CIP List		Sunnyside
62	Hillside Park Detention Pond Retrofit	built in 1997	Pond is filled with sediment and cattails. Inlet pipes are almost completely clogged with sediment roots.	1	1	0	0	WES CIP List		North Happy Valley
63	Carron Estates Detention Pond Retrofit			1	1	0	0	WES CIP List		North Happy Valley
64	Cavalier Storm line Root Removal	There is approx. 2,000 ft. of storm pipe with tree roots that are clogging the pipe off of Webster Road. The ditch inlets are old and starting to fail. Solution: Need to remove the tree roots and potentially re-line the pipes. Plan: Develop RFP to solicit bids for root removal, pipe assessment and pipe lining.		0	1	0	1	WES CIP List		Kellogg Creek
65	Drainage: Jensen_MilwaukieHillcrest	Complaint about flooding from drainage easement near Cardinal, limited number of catch basins in the area, may be inadequate infrastructure; likely need a design to capture/convey or infiltrate.	WES maintenance staff are unaware of any issues here. There are two catch basins for a long, wide road.	0	1	0	0	WES CIP List		Kellogg Creek
66	Spring Mountain Storm line Root Removal	Slip line pipe due to roots clogging pipe near 129th off of Sunnyside Road. Storm line behind homes. Misaligned joints with tree roots and runs into three backyards.		0	0	0	0	WES CIP List		Mt Scott
67	Royal View Estates Detention Pond Retrofit	RETROFIT IN PROGRESS		1	1	0	0	WES CIP List	RETROFIT IN PROGRESS	Sunnyside
68	Kensington Bluff Detention Pond Retrofit	Built in 2003	See description of KI #69. Two noted differences are that this pond appears to provide flow control and the cinderblock wall down the center (limiting short-circuiting) is failing.	0	1	0	0	WES CIP List	CLEANED	Mt Scott
69	SE 92nd Ave Detention Pond Retrofit (Kensington Bluff)	Built in 1997	Trees were recently removed but are growing from the stumps. Pond may not have flow control, otherwise design seems okay for water quality. There is a single ditch inlet to collect flow.	0	1	0	0	WES CIP List	CLEANED	Mt Scott

UNIQUE ID	Full Name	Long Description	Site Visit Notes	Quality	Quantity	Erosion	Maintenance	Source	Maintenance Comment	Study_Area
70	Drainage: Kessler_Hillcrest	Water from 95th Court does not enter the storm collection system. Sheet flows down the cul-de-sac on 95th Court and onto a private driveway. Floods the Kessler property.	Large roadway area is directed to two catch basins. But the position of the catch basins allows for runoff to bypass the inlets and runs along the curb till it ends and then into the backyard and swimming pool. A couple of the roof drains are downstream	0	1	0	0	WES CIP List		Mt Scott
71	Drainage: Kindred_Diamond Ct.	The stormwater drainage system behind the Kindred property is filled with tree roots; resulting in flooding along the fence line of Kindred Court property. The manholes and pipes are old and failing, need to be replaced. Detention pipe is full of debris. Corrugated steel pipe is degraded. 21" pipes drain to 12" pipes. Solution: Need to repair/rehab/replace manholes and pipe sections. Several trees need removed. Hydraulic/capacity engineering analysis is needed. Replace or upgrade existing pipes and manholes based on engineering results. Site access is limited. Based on field visit there are one or two options to access the site from vacant properties or private properties. Plan: Prepare RFP and initiate solicitation for engineering analysis bids to remove vegetation. Once completed, construction bids will be initiated		0	1	0	0	WES CIP List	FIXED	Clackamas River Drainage
72	Wexford Detention Pond Retrofit	Built in 2003		1	1	0	0	WES CIP List		North Happy Valley
73	SE Lake Rd & SE Rusk Rd Willing Seller Buy Out Program	Apartment Complex manages flooding with sandbags. Potential program: acquire other houses in the area that are constantly flooding. The general area does not have sumps and drywells fill up.		0	1	0	0	WES CIP List	Hot spot. Bought two houses (not WES). Apartment complex does maintenance. Downstream from Three Creeks.	3 Creeks
74	Drainage: Libby_MountainGate (DONE)	Clogged/non-functioning swale located within an easement on private property (??)		0	1	0	0	WES CIP List		North Happy Valley
75	Drainage Repair - Lincoln Heights Detention Pond	Vegetation replacement, and possibly retrofit ponds. Taken over by willow trees. Fences falling down by the willows. Needs complete vegetation removal. Add low growth plants.		1	1	0	0	WES CIP List		Mt Scott
76	McNary Meadows Detention Pond Retrofit	Built in 2000. HOA		1	1	0	0	WES CIP List		Kellogg Creek
77	Drainage: Morgan_130th Ave	Continuous clogging of catch basins upstream of here that force run-off down to the intersection where it ponds, then comes up the driveway into the yard and garage.		0	0	0	1	WES CIP List		Sunnyside
78	Mt Sun Village Detention Pond Retrofit	WQ and hydrology improvements		1	1	0	0	WES CIP List		Sunnyside

UNIQUE ID	Full Name	Long Description	Site Visit Notes	Quality	Quantity	Erosion	Maintenance	Source	Maintenance Comment	Study_Area
79	Aldercrest Ct. Culvert Removal & Creek restoration	Need a creek rehab to remove the unused culverts and remove the buildup of sediment. This is a series of culverts, Upper Kellogg assessment.	Natural channel was straightened and regular maintenance to remove sediment and vegetation. Dual 24" CMP culverts with adverse slope are causing backwater.	0	1	1	0	WES CIP List		Kellogg Creek
80	132nd Parachute Detention Pond Retrofit	Pond retrofit/ outlet retrofit. Between 132nd and 122nd; long easement thru backyard; issues with outlets plugging; possible outlet modifications; improve access; new homeowner.		1	1	0	1	WES CIP List		Sunnyside
81	Northern Heights Detention Pond Retrofit	Built in 2006		1	1	0	0	WES CIP List		North Happy Valley
82	142nd and Sunnyside New SW Facility	NCPRDs/Church property. Existing detention tank. Land under power lines. Eastridge Church. Ali Maria St. Maintenance access might be limited. Sieben Cr. Residential Area.		1	0	0	0	WES CIP List		Sunnyside
83	Trillium Creek Tributary stabilization	Easement needed, NCPRD owned, also involves an ODOT culvert		0	0	1	0	WES CIP List		Rock Creek
84	Rock Creek Detention Pond Retrofit			1	1	0	0	WES CIP List		Rock Creek
85	Oetken Glen Detention Pond Retrofit	Built in 2005. HOA		1	1	0	0	WES CIP List		Kellogg Creek
86	Ryan Meadows Detention Pond Retrofit			1	1	0	0	WES CIP List		Sunnyside
87	Merganser Court Detention Pond Retrofit	Built in 1999. Private Property?		1	1	0	0	WES CIP List		Kellogg Creek
88	Red Rose Detention Pond Retrofit		During heavy rain or when creek is backwatered, pond floods roadway. Low flow entrance to flow control structure is easily plugged.	1	1	0	0	WES CIP List		North Happy Valley
89	SE Parmenter Rd Culvert Replacement			0	1	0	0	WES CIP List		Kellogg Creek
90	Robhill Estates Detention Pond Retrofit	Built in 2004. HOA		1	1	0	0	WES CIP List		Kellogg Creek
91	Drainage:Sanetel_ClackamasRd	Refer to 5. Chronic flooding at Sanetel property. Storm assets located at 6592 Clackamas are clogged or not functioning and water is flooding that property and the street. Solution: an Engineering hydraulic capacity analysis of the existing storm systems adjacent to the Sanetel property. May need to replace or repair with a larger system to address the water volume. Plan: Develop an RFP and solicit proposals from engineers to assess the problem and solution. Possible property acquisition	Possible underlying issue is that the culverts are creating backwater in Kellogg Creek and limiting its capacity. Other issue is that the house is at the low point in the road and in floodplain.	0	1	0	1	WES CIP List	Floods annually, in the floodplain. Client wants hydraulic analysis of creek prior to acquisition.	Kellogg Creek
92	Nicholas Court Detention Pond Retrofit	Built in 2003, 30" inlet	Detention pond on rehab list. Outlet structure needs ongoing maintenance. Otherwise, maintenance staff do not know of problems with this pond. It was on rehab list.	1	1	0	0	WES CIP List		North Happy Valley
93	SE 129th Road Detention Pond Retrofit	Built in 1998 located near 145th Street.	No visible flow control structures. Pond appears to provide only water quality treatment.	1	1	0	0	WES CIP List		North Happy Valley

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94	Rustling Ridge/Echo Valley Meadows Detention Pond Retrofit			1	1	0	0	WES CIP List		Sunnyside
95	South 172nd Ave New Regional Detention Basin	Property owned by Sunrise Water Authority		1	1	0	0	WES CIP List		Rock Creek
96	Golden Eagle/Vista Woods Detention Pond Retrofit			1	1	0	0	WES CIP List		Mt Scott
97	SE Clackamas Rd. & SE Mabel Rd Willing Seller Buy Out Program			0	1	0	0	WES CIP List		Kellogg Creek
98	Rose Ck Land New Detention Pond	Have assessment and rough concept plan. (ESA concept plan report). Existing headcut. Building stream resiliency.		1	1	0	0	WES CIP List		Sunnyside
99	Thelma circle Detention Pond Retrofit	Built in 1994 ** CCSD#1 Property **		1	1	0	0	WES CIP List		3 Creeks
100	Royal View Estates Detention Pond Retrofit	The structure is plugged and causes flooding. Was cleared out but still causing issues in the cul-de-sac and backyards. Need to change the outlet structure (maybe a ditch inlet). The homeowner is ready to go to the Board of County Commissioners. CCSD#1 owned pond. There are diseased trees that need to be removed or possibly replaced and vegetation enhancement. (Allison Court) RETROFIT IN PROGRESS		1	1	0	1	WES CIP List	RETROFIT IN PROGRESS	Sunnyside
101	Rock Creek Confluence Vegetation Enhancement	Small amount of work remaining, then plant establishment. Contract with CRBC thru 2018		0	0	0	0	WES CIP List		Rock Creek
102	North 172nd Ave New Regional Detention Basin	In PVNC Area		1	1	0	0	WES CIP List		Rock Creek
103	Liberty View Detention Pond Retrofit			1	1	0	0	WES CIP List		North Happy Valley
104	122nd and Mountain Sun - Drainage & Detention Pond Retrofit	Overgrown Cottonwood trees and excess vegetation are clogging the pond. The pond is not functional and the outlet had a historic retrofit and currently plugs during every storm. When the pond is full, it floods Mt. Sun Road and private backyards. Solution: The pond needs to be cleared out to remove vegetation and then replanted/seeded. The outlet structure needs modifications. Plan: Hire contractor for clean out and re-vegetation. Determine if full engineering analysis is needed.		1	1	0	1	WES CIP List	RETROFIT IN PROGRESS	Sunnyside
105	U-Haul Site Stream Restoration	SOLV is doing existing planting in this area. (SE McBride Street) - Stream Restoration and Culvert Replacement		0	0	0	0	WES CIP List		3 Creeks
106	Sunnyside at 145th Detention Pond Retrofit	Built in 2007		1	1	0	0	WES CIP List		Sunnyside

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107	Steen Ct. Drywell Decommission	Floods a house, house built lower than road, drywell fills and floods driveway. Solution: Put in drywell to mitigate, annual cleanings would help too, but are not a priority. Severe shallow ground water issues due to the area being mostly river rock. Need to assess properties and develop recommendations. Need plan. CCSD#1 owned properties. (Two different properties. Same activities)	High groundwater. Drywells fill up around December each year. Nearest MS4 pipe to connect into is uphill on Lynwood.	0	1	0	0	WES CIP List	Floods a house, house built lower than road, dry well fills and floods driveway.	NCRA
109	Causey & Fuller Storm line Root Removal	Line pipe/root removal. There are a couple of sections of pipe near the Fire Station on Causey that are always plugged with tree roots. Potentially slip line and line with fiberglass. Possibly combine with DTD Monroe project.		0	1	0	1	WES CIP List		3 Creeks
110	Drainage: Packard_Rimrock			0	1	0	0	WES CIP List		North Happy Valley
111	Marquam Estates/Sunny Way	Field Ops - Drainage causing erosion, eroding HV path. Path is planned for extension from Parks Dept. Per 10/2/19 mtg notes, issue has been resolved through a CIP		0	1	0	1	WES CIP List	FIXED FLOW	Mt Scott
112	Valley View Church Detention Pond Retrofit	Built in 2001		1	1	0	0	WES CIP List		Mt Scott
113	ODOT Property New Detention Pond	Install/Add a detention pond in this potential location. Construction of New Extended Dry Detention Pond NW of Sunnybrook and 82nd Avenue.		1	1	0	0	WES CIP List		3 Creeks
114	SE 84th Ave New Rain Gardens	Along SE 84th from SE Sunnyside Road to Sunnybrook Blvd. CCSD#1 Taxlot. Control volume and add WQ treatment - currently lacking both. WQ primary driver. High impervious. Commercial. Half street that could potentially catch runoff. Existing MS4. Near Phillips. Add white oak.		1	0	0	0	WES CIP List		Rock Creek
115	Phillips Creek Detention Pond Retrofit	Potential location to utilize Opti technology / Outlet Valve Replacement.		1	1	0	0	WES CIP List		3 Creeks
116	Sunnyside Village Green Detention Pond Opti Installation	OptiRTC Technology Retrofit		1	1	0	0	WES CIP List		Sunnyside
117	Jacob's Meadows Detention Pond Retrofit	Built in 1996		1	1	0	0	WES CIP List		Rock Creek
119	New Clackamas Industrial Area WQ Facility	Extended Detention WQ Facility - Clackamas Industrial Area (Clackamas River Water Property)		1	1	0	0	WES CIP List		Clackamas River Drainage
120	South 172nd Ave New Regional Detention Basin - Property Acquisition	New regional detention basin, would require property acquisition (owned by Sunrise Water Authority)		0	0	0	0	WES CIP List		Rock Creek
121	North 172nd Ave New Regional Detention Basin - Property Acquisition	New regional detention basin, would require property acquisition		0	0	0	0	WES CIP List		Rock Creek

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122	SW Reao Court Drainage Repair	Unclear if there is a drywell in the heart of the sinkhole, or if there is merely a crushed/broken surface-discharging pipe in there. This is a drainage improvement project that could potentially also have some water quality benefits.		0	1	0	0	WES CIP List		SWMACC
123	SW Borland Road Ditch Vegetation	Address or Tax lot listed are potential locations for this project. Carol Drudis did some work out there a few years ago. This is a proposed Nonpoint Source TMDL project.		1	0	0	0	WES CIP List		SWMACC
124	Three Creeks Flood Control Facility Performance Improvement	Design of Phase 1 is in progress.		0	1	0	0	WES CIP List		3 Creeks
125	Aldercrest & Rusk Drainage Improvement	Inadequate drainage in area WES works is not accurate. Look at area for possible upgrades. Upper Kellogg assessment.		0	1	0	0	WES CIP List		Kellogg Creek
126	Rock Creek Enhancement - Verizon Site	Need initial Plan. Owned by CCSD#1 for sanitary needs/pump station. No improvements on property. Riparian area. Needs a plan, need to transfer property to Watershed to protect from sanitary. (Behind Verizon Property)		0	0	0	0	WES CIP List		Rock Creek
127	Ongoing Small Restoration Projects	Instream, between SE Minerva Court and SE Roethe Lane. Project in a CE-project will begin soon, multi-years.	Undetained flows are eroding sideslopes of channel. The steep slopes have the potential for landslides and are a threat to adjacent properties.	0	0	0	1	WES CIP List		Kellogg Creek
128	Rose Ck - Hines Drive New Detention Pond			1	0	0	0	WES CIP List		Sunnyside
129	SW Ribera Lane New SW Facility	Devin Patterson has identified at least one location in this paving project's area where funds from the SWMACC could be used to reduce stormwater pollution.		1	0	0	0	WES CIP List	The adjacent property owner wants this section of ditch to be converted into a swale, which is a big plus.	SWMACC
130	Drainage: Sydney_PebbleBeachDr	Surface water/ springs containment; possible french drain; park near 147th; HOA open space. Floods drains and goes into property owners backyard. Stormwater ditch inlet; many springs; need more structures or french drains to direct water to storm system.		0	1	0	0	WES CIP List		North Happy Valley
131	Pleasant Valley Golf Course Instream restoration	Rock Creek and two tributaries west of SE 172nd Ave between Hagen Road and Tristin Lane. Easements needed, developer may do some of this work		0	0	1	0	WES CIP List		Rock Creek
132	Rock Creek headwater tributary stabilization	Easement needed, private ownership		0	0	1	0	WES CIP List		Rock Creek
133	Clackamas Mitigation Bank Establishment	Mitigation report done by Keri Nichols/Carol		0	0	1	0	WES CIP List		Clackamas River Drainage
134	Sieben Creek Stream Stabilization			0	0	1	0	WES CIP List		Sunnyside

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135	Rose Creek Instream Restoration	Have assessment and rough concept plan. (ESA concept plan report). Existing headcut. Building stream resiliency.		0	0	1	0	WES CIP List		Sunnyside
136	Echo Valley Meadows Phase 2 Restoration	Need easement. Have concept plans. Wetland enhancement/restoration/flow mitigation.		0	1	0	0	WES CIP List		Kellogg Creek
137	Town Center Collection system rehabilitation	Control Structure Retrofit		0	1	0	0	WES CIP List		3 Creeks
138	84TH Ave & Last Rd Vegetation Enhancement	Need to assess properties and develop recommendations. Need a plan. CCSD#1 owned properties. (Two different properties. Same activities)		1	0	1	0	WES CIP List		3 Creeks
140	Claremont Detention Pond Retrofit			0	1	0	0	WES CIP List		North Happy Valley
141	Rancho-Molt-Renada New Rain Garden	Drywells decommissioned. Historic drainage/flooding problem near Thiessen & Kellogg Creek. SE Rancho, Molt, Renada area.		1	0	0	0	WES CIP List		Kellogg Creek
142	162nd Ave New Regional Detention Basin			1	1	0	0	WES CIP List		Rock Creek
143	162nd Ave New Regional Detention Basin - Property Acquisition			1	1	0	0	WES CIP List		Rock Creek
144	North Clackamas Park Drainage Improvement	Inadequate drainage in area. Include in Aldercrest assessment		0	1	0	1	WES CIP List		Kellogg Creek
145	129th Ave Culvert south of King Rd	Built in 1998		0	1	0	0	WES CIP List		North Happy Valley
146	SE 129th & King Rd Storm Pipe Repair	Culvert crossing		0	1	0	0	WES CIP List		North Happy Valley
301	SE 147th Ave Cul-de-sac Field Inlet	Field inlet at end of cul-de-sac plugs up and floods the two houses below on 147th. No curb or sidewalk.		0	0	0	1	Happy Valley		North Happy Valley
302	SE 145th & SE Micah Field Inlet	Field Inlet plugs up at 145th and SE Micah. Check if WES has fixed this inlet.	No apparent ditch inlet at this location. However, there is a need for one. Visible channelization and erosion next to sidewalk.	0	1	1	1	Happy Valley		North Happy Valley
303	SE Lampert Ct Drainage	Field Inlet behind houses plugs and/or jumps the bank (it's open drainage into pipe) and floods yards. The overflow goes to a different inlet on the cul-de-sac to the east.	Known Issue has been addressed by new construction replacing field inlet with a stormwater pond.	0	0	0	1	Happy Valley		North Happy Valley
304	SE Cedar Way Culvert	Culvert Inlet Capacity issue. Causes residential property flooding. Any relation to the Scott Creek Estates Detention ponds?	No visible evidence of culvert inlet capacity problem. Known issue may have been addressed by Cedar Way Phase 2 stream restoration project.	0	1	0	0	Happy Valley		North Happy Valley
306	Solomon Court Outfall	Informal modification of the drainage to fill it and place a culvert under a pathway. Size and condition of culvert is unknown, except that the downstream end is eroding the natural drainage. There is concern that a pond may form, burst, and then cause flooding downstream. Potential location for a "Nature in the Neighborhood" grant to restore the stream and possibly install a pedestrian bridge. Flood makes a lake in front of the Fire Station.	Fill and culverts that were installed to create pedestrian path over the creek are now eroding away. Fill and culverts should be removed. Path appears to only be for local, private use.	0	1	1	0	Happy Valley		North Happy Valley

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307	Sunburst Culvert	Culvert in right-of-way that extends downhill from Sunburst. It is also connected to an inlet on Greiner Lane. But, configuration, size and condition are unknown. The residence south of the right-of-way floods.	Unsure whether we observed the known issue described. Need to discuss with Happy Valley. Did observe that the inlet may overflow due to connection to nearby manhole and detention pipe with gravel in it.	0	1	0	0	Happy Valley		North Happy Valley
308	SE Idleman Rd & SE Nicole Ln Ditch Inlet	Ditch runs down SE Idleman Rd, ends at inlet which clogs and overflows into the two houses downstream. Old system drains to open space but will drain to yards/homes if plugged. Homeowners have to keep up sandbags year round. Field inlet plugs up and overflows which causes flooding to houses down the road. The upstream ditch is under-sized.	Ditch along Idleman is collected with a small ditch inlet. Ditch inlet is regularly clogged with debris which causes the runoff to flow into the street and neighboring yards.	0	1	1	0	Happy Valley		Mt Scott
312	SE Callahan Rd Inlet	The inlet is under-capacity and it floods the detached home in the backyard of this property.		0	1	0	0	Happy Valley		North Happy Valley
313	SE Margie & SE 132nd Pond	The pond at SE Margie & SE 132nd is filled with vegetation and is causing floods in the area. WES opens the outlet structure to let it overflow/allow flow to bypass when flooding is occurring or imminent.		1	1	0	0	Happy Valley		North Happy Valley
314	SE Adoline Ave	Culvert inlet capacity issues. Floods residential properties.	A new beehive-shaped inlet grate (which WES staff call the Dillon & Bob solution) has addressed the culvert inlet problem.	0	0	0	0	Happy Valley		North Happy Valley
320	SE 137th Drive hillside	Drainage off hillside is washing out into the street.		0	1	1	0	Happy Valley		Sunnyside
321	SE 162nd Culvert	Creek crossing overflow		0	1	0	0	Happy Valley		Rock Creek
322	SE 172nd Ditch	The ditch is at capacity. The culvert is not sized for the volume of water.		0	1	0	0	Happy Valley		Rock Creek
323	SE Cedar Way Drainage	Drainage threatening the properties		0	1	0	0	Happy Valley		North Happy Valley
324	11183 SE Cedar Way	There is a small asphalt concrete depression east of the driveway. Water and sediment gathering in the driveway gutter line is unable to reach the catch basin to the west of the driveway.		0	1	1	0	Happy Valley		North Happy Valley
325	Hamilton Lane	There is a negative flow into catch basin at end of cul-de-sac. The owner has property leading to just inside of the curb.		0	0	0	0	Happy Valley		Mt Scott
326	Idleman Catch basin	The velocity of water is great enough that water surcharges out of the catch basin		0	1	0	0	Happy Valley		Mt Scott
327	SE Lampert Ct Drainage	V-ditch directs water into the backyard		0	1	0	0	Happy Valley		North Happy Valley
328	Monterey Ave retaining wall drainage	The saturated surface causes sheet flow to cascade off of the retaining wall and into the street and sidewalk.	Underdrain pipe from the golf course outfalls at top of wall. Runoff seeps through the wall onto the sidewalk and roadway. During high flows runoff cascades over the wall.	0	1	0	0	Happy Valley		Mt Scott
329	SE Mountain Gate Rd at WE Oregold Ct Catch Basin	The catch basin is unable to the handle flow.	Curb inlets get overwhelmed during high flows. Water bypasses curb cuts and there are no grates.	0	1	0	0	Happy Valley		North Happy Valley

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330	SE Cougar Pl & SE William Otty Rd Inlet	There is debris clogging the inlet and causing it to overflow. The inlet is unable to take the flow from the hillside.		0	1	0	1	Happy Valley		North Happy Valley
331	SE Overlook Ln & SE Westview Ct Inlet	The inlet is unable to take flow from hillside. It is buried in mud and we are unable to locate the inlet to remove the debris.		0	0	0	0	Happy Valley		Mt Scott
332	SE Page Park Ct gutter line	There is sediment gathering in the driveway gutter line. We may need to grind down the side of the catch basin to allow for flow.		0	0	1	0	Happy Valley		Sunnyside
335	SE 172nd Ditch	Ditches and culverts are not sized for the volume of water		0	1	0	0	Happy Valley		Rock Creek
401	NCRA Drywells	Drywells overflowed - 31 were cleaned last year (2018) - associated with #73		0	1	0	0	WES Maintenance	Lots of drywells.	NCRA
402	Creswell Cove detention pond	This is a ditch and detention pond. The structure seems fine but the running water is attracting beavers.		0	0	0	1	WES Maintenance		Rock Creek
403	Echo Valley Meadows Pond Retrofit	This is a large area that needs to be cleared regularly and is expensive. There is a pond with a culvert that outfalls. The site is a private development.		0	0	0	1	WES Maintenance		Sunnyside
404	SE Summer Place Pond Rehab	Incising is occurring, causing the fence to fall. The water drains between Summers and Green Fir Drive.	When we visited this pond, WES staff indicated there were no problems with it. However, the creek between Summer Pl and Green Fir Drive is silted in, lacks a channel, and prevents upstream area from draining. Stream area appears to be a wetland. Pipe culvert is clogged with vegetation.	0	0	1	0	WES Maintenance		Sunnyside
405	Creek Outfall near Sunnycreek Ln	The pipes daylight over the stream embankment. Erosion is occurring under the pipes and is causing them to crack and break off. The neighbors have requested a fix.	This culvert may also be undersized	0	1	0	0	WES Maintenance		Sunnyside
406	Sunnyside Pl Culvert	Ditch and culvert that belongs to transportation dept. is flooding an apartment complex. 124th Road is failing and a high priority for the road department. When it rains the stream backs up to the road. The culvert on 122nd is clear. Stream incised and needs stream restoration.	At downstream end of culvert, stream gradient flattens briefly and sediment collects. Culvert is likely undersized. The culvert is long, under a road and a few yards.	0	1	0	0	WES Maintenance		Sunnyside
407	Drainage off Mt. Talbert	Drainage from Mt. Talbert is not getting into the field inlet. The area on top of Mt. Talbert is overgrown and hard to access. The inlet is a poor design and needs to be larger.	Ditch inlet is located on a steep hillside, making it difficult to access for maintenance.	0	1	0	1	WES Maintenance		Sunnyside
408	SE Willingham Ct conveyance	The homeowner used concrete to divert to the street which has resulted in flooding of the road and a house downstream.	New homeowner has addressed the problem. Concrete channel no longer receives flows. A new pipe has been installed.	0	0	0	0	WES Maintenance		Sunnyside
409	SE Mystery Strings Ct Backyard Pipe	Storm pipe behind houses has surcharged a few times due to root intrusion. There is poor access and cannot be cleaned out. A house's crawl space and landscaping has flooded as a result of the surcharge.		0	0	0	1	WES Maintenance		Sunnyside

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411	SE Parmenter Dr	The homeowner filled up a low point in the channel because they didn't want water on their property and they knew there was not an easement. Water has moved to the adjacent property and that owner has installed storm pumps. The storm pipes daylight here. This fill-in affected all properties in the cul-de-sac. Before the fill-in there were no issues. Storm pipes daylight. Owner buried the channel and outlet and it is impacting neighbors.	Multiple homes in small development all connected to a drain field. The drain field was located in a backyard and was filled in by the home owner. The lack of conveyance how cause flooding issues at several locations. The current solution is to use a pump at one of the catch basins but where it goes is unknown.	0	1	0	0	WES Maintenance		Kellogg Creek
412	Orchard Lane I-205 drainage	The easement pipes were TVed but needs to be looked at again. The pipes drain off of I-205 including a large area of the basin upstream. The ODOT pipe ends 30 ft from I-205, someone attached a pipe here but it was initially supposed to be a ditch. There is a sinkhole at end of the ODOT pipe.	The reported problem could not be verified. GIS shows the ODOT pipe outfalling into a Creek, but the creek was so heavily grown that we could not find the outfall. There was no evidence of a sinkhole.	0	0	0	0	WES Maintenance		3 Creeks
413	SE Valley View Terrace Cul-de-sac	The pipes are overwhelmed, water flows onto the street then overtops the curbs and hits the side of the house. This is a steep area with lots of water flowing to one small inlet. There may need to be additional storm infrastructure added. There are also broader upstream area issues.	Inlet is undersized for the amount of runoff it receives. Sediment coming from hillside runoff. Catch basin and pipe may get clogged with sediment, causing flooding. Pipe may also be undersized.	0	0	0	0	WES Maintenance		Mt Scott
414	SE Valley View Crushed Pipe	A pipe was recently drilled through for a second time. Valley View Road is steep and probably not a county-maintained road. The eastside is composed of water heater tanks turned into culverts/pipes, with catch basins in the middle. Water misses the catch basin. The road is also in poor condition.		0	0	0	1	WES Maintenance		Mt Scott
415	SE Dundee Dr near Carnaby Way	Working on a fix with Parametrix. Existing pipe goes to greenspace and was added due to lack of water capacity downstream. Consistently floods driveway of a resident nearby.		0	1	0	0	WES Maintenance		Mt Scott
416	SE Idleman Rd & SE 96th Drainage	The entire eastside is not functioning, water misses the catch basin. There is no curb so water flows to private property. The owner leaves sandbags out year round to stop flooding.	The roadway is very steep with alternating curb and no curb. Areas with no curb have a very small asphalt lip that directs flow to catch basins that are infrequent and often plug. When the inlets are plugged runoff washes into several different homes yards	0	1	0	0	WES Maintenance		Mt Scott
417	Sunnyside Rd Sound Barrier at SE 106th	Issues started with the widening of Sunnyside Road and the sound barrier. The inlet plugs up with leaves and floods the road.		0	0	0	1	WES Maintenance		Mt Scott
418	Sunnyside Rd Sound Barrier at Spruce View Ln	Pipe is hard to locate as the Sunnyside Road sound barrier is built on top the pipe. Has flooded during large storm events.		0	1	0	1	WES Maintenance		Mt Scott

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501	Riverview Mobile Estates Inlet	Open conveyance, leaves are clogging the inlet and cause flooding at the trailer park. A ditch was recently added and water comes down hill and into an area with a building at the bottom of the hill. Also, the wetland area needs maintenance. The field gate (at the Apartments) was supposed to help with stormwater detention. ODOT may have helped with something here. Inlet should be on hotspot list. Jan Johnson outlet.		0	1	0	1	DTD Meeting		Rock Creek
502	Open Conveyance near Lawnfield Gardens Apartments	Conveyance down the hillside could become a problem in the future. It will need ongoing maintenance. Dan Johnson/Vince DTD created the ditch		0	1	0	0	DTD Meeting		Mt Talbert
503	Clackamas High School	There are water quality issues at the High School. The ditch running through the school field collects from another field with animals on it. Poor water quality, the culvert is crushed and failing and the pipes drain across an open field with livestock and discharges into a catch basin on Hubbard Road. The school is interested in fixing the failing system in the field. There is also a new Agriculture building.	Private stormwater pond outfalls into a livestock field, creating water quality problems. Field has drain tiles, some of which are broken.	1	1	0	0	DTD Meeting		Sunnyside
504	Mt Scott Creek at 97th & Sunnybrook Rd	97th and Sunnybrook Road has a lot of debris. Logs and trash cause the water to backup and flood the area.		0	0	1	1	DTD Meeting		Mt Scott
505	SE Boyer Dr Parking Lot	Public water goes through a private parking lot that is not in great shape. Open drainage and failing culverts are on private property and drains to a public system which has not yet completely failed. WES helped with this pipe area a few years ago. Offered to takeover but WES did not do that.		0	1	0	0	DTD Meeting		3 Creeks
506	SE Monterey Ave Roadway Improvements	The concrete road is deteriorating and in poor condition. WES is working with DTD on road improvement and added water quality. DTD will send WES additional info.		1	0	0	0	DTD Meeting		3 Creeks
507	Safeway Distribution Center	The road drainage mixes with Safeway's and a private storm system. This discharges poor water quality with limited or no treatment.		1	0	0	0	DTD Meeting		Clackamas River Drainage
508	SE Shady Meadow Ct Backyard Conveyance	The old backyard conveyance system will be an issue when it fails.		0	1	0	0	DTD Meeting		Mt Scott
509	SE Aldercrest Rd Culvert	This is a cross culvert. Debris needs to be cleared from the inlet.		0	0	0	1	DTD Meeting		Kellogg Creek
510	SE Hillcrest Rd & 100th Ave Catch Basin	The catch basin at the intersection with 100th Avenue (off of the left shoulder) needs to have the debris cleaned off of the grates.		0	0	0	1	DTD Meeting		Mt Scott
511	SE Stevens Way & 96th Catch Basins	Check catch basins in the area of the intersection at Stevens Way and 96th Avenue		0	0	0	1	DTD Meeting		Mt Scott
512	Greenwood Court Catch Basin	The catch basin Inlet to the north side of the barricade on Greenwood Court and SE Rock Creek Court needs maintenance / repair.		0	0	0	1	DTD Meeting		Rock Creek

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513	SE Armstrong Circle Inlets	Vegetation and debris needs to be cleared off of the grates.		0	0	0	1	DTD Meeting		Rock Creek
514	SE Roethe Rd & SE Byron Dr Inlet	There is vegetation and debris from the hog panel at the inlet. The location is next to the walking path but not within the boundary.		0	0	0	1	DTD Meeting		Kellogg Creek
601	SE Vista Ln Inlet		Inlet was constructed on the upstream of a cul-da-sac and outfalls into the street. Runoff runs down road and into vegetated area. Runoff pools in a valley gutter across the driveway before the vegetated area.	0	1	0	1	Site Visits		Kellogg Creek
602	SE Tidwells Way bridge	Heavy upstream sediment is limiting the flow under the existing bridge. This area is all collected with a single ditch inlet. The ditch inlet was placed where an existing channel was filled in. The wetland often floods the road due to the limited conveyance	Heavy upstream sediment is limiting the flow under the existing bridge. This area is all collected with a single ditch inlet. The ditch inlet was placed where an existing channel was filled in. The wetland often floods the road due to the limited conveyance.	0	1	1	0	Site Visits		Kellogg Creek
603	SE Tidwells Way Pond	Pond is filled in with cottonwood trees. The outlet structure is too high and poorly designed. WES' modifications to the outlet structure makes the pond non-functioning. The berm overflow floods private property.	Pond is filled in with cottonwood trees. The outlet structure is too high and poorly designed. WES' modifications to the outlet structure makes the pond non-functioning. The berm overflow floods private property.	0	1	0	1	Site Visits		Kellogg Creek
604	SE Aldercrest Ct Channel	Channel has been hardened with concrete moat style channel (modifications from the 1960's or 1970's). Increased channel velocities and disconnection to the natural floodplain. Offline ponds would also reduce water quality.	Channel has been hardened with concrete moat style channel (modifications from the 1960's or 1970's). Increased channel velocities and disconnection to the natural floodplain. Offline ponds would also reduce water quality.	0	1	1	0	Site Visits		Kellogg Creek
605	Rose Creek trail / 14701 SE Territory Dr	During heavy rains, water surcharges from the MH in NW corner of property. Stormwater flows from yard across trail, eroding a portion of the trail and washing sediment into Rose Creek.		0	1	1	0	WES Staff		Sunnyside

Exhibit D

Maps

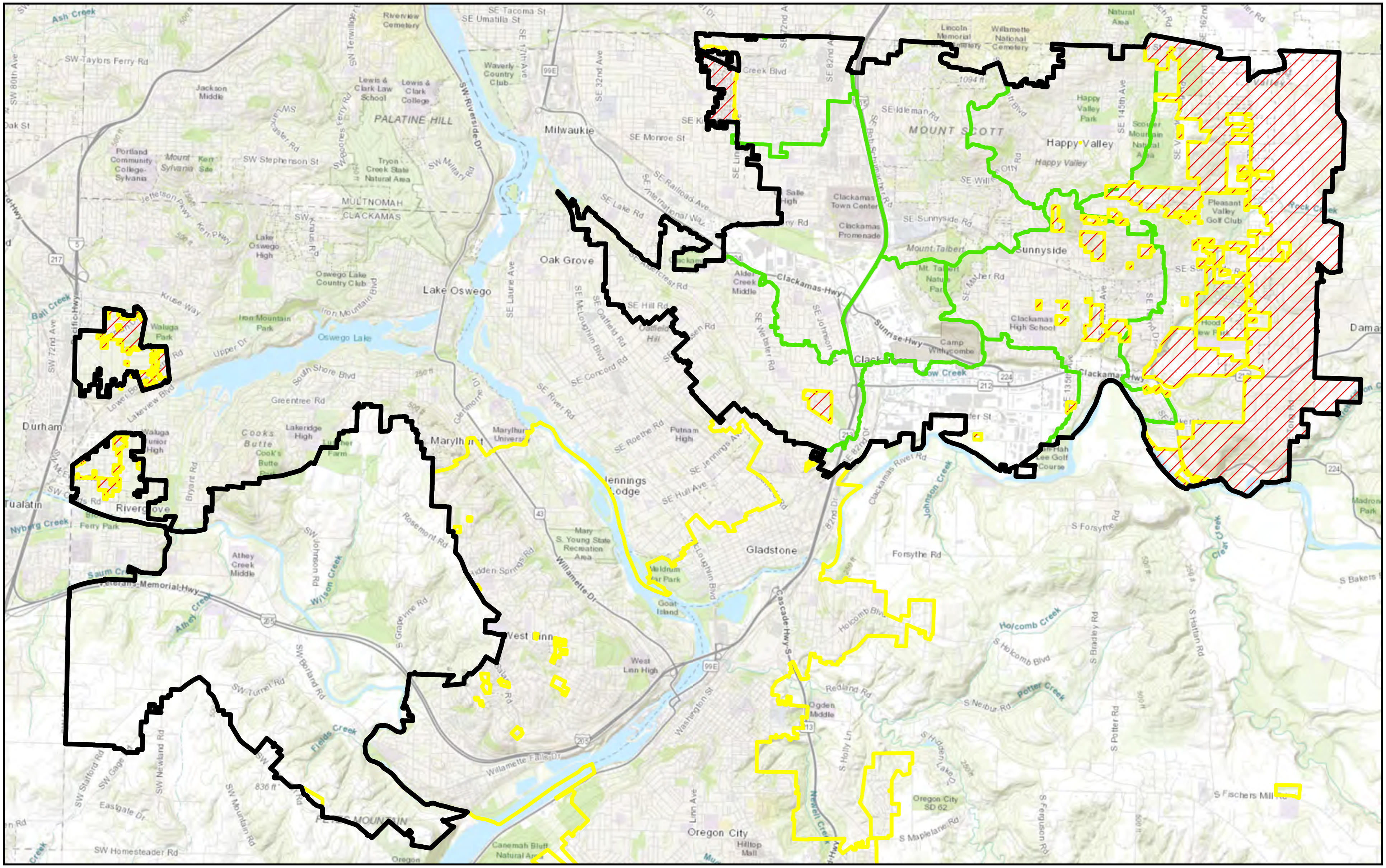

FIGURE D-1

PLANNING AREA BOUNDARY

WES & HAPPY VALLEY STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY | OREGON

MARCH 20, 2020

LEGEND

- Planning Area
- Outside WES Service District
- WES Service Area
- Study Areas

WATER ENVIRONMENT SERVICES

HAPPY VALLEY, OR EST. 1965

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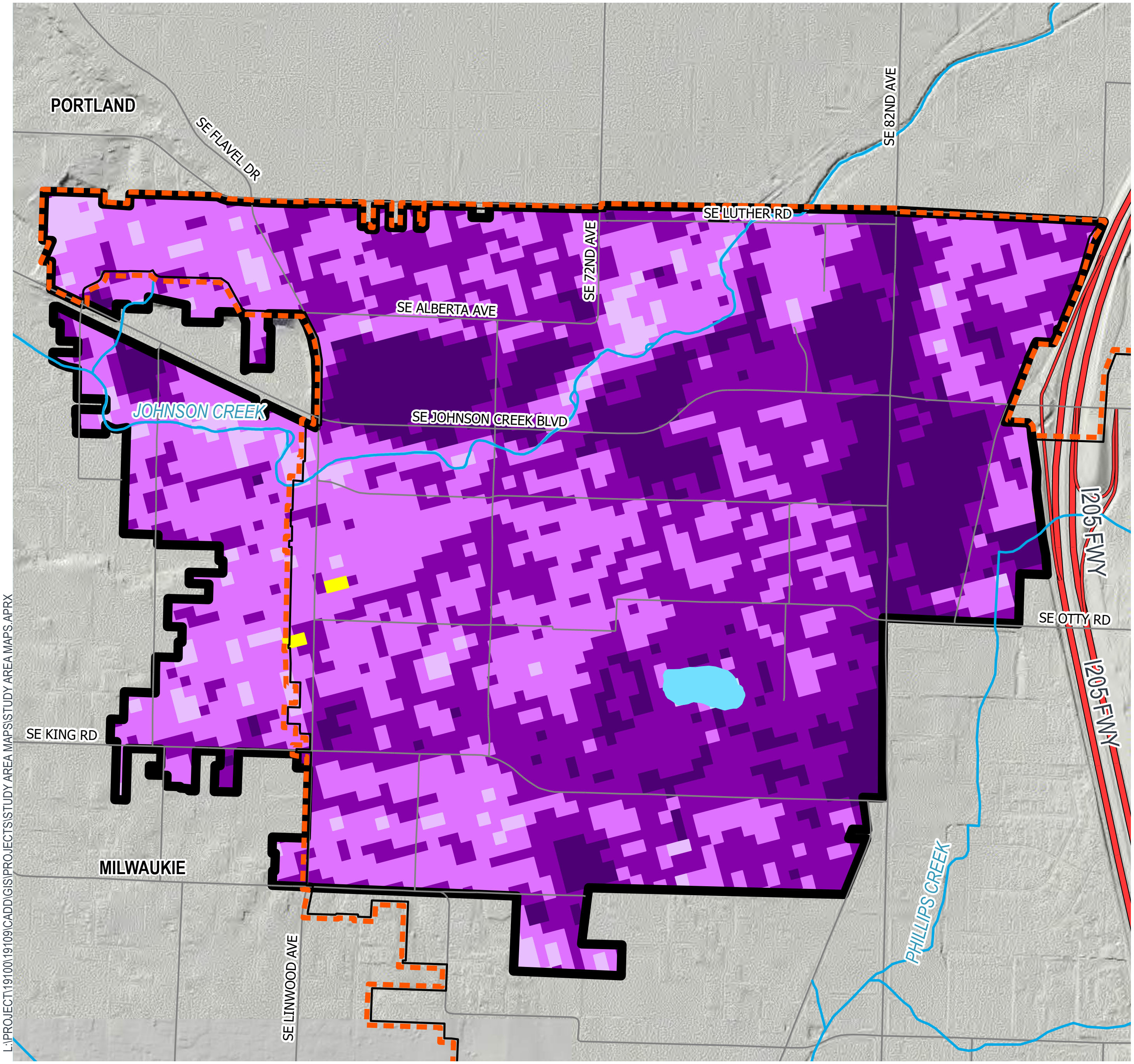
NCRA STUDY AREA EXISTING LAND USE

WES & HAPPY VALLEY STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY | OREGON



Legend

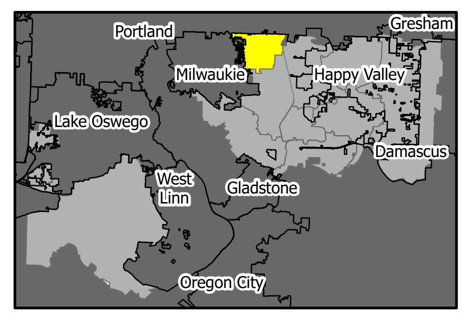
- Study Area Boundary
- WES Service Area
- Happy Valley
- Streams
- Water Bodies

Roads

- Highway
- Highway Ramp
- Arterials
- Major Roads

Existing Land Use

- Developed, High Intensity
- Developed, Medium Intensity
- Developed, Low Intensity
- Developed, Open Space
- Pasture
- Forest
- Wetland
- Open Water



DATE: 3/20/2020

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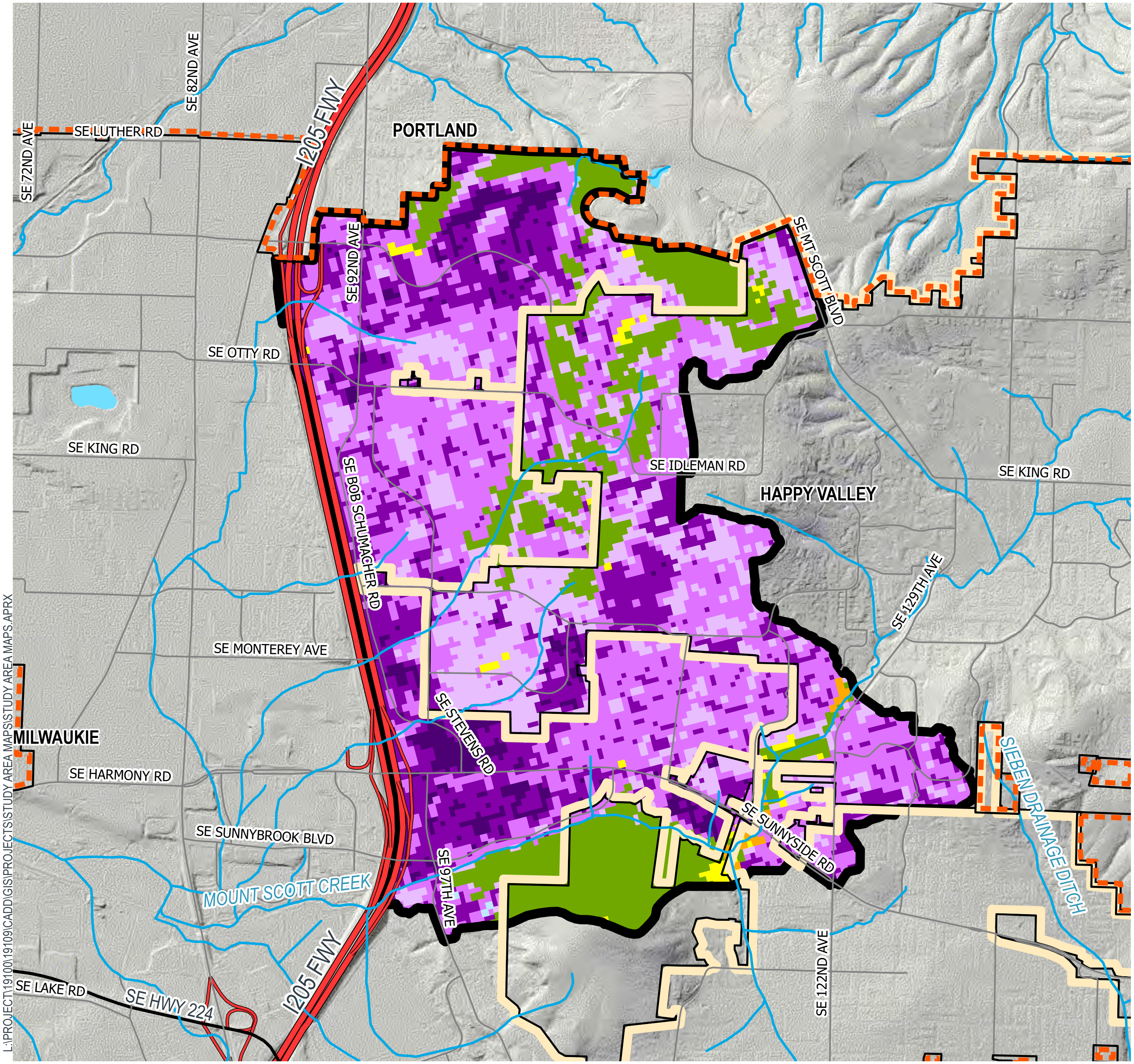
Water Environment Services   HAPPY VALLEY, OR EST. 1965   Otak



MT SCOTT STUDY AREA EXISTING LAND USE

WES & HAPPY VALLEY STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY | OREGON

Legend

- Study Area Boundary
- WES Service Area
- Happy Valley
- Streams
- Water Bodies

Roads

- Highway
- Highway Ramp
- Arterials
- Major Roads

Existing Land Use

- Developed, High Intensity
- Developed, Medium Intensity
- Developed, Low Intensity
- Developed, Open Space
- Pasture
- Forest
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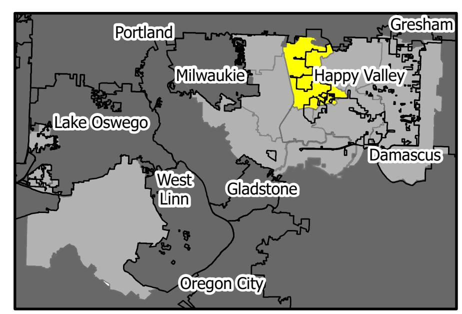
- Open Water



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WATER ENVIRONMENT SERVICES

HAPPY VALLEY, OR EST. 1965

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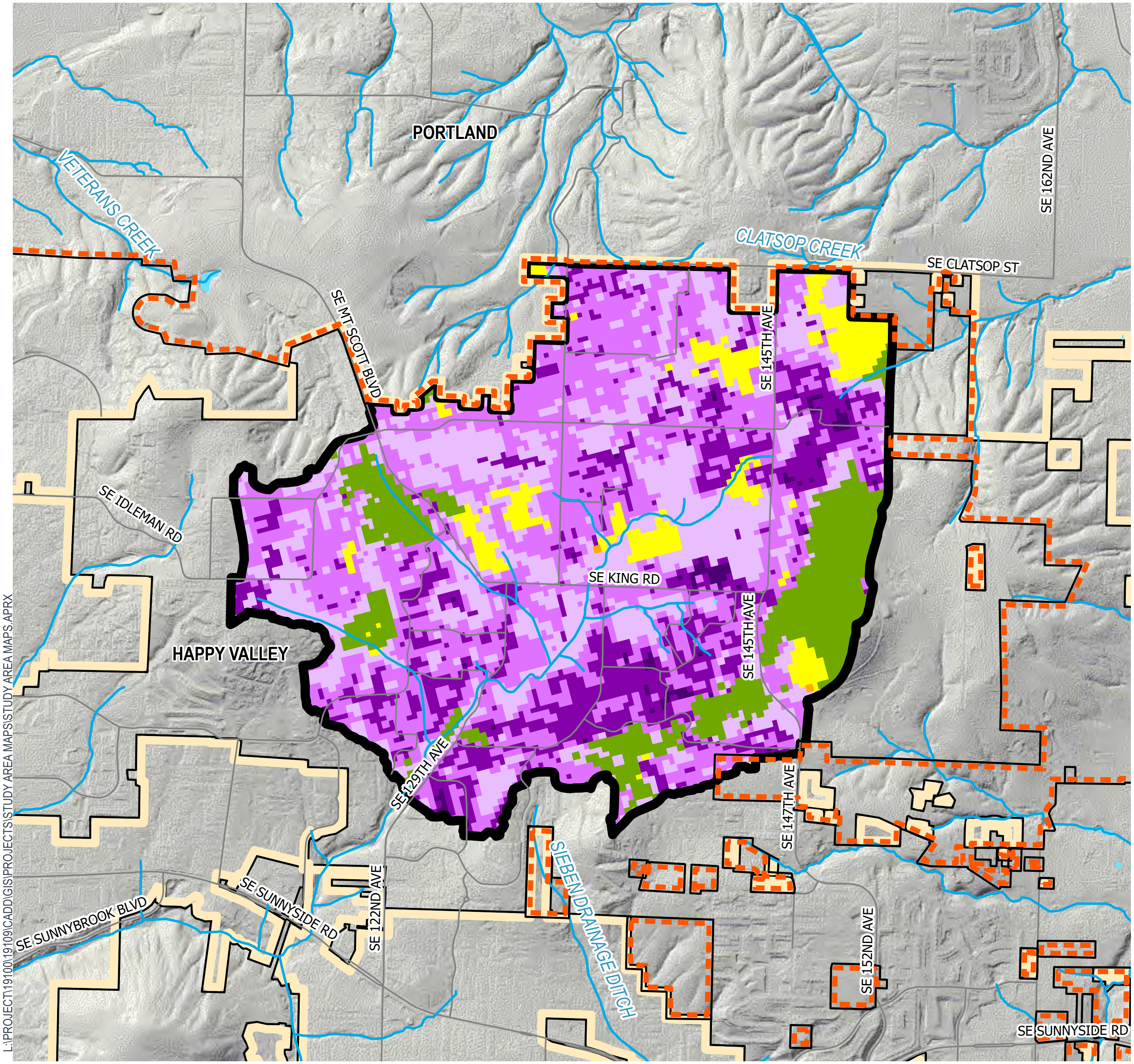
NORTH HAPPY VALLEY
STUDY AREA EXISTING LAND USE

WES & HAPPY VALLEY STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY | OREGON



Legend

- Study Area Boundary
- WES Service Area
- Happy Valley
- Streams
- Water Bodies

Roads

- Highway
- Highway Ramp
- Arterials
- Major Roads

Existing Land Use

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- Developed, Medium Intensity
- Developed, Low Intensity
- Developed, Open Space
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- Forest
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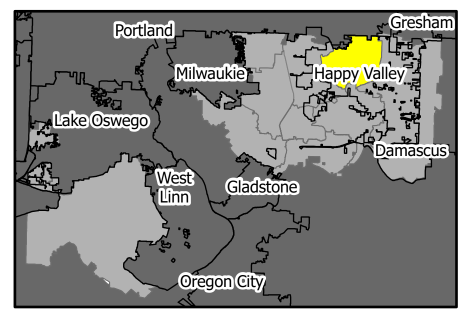
- Open Water



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DATE: 3/20/2020

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WATER ENVIRONMENT SERVICES

HAPPY VALLEY, OR EST. 1965

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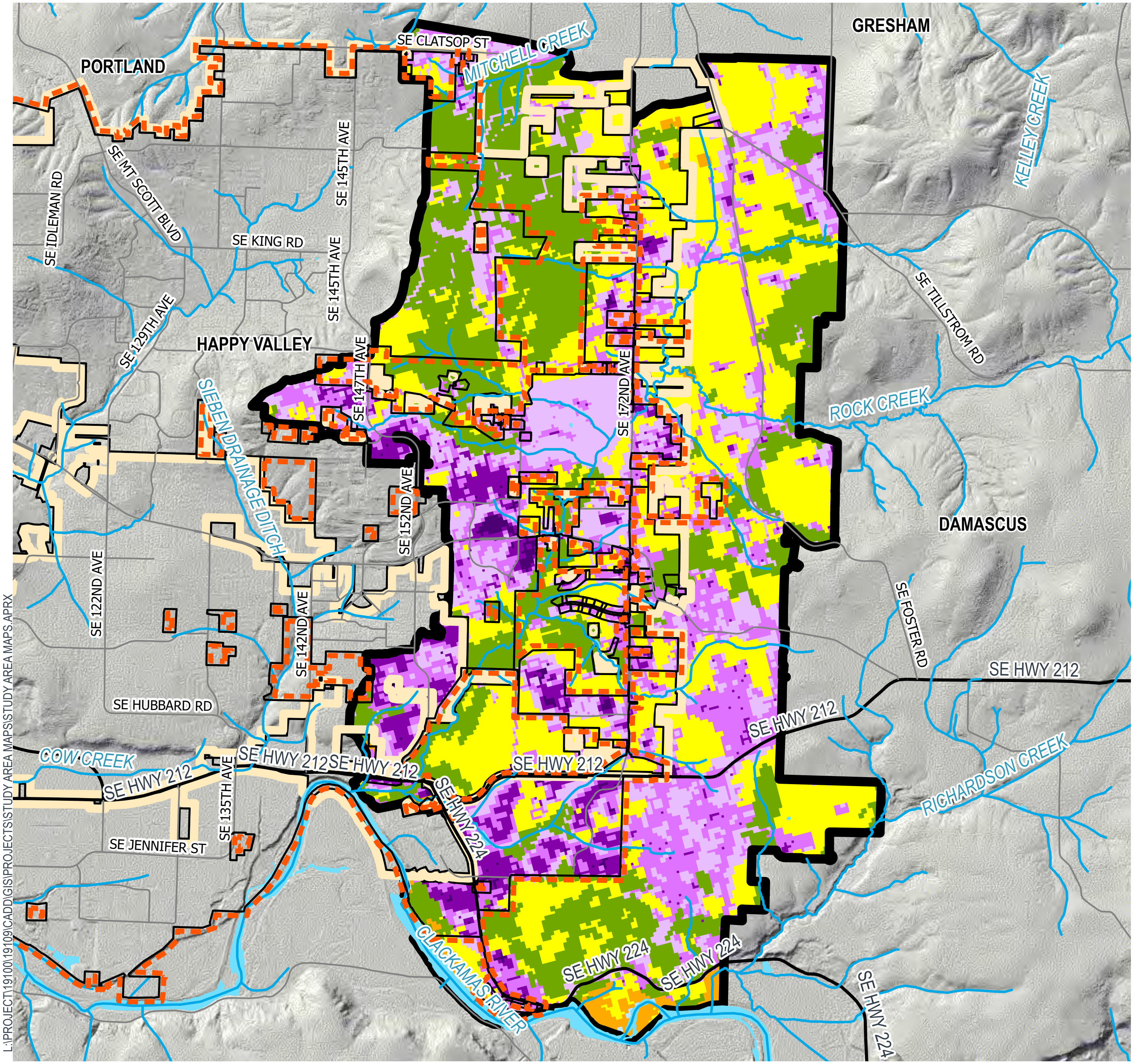
ROCK CREEK STUDY AREA EXISTING LAND USE

WES & HAPPY VALLEY STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY | OREGON



Legend

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- Water Bodies

Roads

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- Highway Ramp
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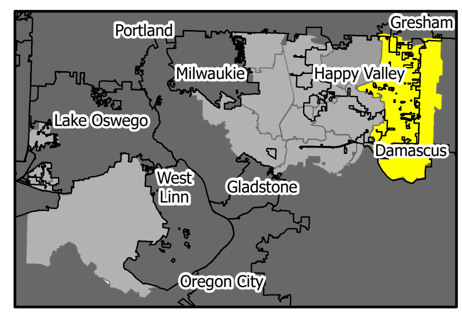

DATE: 3/23/2020

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Water Environment Services | HAPPY VALLEY, OR EST. 1965 | Otak

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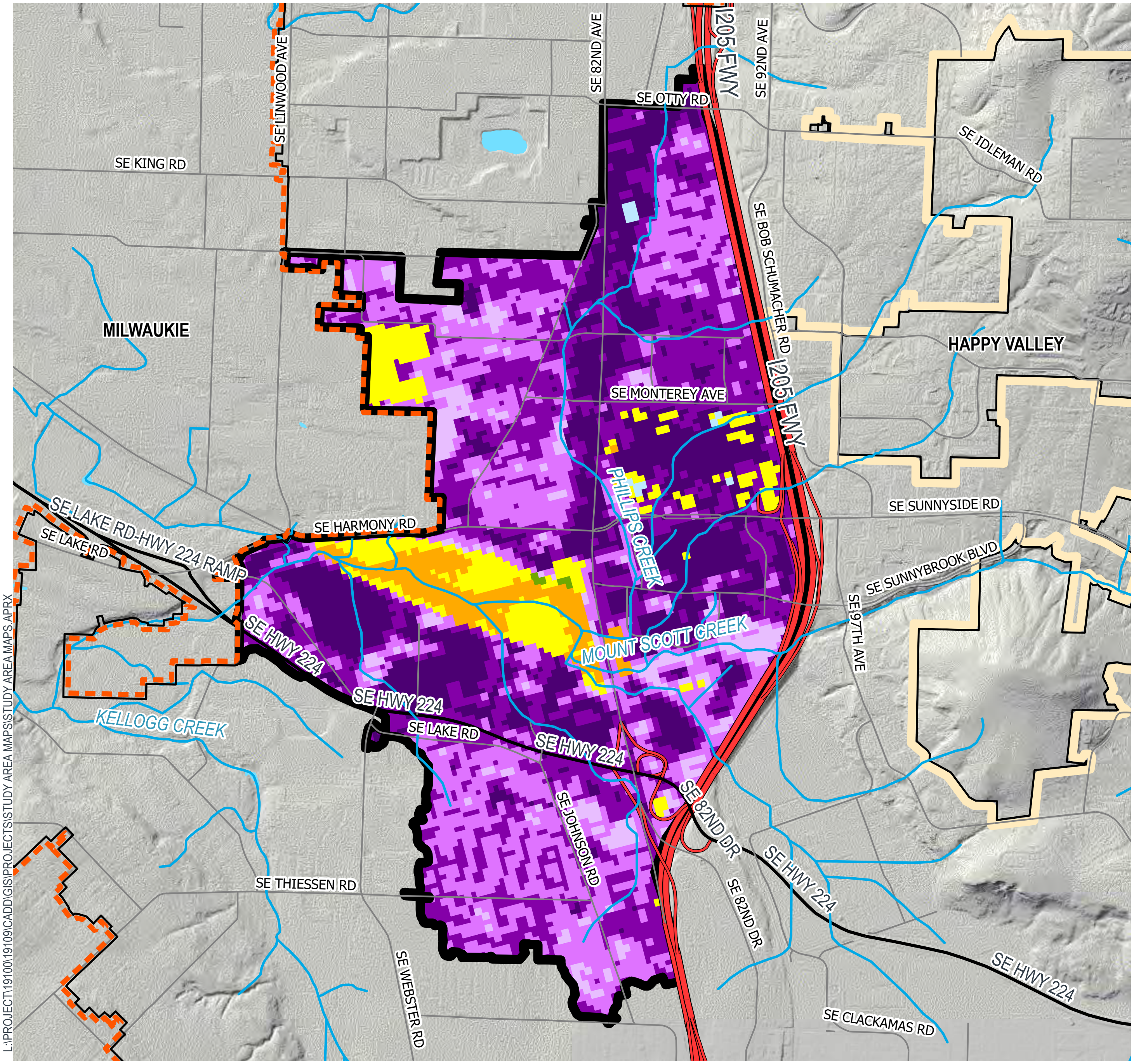

THREE CREEKS STUDY AREA EXISTING LAND USE

WES & HAPPY VALLEY STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY | OREGON

Legend

- Study Area Boundary
- WES Service Area
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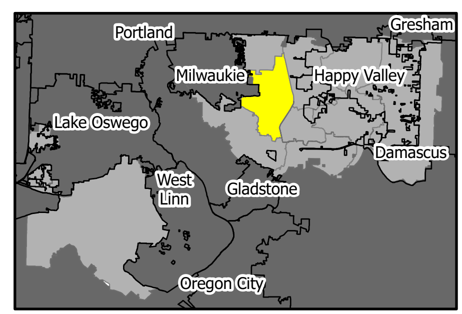

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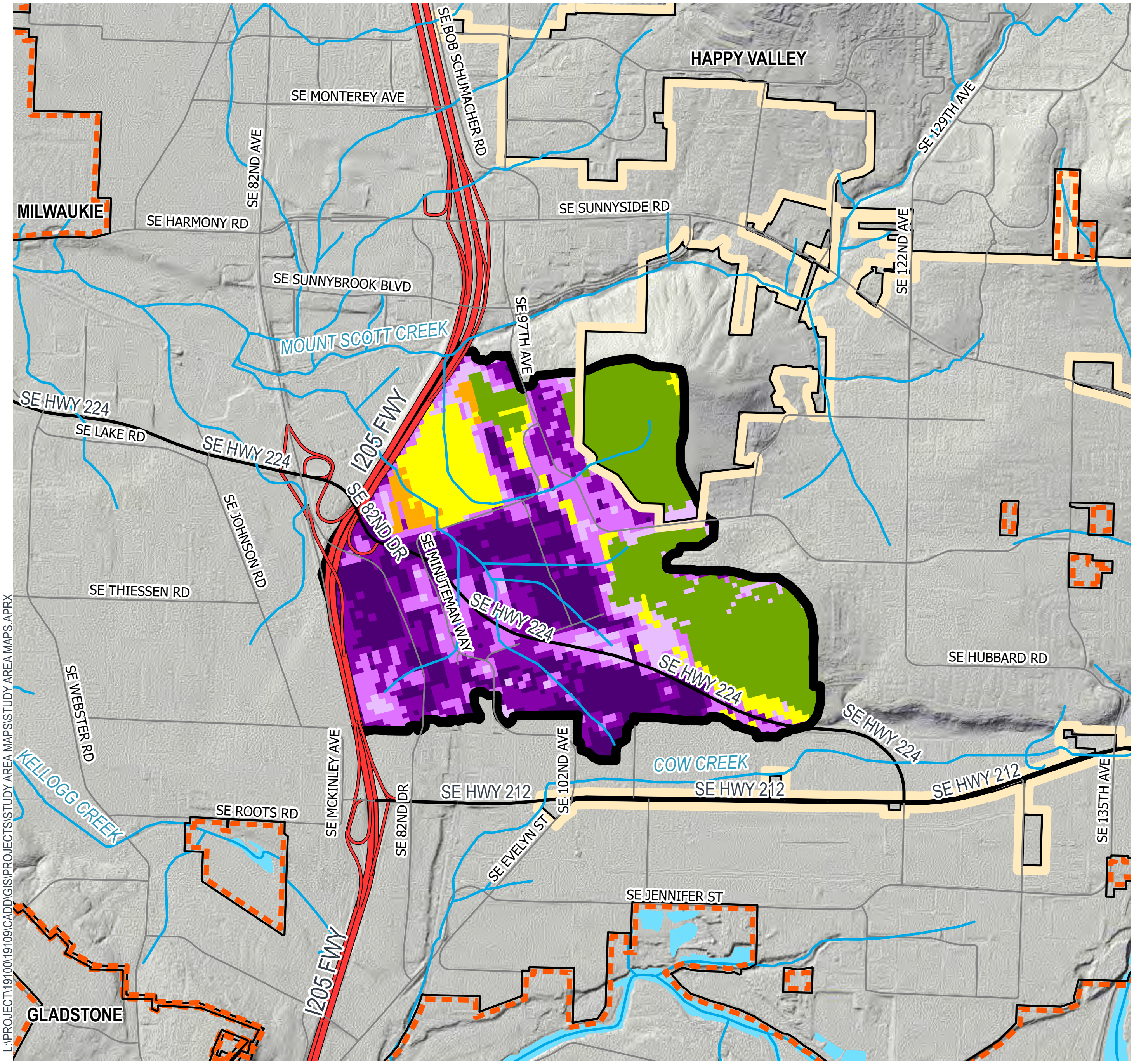
MT. TALBERT STUDY AREA
EXISTING LAND USE

WES & HAPPY VALLEY STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY | OREGON



Legend

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- WES Service Area
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- Water Bodies

Roads

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Existing Land Use

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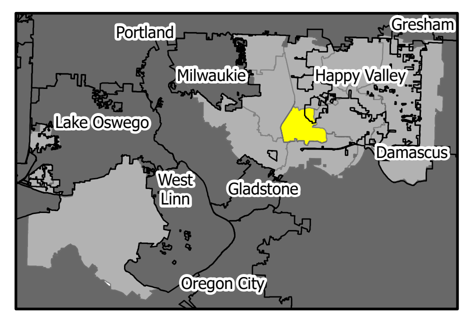

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DATE: 3/20/2020

WATER ENVIRONMENT SERVICES | HAPPY VALLEY, OR EST. 1965 | Otak

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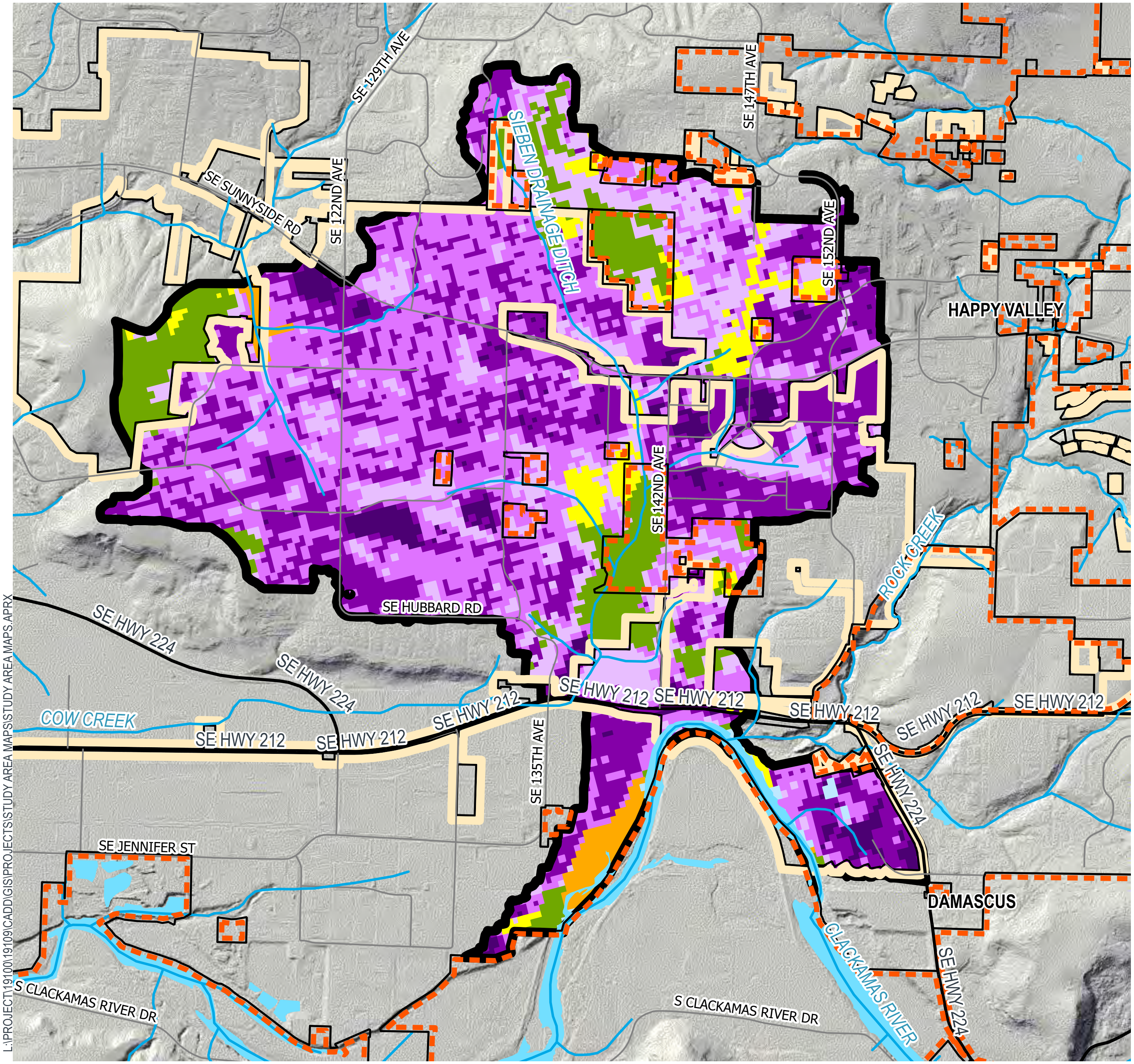
SUNNYSIDE STUDY AREA
EXISTING LAND USE

WES & HAPPY VALLEY STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY | OREGON



Legend

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- WES Service Area
- Happy Valley
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- Water Bodies

Roads

- Highway
- Highway Ramp
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Existing Land Use

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- Developed, Low Intensity
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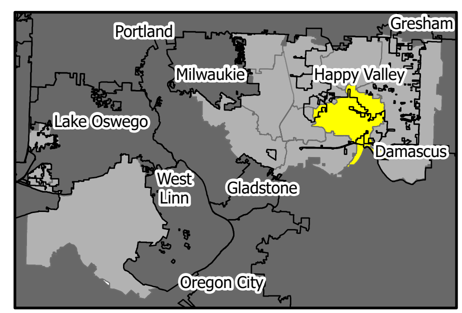

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DATE: 3/23/2020

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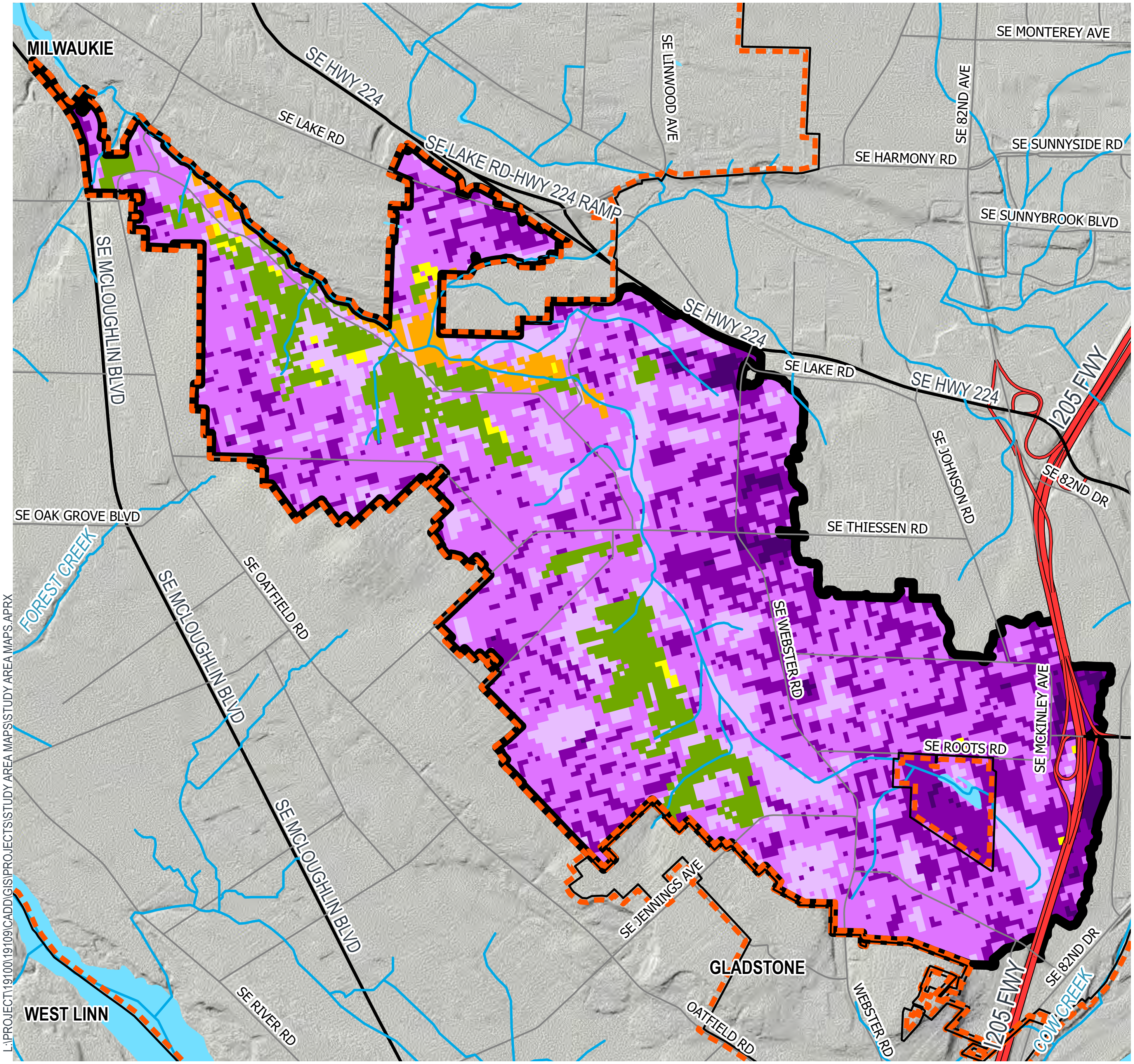

KELLOG CREEK STUDY AREA EXISTING LAND USE

WES & HAPPY VALLEY STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY | OREGON

Legend

- Study Area Boundary
- WES Service Area
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Existing Land Use

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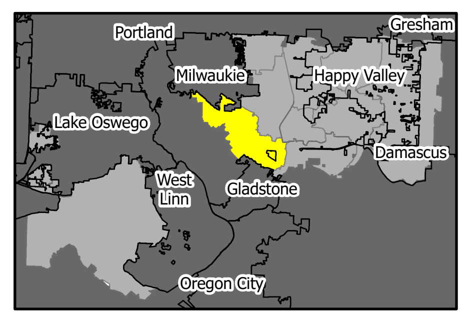

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Water Environment Services | HAPPY VALLEY, OR EST. 1965 | Otak

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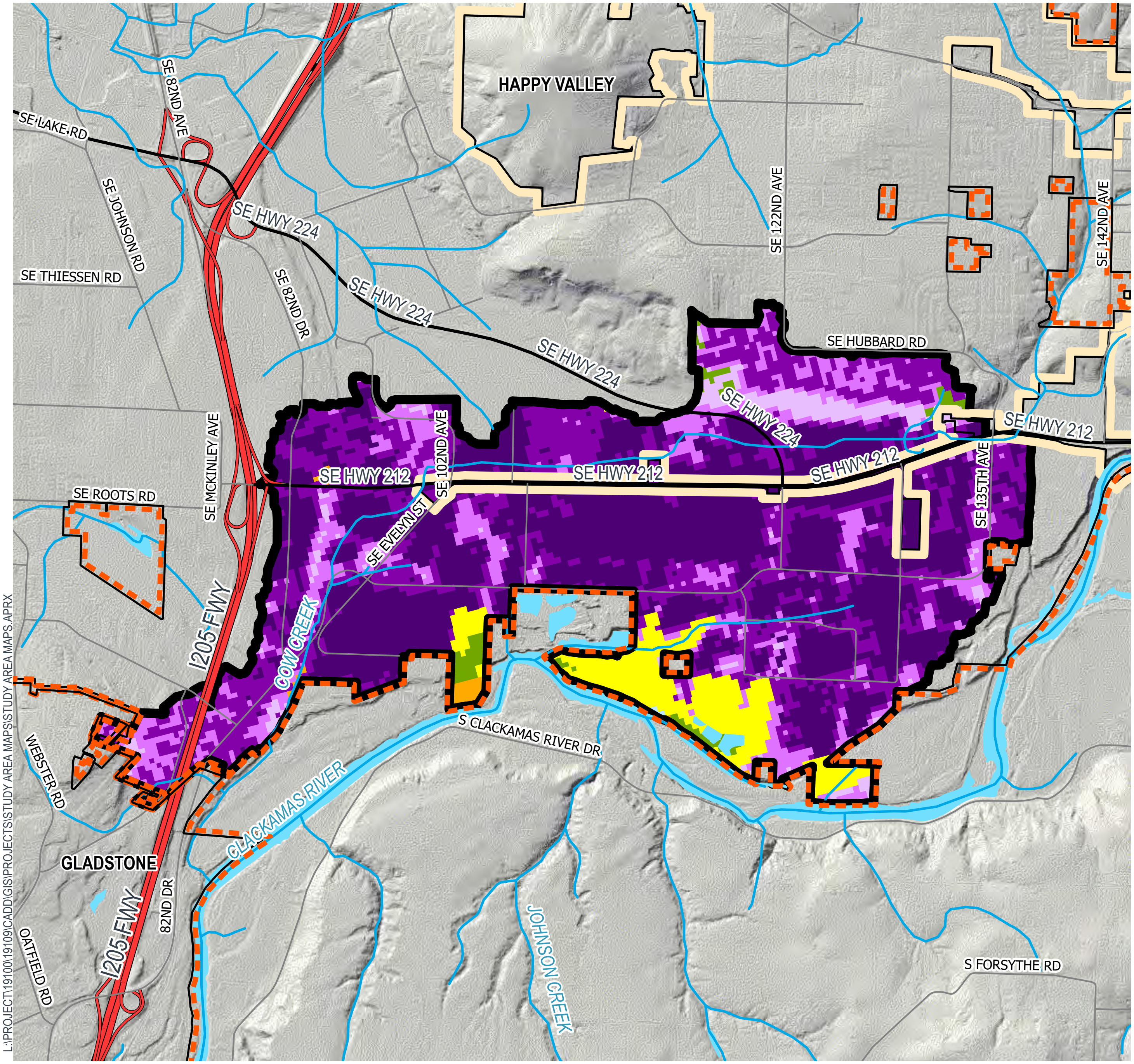
CLACKAMAS RIVER DRAINAGE STUDY AREA EXISTING LAND USE

WES & HAPPY VALLEY STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY | OREGON



Legend

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- Happy Valley
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- Water Bodies

Roads

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Existing Land Use

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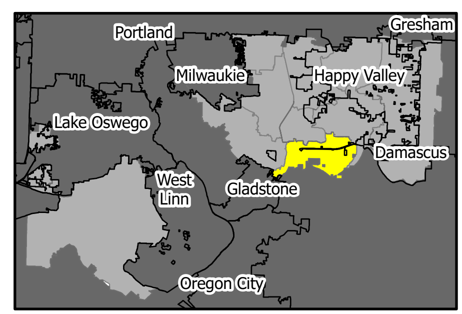

DATE: 3/20/2020

WATER ENVIRONMENT SERVICES

HAPPY VALLEY, OR EST. 1965

Otak

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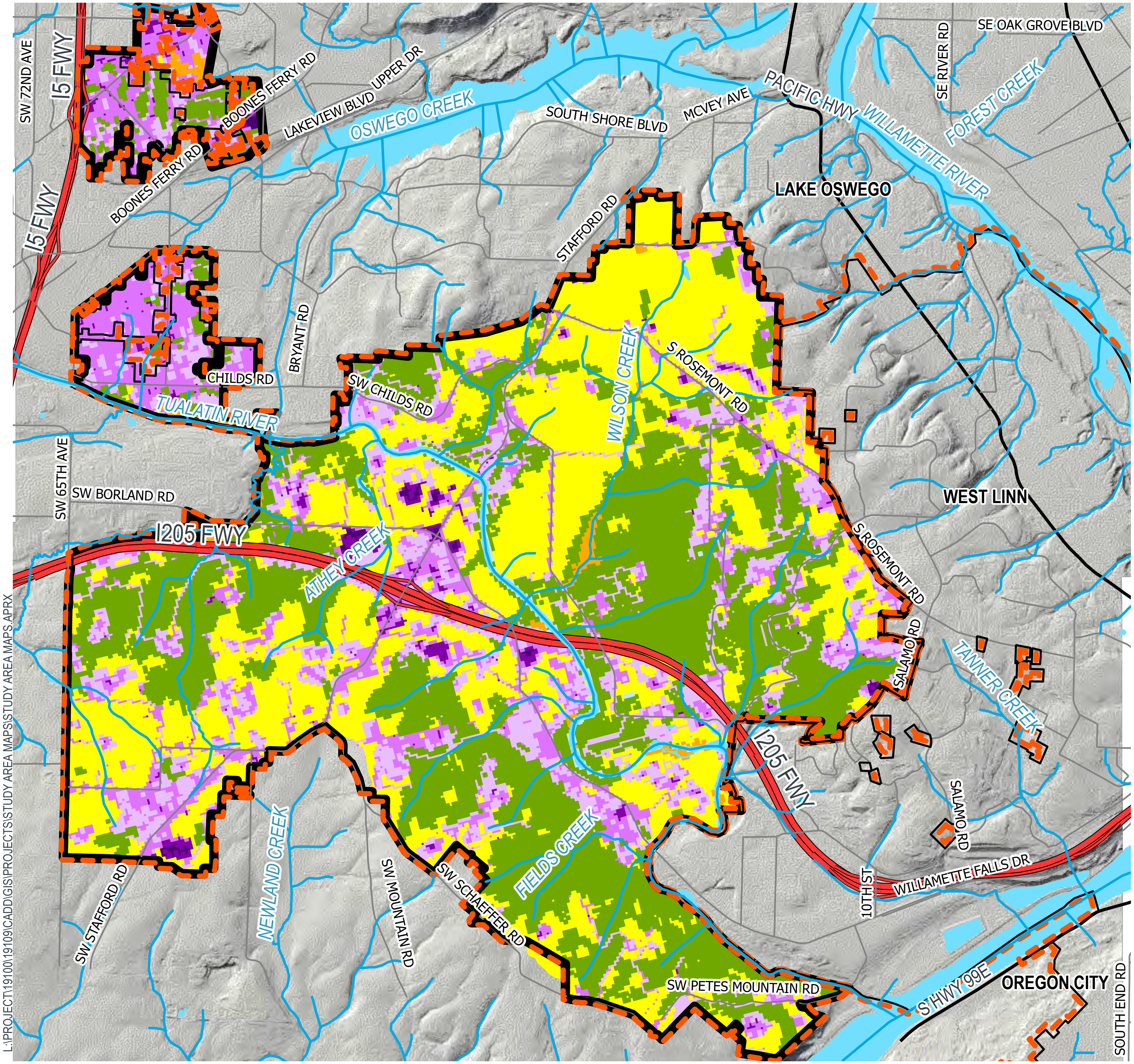
SWMACC STUDY AREA EXISTING LAND USE

WES & HAPPY VALLEY STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY | OREGON



Legend

- Study Area Boundary
- WES Service Area
- Happy Valley
- Streams
- Water Bodies

Roads

- Highway
- Highway Ramp
- Arterials
- Major Roads

Existing Land Use

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- Developed, Medium Intensity
- Developed, Low Intensity
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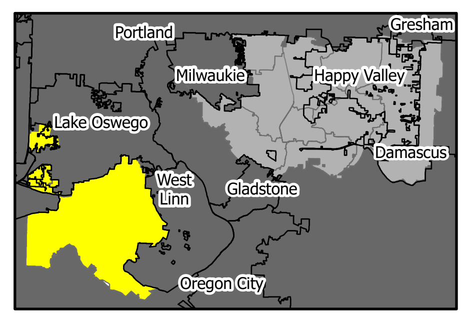

DATE: 3/23/2020

WATER ENVIRONMENT SERVICES

HAPPY VALLEY, OR EST. 1965

Otak

FEET
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Appendix E
Known Issues Atlas

- Provided under separate cover -

Appendix F

CIP Rating Criteria

WES Storm System Master Plan
CIP Rating Criteria
October 12, 2020

						Score				
ID	**Weight**	**High Score**	**Max Total**	**Criterion**	**Description**	**0**	**1**	**3**	**5**	**Scoring Notes**
1. Watershed Health Improvements										
A	1.00	5	5.0	Ecosystem Health	Does the project directly improve biological communities and riparian habitat?	No	Few improvements	Moderate improvements	Significant improvements	5 for vegetation and/or habitat improvements directly in riparian area. 3 for adding vegetation outside riparian area (e.g. green infrastructure). 1 for projects where the only planting is to restore the construction area.
B	2.00	5	10.0	Stream Channel Stabilization	Does the project directly or indirectly improve stream channel stability, reduce erosion, or reduce stormwater quantity or rate of discharges?	No	Few improvements	Moderate improvements	Significant improvements	This score relates to hydromodification and stream restoration. 1 for outfall stabilization or contributing area flow reduction (detention or LID). 3 for in-stream channel restoration. 5 for floodplain reconnection or large scale projects (detention of runoff from > 20 acres, or >1500 feet of stream restoration). If multiple services are provided by the project, choose the highest applicable score.
	Max points		**15.0**							
2. Water Quality Improvements										
C	2.00	5	10.0	Pollutant Load Reductions	Will the project provide pollutant reductions and water quality benefits (e.g. TSS, bacteria, metals, temperature)?	No	Minor pollutant reduction	_	Significant pollutant reduction	5 for a BMP that provides full water quality treatment. 1 for a BMP that provides partial treatment, for example pre-treatment or a settling basin, or improvements to an existing WQ facility. Instream erosion reduction should not be awarded points in this category.
D	0.50	5	2.5	Treated Land Use	What type of land use will be treated under the project?	None, no new treatment	Mostly residential	Mostly commercial	Mostly industrial or a local cause of pollution requires a treatment BMP	These are not mutually exclusive. Choose the highest scoring answer if multiple land uses will be treated. Categorize institutional uses by the closest of the uses listed in relationship to pollution-generation characteristics.
E	0.50	5	2.5	Acres Treated for Water Quality	How much area will be treated under this project?	None, no new treatment	Less than 10 acres	10-20 acres	More than 20 acres	Use the total acres treated, rather than delineating impervious area.
	Max points		**15.0**							
3. Conveyance & Flooding										
F	1.50	5	7.5	Frequency of Flooding Event	Does the project reduce flooding related to the storm system and, if yes, for flooding at what frequency?	No, does not reduce flooding related to the storm system	Every 6 years or less frequent	Between every 2 and 5 years	Annual flooding	Rate based on observed or modeled flooding behavior that will be alleviated by the project. Do not include river/stream flooding.
G	2.00	5	10.0	Extent of Flooding	To what extent will the project reduce or mitigate flooding impacts?	None, does not reduce flooding related to the storm system	Isolated (e.g. one lot, small portion of any public asset)	Multiple (e.g. several properties)	Widespread (e.g. more than 10 homes, businesses) or a full street block	Property flooding extent.
H	1.00	5	5.0	Flood Protection/Risk Avoidance	What types of properties or assets will be protected from flooding under this project?	None, does not reduce flooding related to the storm system	Non-structural public property such as park (landscape, soft trail) or the non-traffic lane portion of any street	Non-structural private property and uninhabitable structures, such as landscaping, parking lot, shed, or local street's traffic lane	Habitable or occupiable structures or collector/arterial street's traffic lane or utility line/trench/or structure	These are not mutually exclusive. Choose the highest scoring answer if multiple property types will be protected from flooding.
	Max points		**22.5**							
4. Providing Multiple Benefits										
I	1.50	5	7.5	Increased Service	Does the project provide drainage and stormwater management to underserved areas?	No, the project is in an area with sufficient MS4	Somewhat, the project is in an area with insufficient MS4		Yes, the project is in an area with no MS4	Base score on Underserved Areas Map for white paper. Give low score to areas with sufficient MS4; high score to areas without.
J	0.50	5	2.5	Project Coordination	Can the project be coordinated with roadway improvements or other public agencies to achieve cost sharing and/or minimize impacts to the community?	No	_	_	Yes	Note potential financial partnership opportunities with other departments/agencies.
K	0.50	5	2.5	Community Amenities and Benefits	Can the project be expanded to include additional community amenities such as educational or recreational amenities?	No	_	_	Yes	Based on whether site location lends itself to likely including amenities in design.
	Max points		**12.5**							
5. Maintenance Considerations										
L	1.00	5	5.0	Reduce/Streamline Maintenance	Does the project reduce the frequency of required maintenance?	Does not change maintenance frequency	Minor reduction in required maintenance frequency	_	Significant reduction in required maintenance frequency	Score based on reduction to current maintenance needs.
M	2.00	5	10.0	Maintenance Safety/Access	Does the project improve the ease of maintenance and/or safety of staff during maintenance?	No change	Minor improvement to access or safety	Moderate improvement to access or safety	Significant improvement to access or safety	Significant: addressing major safety problem. Moderate: some access improvement.
N	1.50	5	7.5	Extend Useful Life	Does the project extend the useful life of an existing asset(s)? What is the useful life of new assets being constructed under this project?	Temporary solution (<1 year)	Short-term/interim solution (<5 years)	Long-term solution (5+ years)	Long-term solution (5+ years) and proactively prevents addition problems	For repairs short term could include root removal; long-term could prevent possible near-term/imminent failure; and proactive solution could be increasing capacity/asset replacement/major rehabilitation that leads to longer term useful life.
	Max points		**22.5**							
6. Implementation										
O	1.00	5	5.0	Site Constraints	Do major physical conditions such as steep slopes, landslide, or erosion hazard areas constrain the project?	Major constraints	Moderate constraints	Minor constraints	No constraints	Give high scores to projects with fewer constraints; low score to projects with greater constraints. Use engineering judgement to evaluate constraints based on aerial imagery, field visits, and GIS.
P	0.50	5	2.5	Type of Permitting	What is the level of difficulty to obtain the project's permits?	Project will have environmental impacts that will require state and federal permits. Offsite mitigation will be required.	Project will have environmental impacts that will require state and federal permits. The project is self mitigating.	Only local permits will be required for the project.	No environmental permits will be required for the project.	Give high scores to projects with fewer/easier permits; low score to projects with more/more difficult permits.
Q	1.00	5	5.0	Acquisition/ Easements	Will land acquisition and/or new easements be necessary to fully implement the project?	Yes. Requires property acquisition or easement	May require narrow easement for pipe maintenance access	_	No	Check current ownership of tax lots and whether easements already exist.
	Max points		**12.5**							

Total Maximum Points **100**

Appendix G

CIP Project Fact Sheets

Otak

Capital Improvement Project Fact Sheet

Project Rank: 2

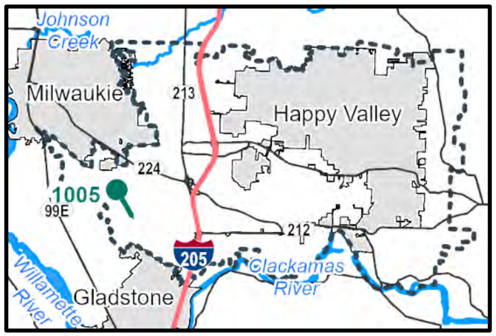
ID: 1005

Name: SE Wildlife Estates Dr Ditch Inlet & Upstream Detention

Study Area: Kellogg Creek

Location: SE Stohler Road at SE Tidwells Way and SE Norma Road at SE Tranquil Court

Problem Summary



The problem area is located near SE Wildlife Estates Drive, just west of the intersection of SE Stohler Road and SE Clackamas Rd. A ditch inlet is located at the bottom of a steep slope where a small tributary stream deposits several dump-truck-sized loads of sediment each year. The rocks and sediment periodically clog the inlet grate, causing flooding of roadways and a few homes at least annually on SE Stohler Road and SE Clackamas Road.

The source of the sediment is a small creek, Tributary C of Kellogg Creek. Portions of the creek's banks are unstable and are collapsing into the stream, carrying sediment to the problem area. The stream's flows are impacted by runoff from a residential neighborhood southwest of SE Norma Road on the ridge above the problem area.

Project Description

The purpose of the project is to prevent flooding and reduce maintenance requirements by decreasing the volume of sediment eroded and deposited at the ditch inlet. The project will involve improvements at the top of the bluff, along the stream, and at the inlet location where debris is deposited. Investigation of stream channel conditions will be required for further development of streambank stabilization design.

The project will reduce erosion by detaining stormwater runoff from the neighborhood in a pond at the top of the hill and stabilizing the creek through enhancement actions. At the bottom of the hill, a settling basin will remove sediment before it reaches the ditch inlet. The inlet will also be improved to reduce the potential for clogging.

In addition to reducing flooding, the project will treat runoff from approximately 50 acres of residential area and limit sediment from entering the storm sewer system. The project will reduce maintenance frequency and difficulty, and it will improve riparian habitat along Tributary C.

The benefits of this project include:

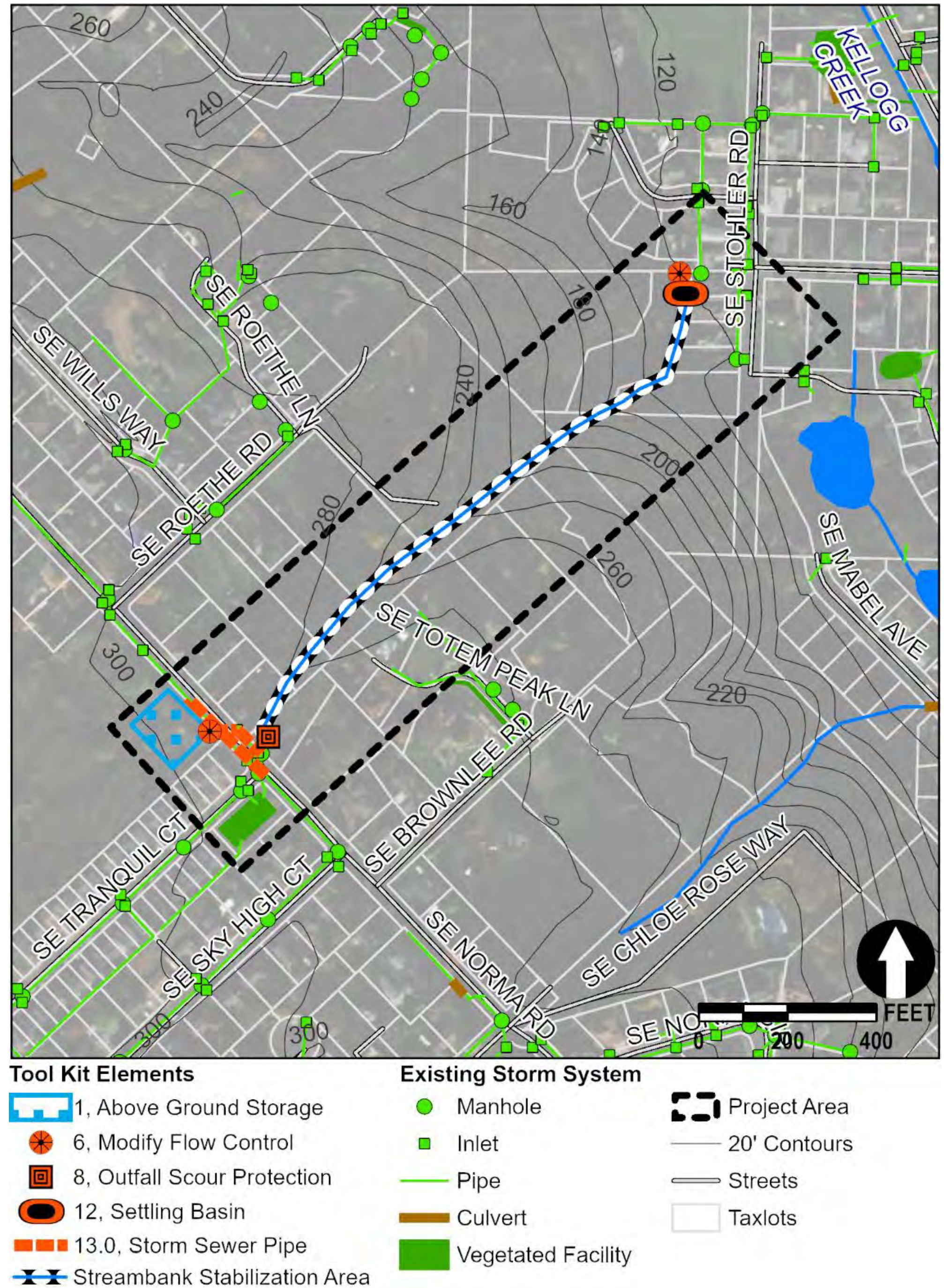
- Reduce erosion and improve habitat in Tributary C of Kellogg Creek
- Reduce flooding of road and private property
- Improve water quality in Kellogg Creek
- Reduce maintenance requirements for WES staff

Cost Estimate

Construction	Qty	Unit	Price	Amount
Stormwater Pond	17000	CF	$5	$79,900
Bioengineered Slope	1560	SF	$101	$157,170
Light Touch Grade Control	60	FT	$60	$3,600
Modify Flow Control, large debris grate	1	EA	$24,500	$24,500
Modify Flow Control, 72-in diam. flow control manhole	1	EA	$14,500	$14,500
Outfall Scour Protection, 12-in to 24-in diam. pipe	1	EA	$1,900	$1,900
Pre-settling Basin, large drainage basin	1	EA	$70,500	$70,500
Storm Sewer Pipe, 24-in to 30-in diam. pipe	380	FT	$235	$89,300
Structural Grade Control	60	FT	$385	$23,100
Vegetation Restoration, for riparian area	15600	SF	$9	$140,400
Mobilization	10%	of Construction		$110,200
Erosion and Sediment Control	2%	of Construction		$22,000
Temporary Water Management				$50,000
Construction Subtotal				***$787,070***
Construction Contingency	40%	of Construction		$314,800
Total Construction Cost				**$1,101,870**

Other	Assumption			
Design	20%	of Construction		$220,400
Basic Permitting				$15,000
Permitting in Jurisdictional Waters				$30,000
Project Administration	12%	of Construction		$132,200
Easement and Acquisition	15000	SF	$6.00	$90,000
Easement Administration	9	Per Lot	$10,000	$90,000
Total Cost				**$1,679,470**

* Assumption: "Streambank Stabilization" of 1300 feet of creek will require 10 grade control structures, 10 light touch grade control elements, and bioengineered slopes along 10% of the stream banks, itemized above.



Capital Improvement Project Fact Sheet

Project Rank: 6

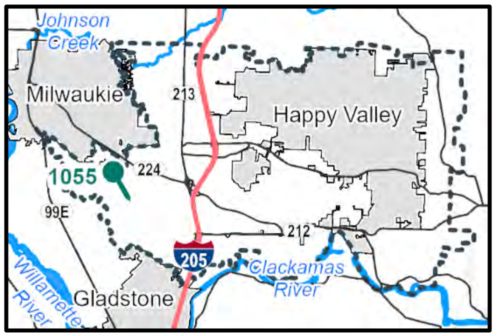
ID: 1055

Name: Thiessen Culvert Replacement & Kellogg Creek Restoration

Study Area: Kellogg Creek

Location: SE Thiessen Road at SE Aldercrest Court

Problem Summary



SE Thiessen Road crosses Kellogg Creek just west of SE Aldercrest Court. Kellogg Creek flows through an undersized (6-foot diameter) culvert which causes the creek to back up at SE Thiessen Road and flood the road and properties upstream. Due to the significant backwater caused by this culvert, the location was identified as one of the highest priority road crossing culvert replacements in the 2019 Upper Kellogg Basin Assessment prepared for Clackamas WES.

Flooding upstream of the culvert occurs annually.

In addition to causing flooding, the culvert is a likely fish passage barrier on Kellogg Creek.

Project Description

The purpose of this project is to replace an undersized culvert where SE Thiessen Road crosses Kellogg Creek. The creek currently passes through a 6-foot diameter round culvert which creates a backwater and floods the roadway and private property upstream.

This project will replace the existing undersized round culvert with an arched culvert 14 feet wide and approximately 5 feet tall. The culvert width will accommodate a natural streambed form to be constructed within the culvert. The wider archway will allow the natural movement of water and sediment in this section of the creek to alleviate the backwater and allow for fish passage. The area at either end of the culvert will be revegetated to restore the habitat along the stream in the project area. The length of the culvert was designed to accommodate the full width of Thiessen Road under the minor arterial designation.

In addition to reducing flooding, replacing the culvert will improve fish passage in Kellogg Creek. There are currently multiple fish passage barriers on the creek, including a large barrier at Kellogg Dam at the confluence with the Willamette River.

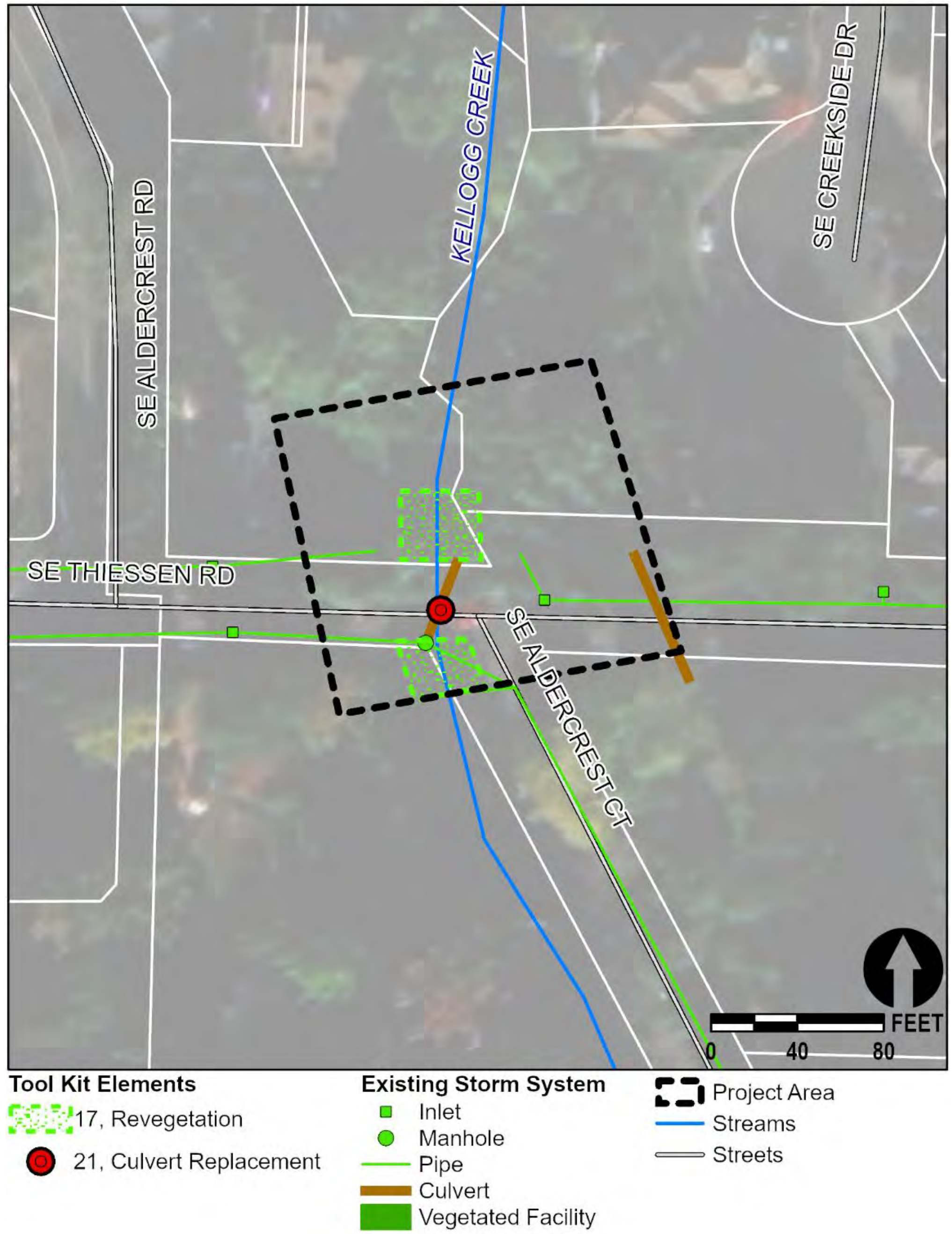
The project will require coordination with the Clackamas County Department of Transportation and Development.

The benefits of this project include:

- Reduce flooding of private property
- Reduce flooding of roadway
- Improve fish passage

Cost Estimate

Construction	Qty	Unit	Price	Amount
Streamed Fill	146	CY	$100	$14,600
Vegetation Restoration, for riparian area	700	SF	$9	$6,300
Culvert Replacement, 14-foot span, 74 ft long arch culvert	1	EA	$183,635	$183,635
Mobilization	10%	of Construction		$56,400
Erosion and Sediment Control	2%	of Construction		$11,300
Utility Conflict Resolution				$20,000
Traffic Control	6%	of Construction		$33,900
Temporary Water Management				$50,000
Construction Subtotal				***$376,135***
Construction Contingency	50%	of Subtotal		$188,100
Total Construction Cost				**$564,235**
Other	Assumptions			
Design	20%	of Construction		$112,800
Basic Permitting				$10,000
Permitting in Jurisdictional Waters				$30,000
Project Administration	15%	of Construction		$84,600
Easement and Acquisition	1500	SF	$6.00	$9,000
Easement Administration	3	Per Lot	$10,000	$30,000
Total Cost				**$801,635**



Capital Improvement Project Fact Sheet

Project Rank: 4

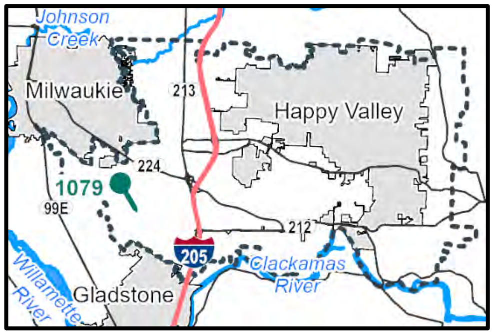
ID: 1079

Name: Aldercrest Culvert Replacement & Kellogg Creek Restoration

Study Area: Kellogg Creek

Location: SE Aldercrest Court

Problem Summary



Kellogg Creek, between SE Clackamas Road and SE Thiessen Road, is confined and restricted by culverts and a concrete channel.

The creek passes between SE Aldercrest Road and private homes to the west. Ten driveways cross Kellogg Creek in the reach. Three of these driveways cross the creek using narrow culverts. The creek also passes through a pair of parallel culverts which are not associated with any crossing of the stream and which appear to be impeding stream flow. At the north end of the project area, a narrow concrete channel across private property confines the creek for about 600 feet.

The culverts are undersized for the flows, and they obstruct stream flow and cause flooding. The stream floods SE Aldercrest Court, driveways, and private property along this section at least annually. Backwater from the culverts in this reach exacerbates flooding upstream at SE Clackamas Road.

Project Description

The purpose of this project is to reduce flooding and improve habitat along Kellogg Creek between SE Clackamas Road and SE Thiessen Road by removing or replacing culverts and stream crossings and naturalizing a concrete channel. Replacement stream crossings will be designed to be fish passable. The project proposes several discrete interventions in this section of Kellogg Creek that could be undertaken as separate projects depending on property owner permission and funding availability.

At the southern end of the creek section, this project will remove one pair of parallel culverts that appear to serve no purpose, replace a small culvert with a concrete slab driveway bridge, and restore native vegetation along a length of the stream.

At the northern end of the creek segment, the project will remove the concrete channel, establish a more natural creek bed and banks, and restore native vegetation within the riparian area. Four driveway crossings will be replaced with concrete slab bridges to accommodate the natural stream form and provide fish passage.

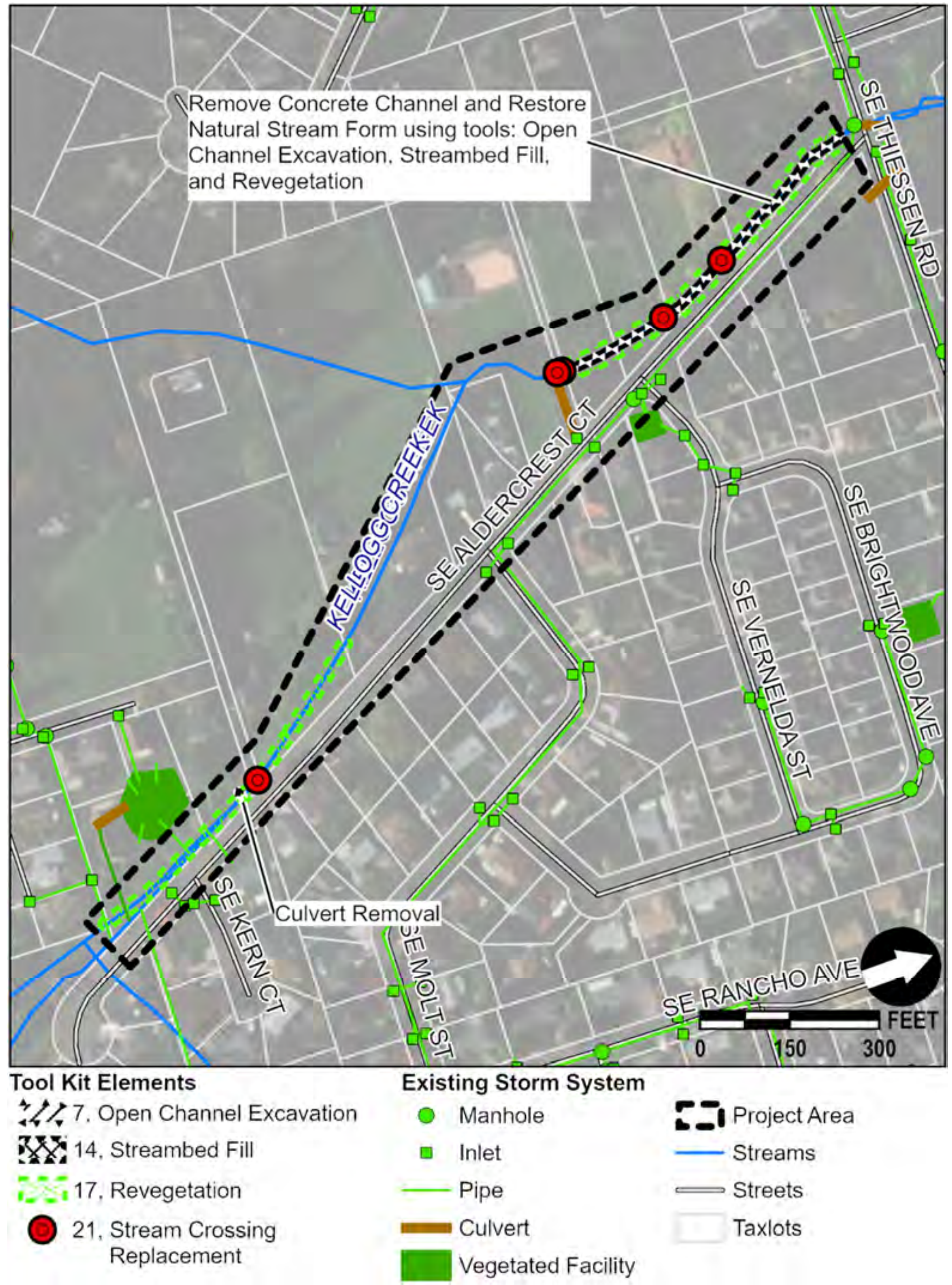
This project could be undertaken in multiple phases to work within the constraints of budgets and/or owner permission. The proposed improvements would take place entirely on private property and will require the permission of multiple property owners. The project presents an opportunity to partner with the North Clackamas Watershed Council. The Council's Streamside Stewards Program assists willing private property owners with planning and conducting stream restoration projects.

The benefits of this project include:

- Reduce flooding
- Improve fish and wildlife habitat

Cost Estimate

Construction	Qty	Unit	Price	Amount
Open Channel Excavation	2099	CY	$37	$77,663
Streambed Fill	459	CY	$100	$45,900
Vegetation Restoration, for riparian area	27,180	SF	$9	$244,620
Culvert Replacement, 13x16 ft concrete slab driveway bridge	5	EA	$54,750	$273,750
Mobilization	10%	of Construction		$116,400
Erosion and Sediment Control	2%	of Construction		$23,300
Temporary Water Management				$50,000
Construction Subtotal				***$831,633***
Construction Contingency	40%	of Construction		$332,700
Total Construction Cost				**$1,164,333**
Other	**Assumption**			
Design	20%	of Construction		$232,900
Basic Permitting				$15,000
Permitting in Jurisdictional Waters				$50,000
Project Administration	12%	of Construction		$139,700
Easement and Acquisition	27,180	SF	$6.00	$163,080
Easement Administration	10	Per Lot	$10,000	$100,000
Total Cost				**$1,865,013**



Capital Improvement Project Fact Sheet

Project Rank: 13

CLACKAMAS WATER ENVIRONMENT SERVICES

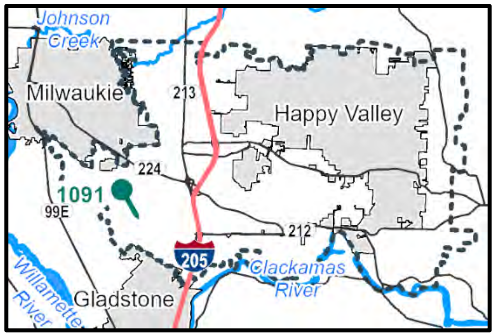
ID: 1091

Name: SE Clackamas Road Drainage Infrastructure

Study Area: Kellogg Creek

Location: SE Clackamas Road and SE Tidwells Way east of SE Stohler Road

Problem Summary



The problem area is located just west of where SE Clackamas Road crosses Kellogg Creek, southwest of Ann-Toni Schreiber Park.

A stream that drains a pond south of SE Tidwells Way is collected by a standard ditch inlet at the edge of a residential property and is conveyed in storm pipes down SE Clackamas Road to Kellogg Creek. The ditch inlet is not large enough to capture the stream flow, especially when debris collects at the inlet. Maintenance crews are called frequently to clear the inlet.

The stream frequently exceeds the capacity of the inlet, flows through a yard, and floods SE Clackamas Road and neighboring homes. The problem is compounded by the fact that Kellogg Creek is very flat at this location (0.1% slope), and the SE Clackamas Road crossing consists of a single undersized culvert. The storm pipes on SE Clackamas Road discharge into Kellogg Creek upstream of the road crossing, where a wetland has formed. Backwater from the undersized crossing limits the capacity of the storm pipes in SE Clackamas Road and contributes to the flooding issue.

Project Description

The purpose of this project is to reduce flooding of properties near the SE Clackamas Road-Kellogg Creek crossing without replacing the culvert or disrupting the wetland upstream of the crossing. This will be achieved by replacing the undersized ditch inlet that collects a tributary stream and routing new storm pipes on SE Clackamas Road to a new outfall on the downstream side of the Kellogg Creek crossing instead of into the wetland upstream of the crossing.

Landowner cooperation and an easement will be required for replacement of the storm pipe across private property.

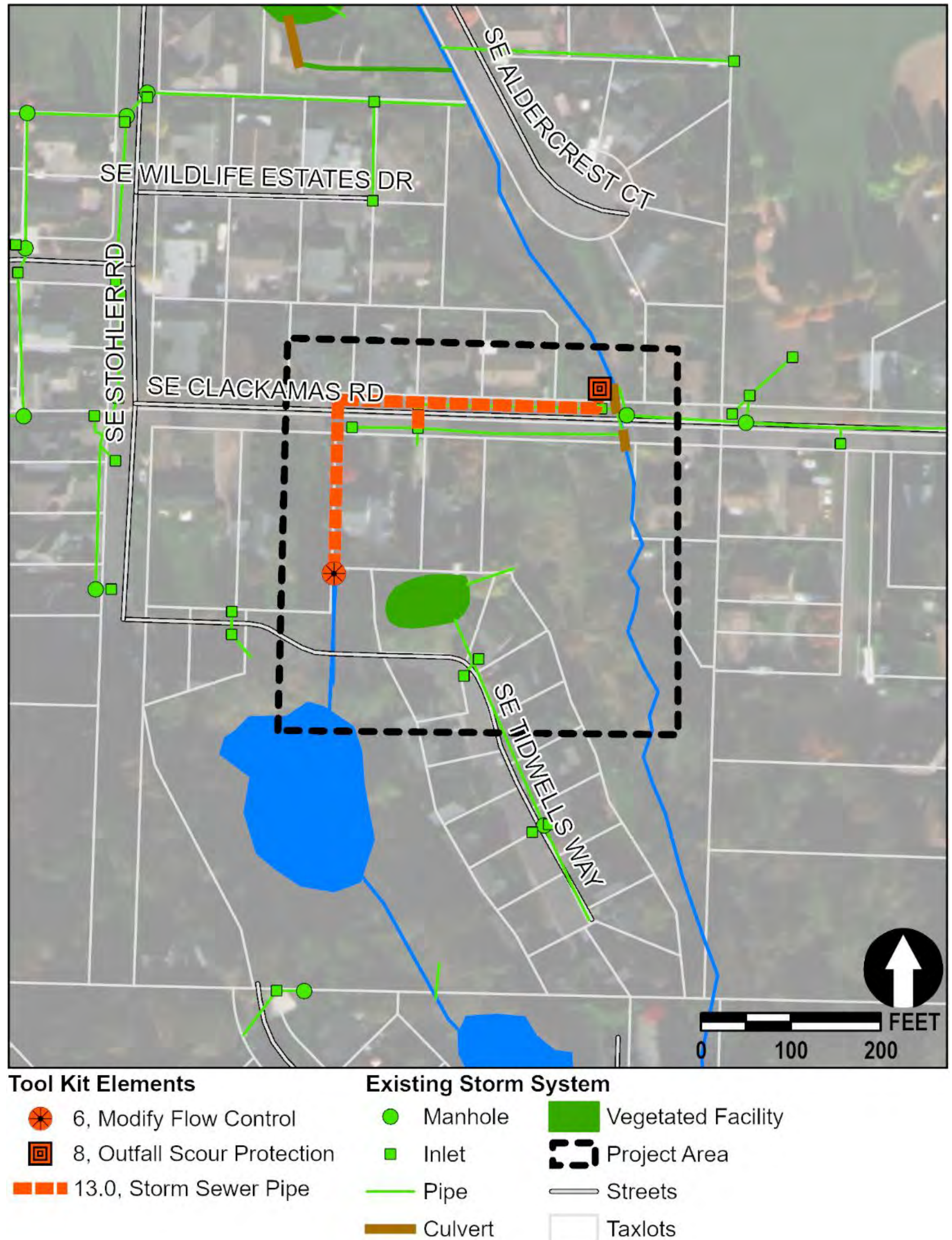
The benefits of this project include:

- Reduce flooding of private property, homes, and a roadway
- Reduce maintenance needs

Otak

Cost Estimate

Construction	Qty	Unit	Price	Amount
Modify Flow Control, large debris grate	1	EA	$24,500	$24,500
Outfall Scour Protection, 12-in to 24-in diam. pipe	1	EA	$1,900	$1,900
Storm Sewer Pipe, 18-in diam. pipe	30	FT	$195	$5,850
Storm Sewer Pipe, 24-in to 30-in diam. pipe	510	FT	$235	$119,850
Mobilization	10%	of Construction		$33,200
Erosion and Sediment Control	2%	of Construction		$6,600
Utility Conflict Resolution				$20,000
Temporary Water Management				$25,000
Construction Subtotal				***$236,900***
Construction Contingency	40%	of Construction		$94,800
Total Construction Cost				**$331,700**
Other	Assumption			
Design	25%	of Construction		$82,900
Basic Permitting				$10,000
Permitting in Jurisdictional Waters				$15,000
Project Administration	15%	of Construction		$49,800
Easement and Acquisition	1500	SF	$6.00	$9,000
Easement Administration	1	Per Lot	$10,000	$10,000
Total Cost				**$508,400**



Capital Improvement Project Fact Sheet

Project Rank: 14

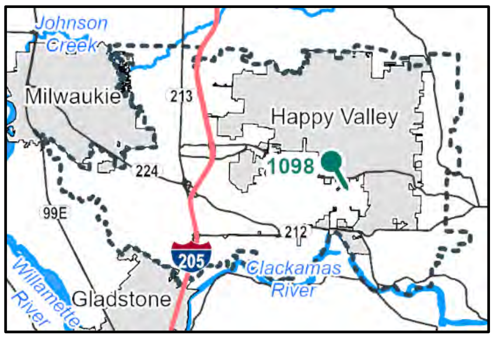
ID: 1098

Name: Rose Creek New Detention Pond and Instream Restoration

Study Area: Sunnyside

Location: South of Oregon Trail Elementary School

Problem Summary



The project site is located at the headwaters of Rose Creek, a tributary of Sieben Creek and the Clackamas River. Rose Creek flows east to west through a 5.64-acre site owned by WES between SE Sieben Park Way and SE 152nd Drive south of Oregon Trail Elementary School. The neighborhood east of the Oregon Trail Elementary School drains to the site and outfalls to Rose Creek at a pipe along SE 152nd Drive.

Rose Creek is a severely degraded watershed. Increased runoff entering the stream through pipe inlets from development around the site is causing erosion and downstream flooding. In the project area, the erosion is causing unstable streambanks, and there is a headcut approximately five feet deep in the stream. The headcut is migrating upstream threatening the pedestrian bridge at SE Hines Drive. The project site is also dominated by invasive plant species and noxious weeds resulting in poor habitat for amphibians and other wildlife.

Project Description

The purpose of the project is to stabilize the stream, prevent future erosion, and improve habitat.

The project will construct a stormwater detention pond and flow control structure upstream of the headcut to treat and detain runoff from the upstream residential neighborhood. This will reduce peak flow rates entering the stream system and help to reduce erosion in the stream. The proposed detention pond receives runoff from a drainage basin of approximately 30 acres, which is assumed to be 25% impervious. For this concept design, the pond was sized using a 6% sizing factor of the contributing impervious area.

Rock grade control structures and stable streambed material will be placed in the stream to raise the level of the streambed and stabilize the headcut, protecting the pedestrian bridge, road, and habitat upstream.

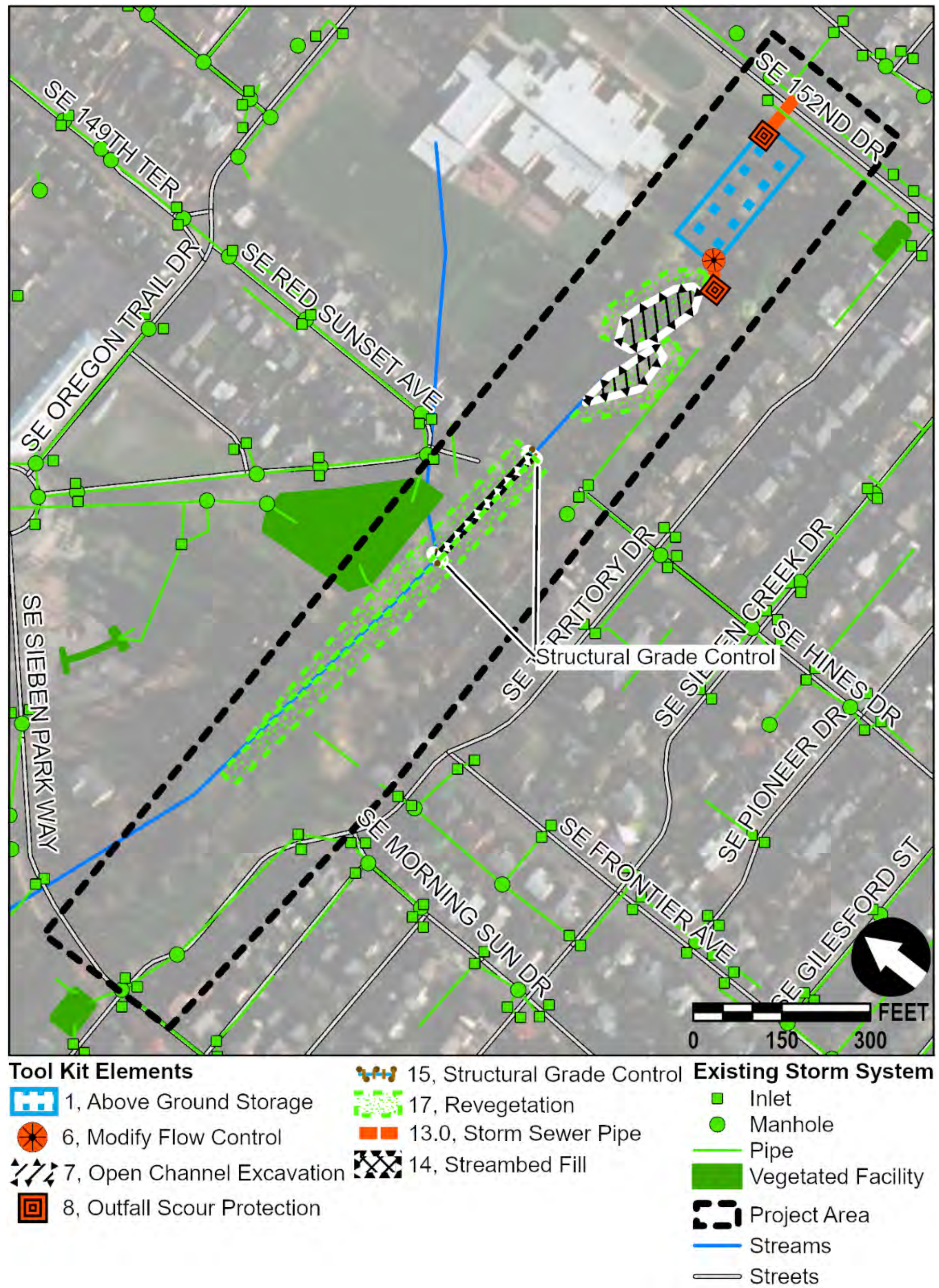
The project will also restore habitat within the riparian corridor of the site. Invasive vegetation will be removed, and native species will be planted. Vegetation restoration will include the establishment of habitat features such as brush piles, snags, and large woody debris. The large woody debris will also slow the flow of water and dissipate energy during high-flow events. Wetland areas will be constructed adjacent to the main channel by excavation and planting with native wetland plants.

The benefits of this project include:

- Stabilize the stream bank and minimize headcutting
- Reduce roadway flooding downstream of the site
- Improve aquatic habitat and water quality

Cost Estimate

Construction	Qty	Unit	Price	Amount
Stormwater Pond	64,000	CF	$5	$300,800
Modify Flow Control, 72-in diam. flow control manhole	1	EA	$14,500	$14,500
Open Channel Excavation	910	CY	$37	$33,670
Outfall Scour Protection, 12-in to 24-in diam. pipe	2	EA	$1,900	$3,800
Storm Sewer Pipe, 24-in to 30-in diam. pipe	140	FT	$235	$32,900
Streambed Fill	160	CY	$100	$16,000
Structural Grade Control	180	FT	$385	$69,300
Vegetation Restoration, for riparian area	64,760	SF	$9	$582,840
Mobilization	10%	of Construction		$201,900
Erosion and Sediment Control	2%	of Construction		$40,400
Temporary Water Management				$50,000
Construction Subtotal				***$1,346,110***
Construction Contingency	50%	of Construction		$673,100
Total Construction Cost				**$2,019,210**
Other	**Assumption**			
Design	15%	of Construction		$302,900
Basic Permitting				$15,000
Permitting in Jurisdictional Waters				$50,000
Project Administration	10%	of Construction		$201,900
Total Cost				**$2,589,010**



Capital Improvement Project Fact Sheet

Project Rank: 15

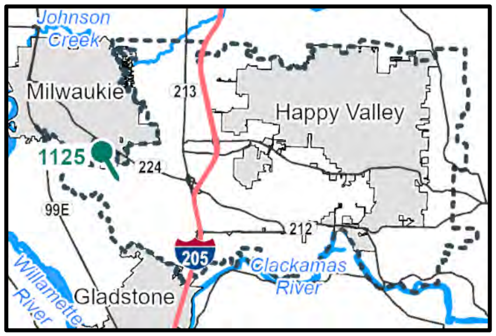
ID: 1125

Name: Aldercrest and Rusk Drainage Improvement

Study Area: Kellogg Creek

Location: SE Aldercrest Road from SE Aldercrest Lane to SE Rusk Road

Problem Summary



The problem area is located on SE Aldercrest Road between SE Aldercrest Lane and SE Rusk Road. SE Aldercrest Road runs southeast to northwest, and the area slopes to the northeast towards Kellogg Creek.

Four houses north of SE Aldercrest Road are below road grade, and water flows off the road towards these houses flooding the yards. The neighborhood and roadway flood annually.

There are two catch basins on the road at the intersection of SE Aldercrest Road and SE Rusk Road; however, the road does not have a curb and gutter to direct flow from the flooding area to the catch basins.

Project Description

The purpose of this project is to improve conveyance and collection infrastructure along SE Aldercrest Road. The improvements will direct runoff into the storm sewer system and prevent flooding of the roadway and yards.

This project will construct a curb and gutter along SE Aldercrest Road to channel water south into catch basins at the intersection of SE Aldercrest Road and SE Rusk Road. The catch basins will also be replaced.

An added challenge of the project is that some of the driveways slope directly down from the road to the houses. The driveway entrances may need to be modified to prevent water flowing down the driveways from the new gutter.

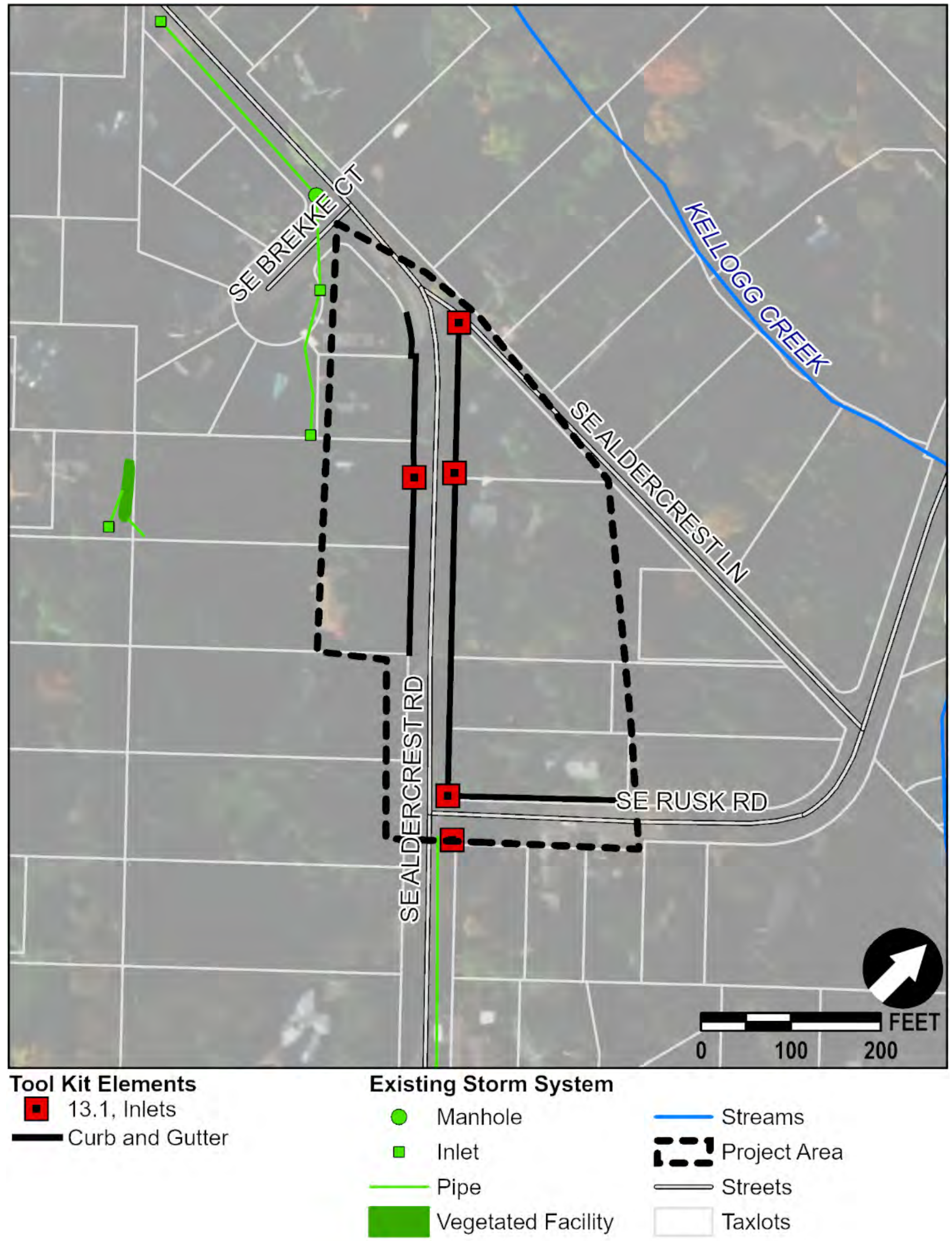
The project will require coordination with the Clackamas County Department of Transportation for road work, and there is an opportunity to combine stormwater improvements with transportation improvements. The stormwater improvements can be placed within the existing right-of-way. However, the Clackamas County Comprehensive Plan classifies SE Aldercrest Road as a collector street. The street does not yet meet the standards for a collector. SE Aldercrest Road needs to be widened to 36 feet, and right-of-way acquisition will be needed to add sidewalks and planter strips along the road.

The benefits of this project include:

- Reduce flooding on private property and roadway

Cost Estimate				
Construction	Qty	Unit	Price	Amount
Storm Sewer Pipe, standard G-2 inlet	5	EA	$3,000	$15,000
Curb and Gutter*	1100	LF	$130	$143,000
Mobilization	10%	of Construction		$30,700
Erosion and Sediment Control	2%	of Construction		$6,100
Temporary Water Management				$10,000
Construction Subtotal				***$204,800***
Construction Contingency	50%	of Construction		$102,400
Total Construction Cost				**$307,200**
Other	Assumption			
Design	25%	of Construction		$76,800
Basic Permitting				$10,000
Project Administration	15%	of Construction		$46,100
Total Cost				**$440,100**

*Curb and gutter costs include paving for 5 feet of road widening.



Capital Improvement Project Fact Sheet

Project Rank: 11

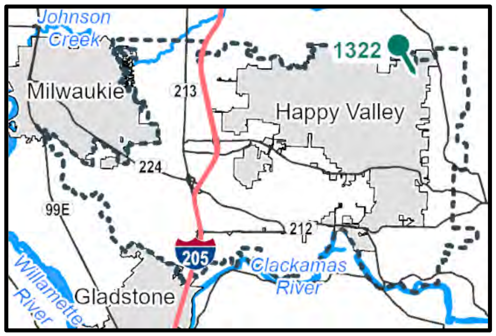
ID: 1322

Name: SE 172nd Ditch Conveyance Improvement

Study Area: Rock Creek

Location: SE 172nd Ave at SE Wooded Heights Rd

Problem Summary



A drainage ditch flows along the west side of SE 172nd Avenue to a local low point at SE Wooded Heights Drive. There the ditch crosses SE 172nd Avenue through two culverts to a natural drainage through private property which connects to Rock Creek to the east. The ditch backs up at the culverts under SE 172nd Ave causing flooding over the roadway and into homeowners' yards.

Based on visual observations, the culverts appear to be 18"-24" in diameter. The culverts and drainage downstream appear to have sufficient capacity. Vegetation growing at the inlets and outlets appears to be blocking the culverts causing the backup. As a result, the ditch overflows and floods the roadway and yards annually.

The area is outside WES jurisdiction and maintenance is infrequent as a result. The lack of maintenance allows the vegetation to grow and debris to accumulate. The area is expected to be annexed into Happy Valley and into WES as part of the Pleasant Valley/North Carver Comprehensive Plan update.

Project Description

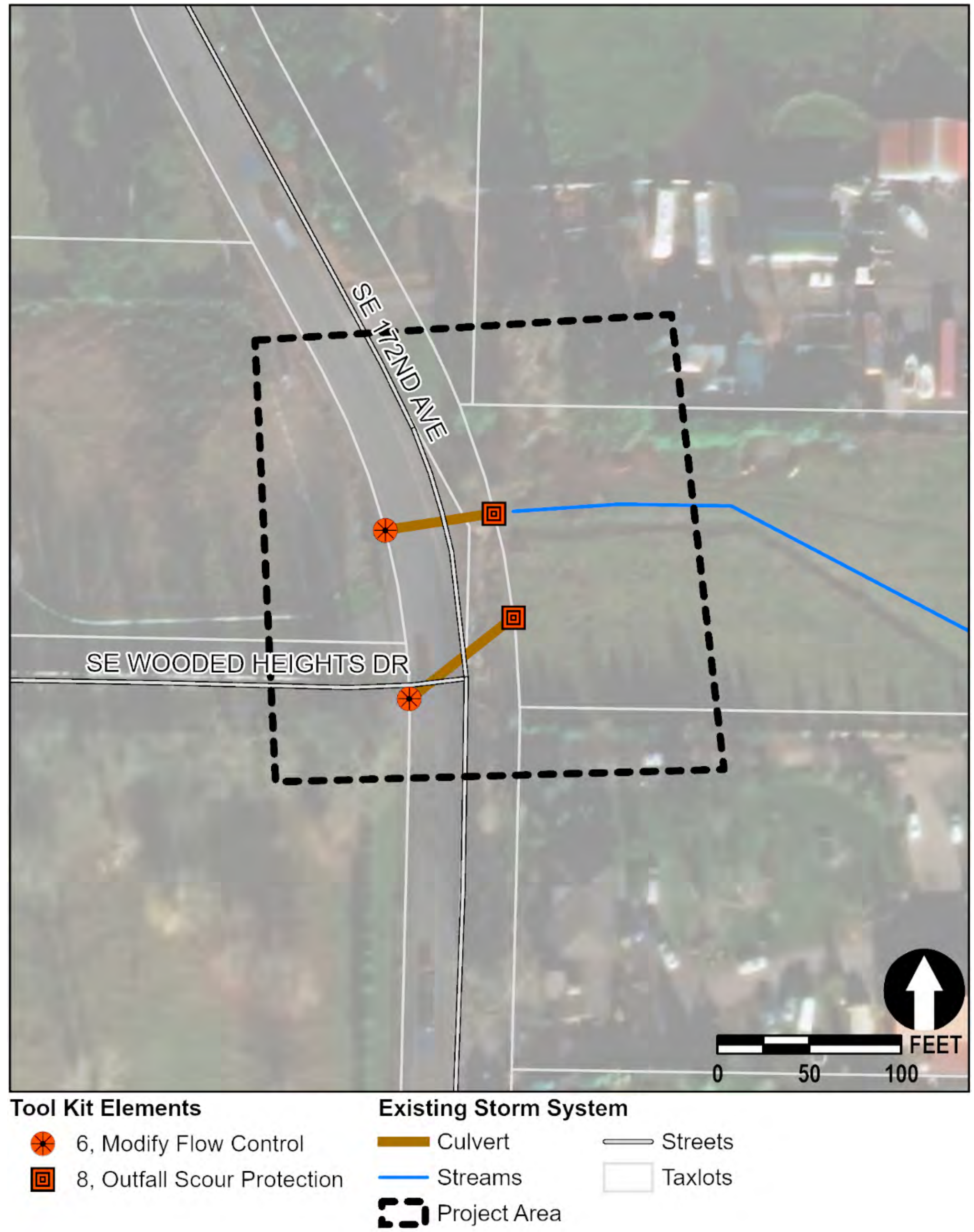
The purpose of this project is to reduce flooding and increase the conveyance capacity of the existing ditch along SE 172nd Avenue.

The project will replace the culvert inlets with beehive grate manholes. These larger inlet structures will be less prone to clogging from vegetation, sediment, and debris. At the outlets, rip rap scour protection or concrete splash pads will be added to keep vegetation from restricting flows and to prevent erosion.

The benefits of this project include:

- Reduce flooding on private property and the roadway

Cost Estimate				
Construction	**Qty**	**Unit**	**Price**	**Amount**
Modify Flow Control, 48-in diam. manhole w/ birdcage	2	EA	$6,500	$13,000
Outfall Scour Protection, 12-in to 24-in diam. pipe	2	EA	$1,900	$3,800
Mobilization	10%	of Construction		$4,900
Erosion and Sediment Control	2%	of Construction		$1,000
Temporary Water Management				$10,000
Construction Subtotal				***$32,700***
Construction Contingency	50%	of Construction		$16,400
Total Construction Cost				**$49,100**
Other	**Assumption**			
Design	25%	of Construction		$12,300
Basic Permitting				$5,000
Permitting in Jurisdictional Waters				$15,000
Project Administration	15%	of Construction		$7,400
Total Cost				**$88,800**



Capital Improvement Project Fact Sheet

Project Rank: 7

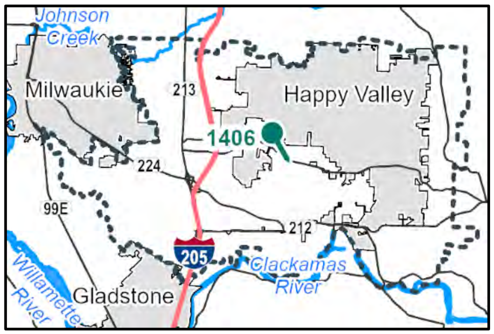
ID: 1406

Name: Sunnyside Place Culvert Replacement and Stream Restoration

Study Area: Sunnyside

Location: Between SE 124th Avenue and SE Sunnyside Place

Problem Summary



The problem area is located just west of SE 124th Avenue where runoff collected in storm pipes from SE 124th Avenue and areas east of the avenue discharges from an outfall into an open channel tributary of Mt. Scott Creek. The tributary flows west from SE 124th Avenue south of SE Sunnyside Road between a small shopping center to the north and a home and apartment complex to the south. The downstream end of the outfall pipe has become buried.

Water backs up and floods SE 124th Avenue at least annually. The asphalt on SE 124th Avenue is degraded as a result of the flooding. Just downstream of the outfall, the creek is deeply incised and actively eroding, threatening the fence line of a residential property to the south.

Project Description

The purpose of this project is to reduce flooding of SE 124th Avenue and protect the stream channel between SE 124th Avenue and SE Sunnyside Place. The project will stabilize the stream channel and uncover the buried outfall.

Sediment at the SE 124th Avenue culvert outfall will be excavated to expose the downstream end of the pipe, and the stream banks will be stabilized and revegetated. These improvements will improve drainage out of the culvert and through the creek, reducing flooding at SE 124th Avenue.

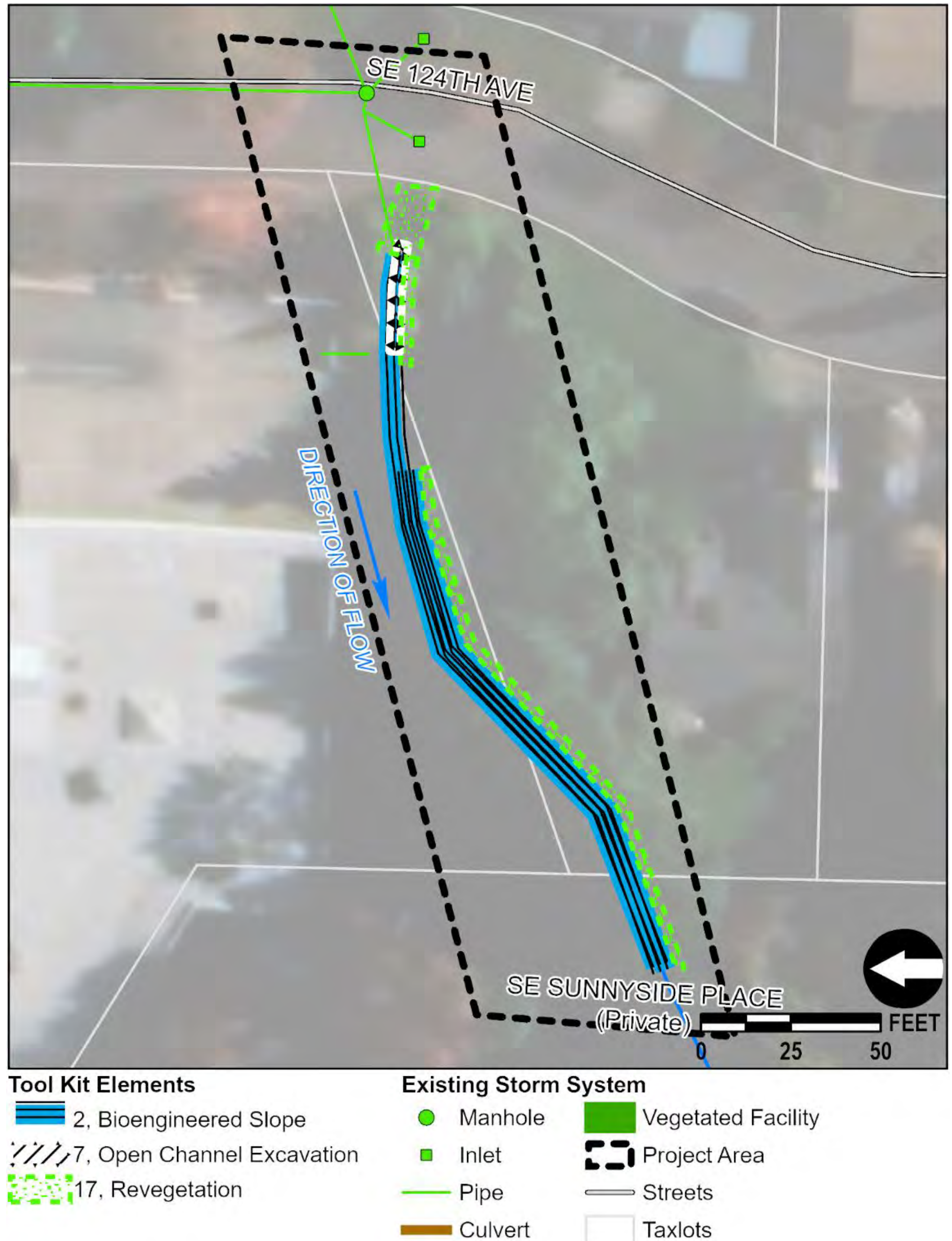
Coordination with the Clackamas County Department of Transportation and Development (DTD) will be necessary to work on the outfall.

The benefits of this project include:

- Reduce flooding on roadway and private property
- Improve habitat and stream channel stability

Cost Estimate

Construction	Qty	Unit	Price	Amount
Bioengineered Slope	1520	SF	$101	$153,140
Outfall Scour Protection	1	EA	$5,300	$5,300
Open Channel Excavation	9	CY	$37	$333
Pre-settling Basin	1	EA	$11,200	$11,200
Streambed Fill	20	CY	$100	$2,000
Vegetation Restoration, for riparian area	1450	SF	$9	$13,050
Mobilization	10%	of Construction		$35,400
Erosion and Sediment Control	2%	of Construction		$7,100
Temporary Water Management				$25,000
Construction Subtotal				***$252,523***
Construction Contingency	40%	of Construction		$101,000
Total Construction Cost				**$353,523**
Other	Assumption			
Design	25%	of Construction		$88,400
Basic Permitting				$10,000
Permitting in Jurisdictional Waters				$30,000
Project Administration	15%	of Construction		$53,000
Easement and Acquisition	1450	SF	$6.00	$8,700
Easement Administration	3	Per Lot	$10,000	$30,000
Total Cost				**$573,623**



Capital Improvement Project Fact Sheet

Project Rank: 9

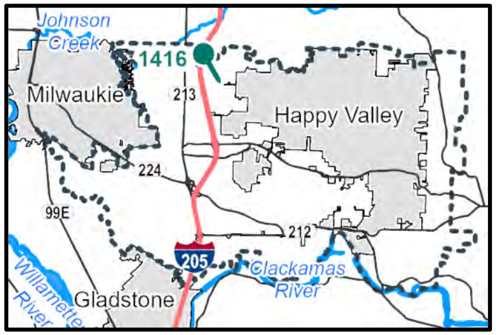
ID: 1416

Name: Idleman Conveyance

Study Area: Mt. Scott

Location: SE Idleman Road east of SE 92nd Ave

Problem Summary



The problem area is located on SE Idleman Road from SE 92nd Avenue east to SE Nicole Lane.

SE Idleman Road slopes steeply at grades of 13% to 15% from east to west and has inconsistent use of curb and gutter. Areas without curbs have a raised asphalt lip which is insufficient to direct water into catch basins during heavy runoff, and the existing catch basins often clog and overflow. Water floods the roadway and neighboring properties.

Flooding is a frequent problem, and some homeowners keep sandbags out along the roadway all year to direct runoff away from private properties. Some driveways slope from the street, providing a direct path for runoff towards homes.

Project Description

The purpose of this project is to improve conveyance and collection infrastructure along SE Idleman Road. The improvements will direct runoff into the storm sewer system and prevent flooding of the roadway and the yards of homes along the road.

The project will construct curbs, gutters, and catch basins along SE Idleman Road between SE 92nd Avenue and SE 99th Court. Curbs already exist on SE Idleman at both ends of the project, and the improvements will require widening the road five feet on the south side to connect to these existing curbs. All catch basins along the project length will be replaced in order to align with the curb and gutter, and new storm pipe will be constructed along the south side of SE Idleman. These improvements may all be completed within existing right-of-way.

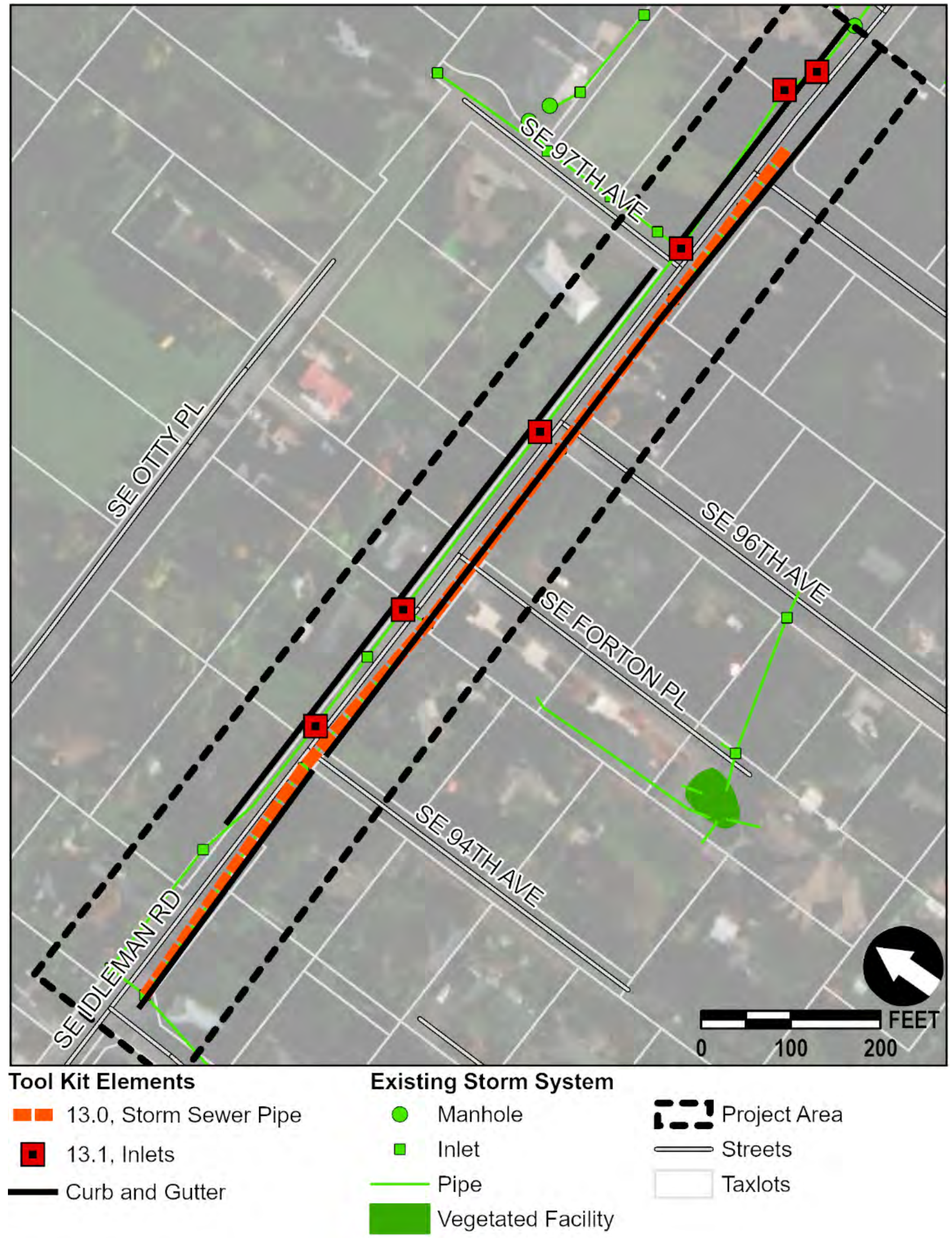
The project will also replace an existing inlet at SE Idleman and SE Nicole Lane that captures flow from a drainage ditch (not shown on map). The existing inlet will be replaced with a larger structure to prevent clogging.

The project will require coordination with the Clackamas County Department of Transportation and Development for road work. This project may provide an opportunity for pedestrian and bicycle improvements along the SE Idleman Road.

The benefits of this project include:

- Reduce flooding of roadway and private property

Cost Estimate				
Construction	Qty	Unit	Price	Amount
Modify Flow Control, 48-in diam. manhole w/ birdcage	1	EA	$6,500	$6,500
Storm Sewer Pipe, 18-in diam. pipe	1200	FT	$195	$234,000
Storm Sewer Pipe, standard G-2 inlet	6	EA	$3,000	$18,000
Curb and Gutter*	2500	LF	$130	$325,000
Mobilization	10%	of Construction		$104,900
Erosion and Sediment Control	2%	of Construction		$21,000
Utility Conflict Resolution				$30,000
Temporary Water Management				$10,000
Construction Subtotal				***$749,400***
Construction Contingency	40%	of Construction		$299,800
Total Construction Cost				**$1,049,200**
Other	Assumption			
Design	20%	of Construction		$209,800
Basic Permitting				$10,000
Project Administration	12%	of Construction		$125,900
Total Cost				**$1,394,900**



Capital Improvement Project Fact Sheet

Project Rank: 5

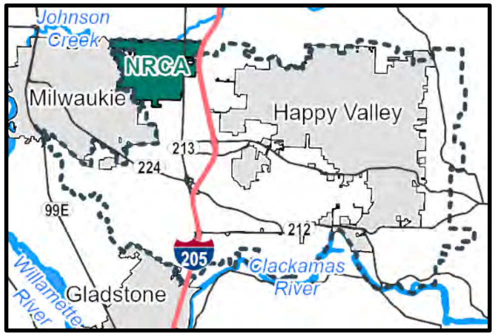
ID: 1606

Name: NCRA Stormwater Plan

Study Area: North Clackamas Revitalization Area (NCRA)

Location: West of I-205 and east of Milwaukie

Problem Summary



The North Clackamas Revitalization Area (NCRA) consists of approximately 1,008 acres of unincorporated Clackamas County between Milwaukie and I-205.

In 2006, Clackamas County adopted the North Clackamas Urban Renewal Plan (plan) to improve infrastructure in the area. The County identified frequent flooding from Johnson Creek and inadequate street storm infrastructure as some of the conditions limiting redevelopment in NCRA. The plan is administered by the Clackamas County Development Agency.

About 10% of the area, including 199 tax lots, is within the 100-year floodplain of Johnson Creek, which floods frequently.

Many streets in the area are not built to County standards and lack adequate storm water service, including curb and gutter for a proper drainage system.

Among other goals, the plan authorized the Development Agency to fund improvements to storm facilities in the area to improve street drainage and assist in mitigating flood impacts.

Project Description

The purpose of this project is to develop a master plan for extending and improving stormwater infrastructure in the NCRA. The master plan will:

- Clearly identify stormwater management goals in the NCRA
- Prioritize regions or improvements to fit within the available budgets and maximum benefit to the stormwater infrastructure.
- Identify other proposed infrastructure improvements in the NCRA that may be combined with stormwater improvements.
- Identify potential property purchases for the construction of regional facilities.
- Update conceptual facility sizing, design, and cost estimates.

Preliminary planning completed for this SSMP study categorizes NCRA into three drainage area types; currently served areas, poor infiltration areas, and good infiltration areas. For each category, a stormwater management concept is proposed.

Currently Served Areas

Areas currently served by existing stormwater infrastructure were identified using GIS data from WES and no stormwater infrastructure improvements are proposed in these areas.

Poor Infiltration Areas

Poor infiltration areas were mapped based on soil types and are generally close to Johnson Creek. The stormwater management concept for poor infiltration areas is extension of public stormwater mains discharging to Johnson Creek, which will provide a point of discharge for developing and redeveloping properties as well as for public improvements.

New public mains should connect to existing pipes and utilize existing outfalls where capacity allows. The map shows a preliminary layout of conveyance pipes that would increase the stormwater service to the poor infiltration area.

The proposed stormwater mains would not alleviate the need for developing and redeveloping properties to provide flow control and water quality treatment on-site. Private developments or roadway improvement projects should incorporate water quality and flow control design elements prior to connection to new public mains. For public roadway improvements water quality treatment and flow control could be accomplished with the use of roadside flow through planters. Costs of flow control and water quality treatment in these areas have not been estimated. As publicly-owned regional detention facilities could reduce impediments to redevelopment, it is recommended the NCRA stormwater master plan study this option in greater detail.

Preliminary planning anticipates 3,800 linear feet of 24-in to 30-in diameter storm sewer mains on more than 10 streets in the poor infiltration area. A cost estimate for the entire set of pipes is presented on page 3.

Good Infiltration Areas

Good infiltration areas were mapped based on soil types. They are generally relatively flat and are distributed through the NCRA. In many cases, they are far from any existing stormwater mains. The stormwater management concept is to upgrade streets in poor condition to "green streets," incorporating roadside stormwater planters to treat and infiltrate stormwater runoff. The concept is similar to the one described in the Street, Curb, and Sidewalk Improvement Program of the 2006 Proposed NCRA Design Plan (2006 Design Plan).

The green streets concept assumes that streets will be improved to County standards, including a two-lane residential street with 12-foot lanes, six-foot sidewalk and curb, and four-foot landscaping strip. Stormwater planters replace the landscaping strips. Stormwater planters are sized at 10% of the contributing basin with intent to provide both water quality treatment and flow control through infiltration. Contributing areas are assumed to equal the area of improved right-of-way on the same block. Estimated costs include the stormwater planters plus curb equal to 25% of the planter length.

Two separate cost estimates have been prepared for the green streets concept: an option for a pilot green street and an area-wide application of green streets. Each estimate is shown separately on page 3. The estimates are of the storm system portion of a green street project completed in cooperation with Clackamas County Development and Transportation Agency (DTD) and the Clackamas County Development Agency. It is assumed WES will fund the stormwater planters plus a small portion of the curb or street drainage infrastructure needed to direct flows to the planter. Estimated costs do not include right-of-way acquisition, paving, sidewalks, remaining curb and gutter, pipe conveyances, or street trees. The share of project costs to be assumed by DTD and the Development Agency have not been estimated; however, the 2006 Design Plan estimated costs to upgrade the non-conforming residential streets to a standard residential street of 26-foot width, curbs, drainage, planter strip with street trees, and sidewalk. The 2006 estimate was $480 per linear foot of centerline.

One option for the pilot green street is the two-block segment of SE 76th Ave. between SE Overland St. and SE Otty St. This segment was found to be in poor condition in the 2006 Design Plan. The centerline distance of these blocks is approximately 750 feet. About 13 stormwater planters at a total length of 650 feet are needed, which would occupy about 40% of the frontage on both blocks. Preliminary planning did not assess utility conflicts, parking concerns, or landscaping requirements. Selecting one of the other streets in the Good Infiltration Area as a pilot would have a similar cost.

The area-wide application of green streets includes all remaining streets within the Good Infiltration Area that were found to be in poor condition in the 2006 Design Plan. These are SE 79th Ave. and SE 78th Ave., each between SE Overland St. and SE Otty St., and SE Pierce St. between SE Bell Ave. and SE Eckler Ave.

Cost Estimate – Area-wide Stormwater Conveyance				
Construction	Qty	Unit	Price	Amount
Storm Sewer Pipe, 24-in to 30-in diam. pipe	3800	FT	$235	$893,000
Mobilization	10%	of Construction		$137,600
Erosion and Sediment Control	2%	of Construction		$27,500
Temporary Water Management				$0
Construction Subtotal				***$1,058,100***
Construction Contingency	30%	of Construction		$317,400
Total Construction Cost				**$1,375,500**
Other		Assumption		
Design	15%	of Construction		$206,300
Basic Permitting				$50,000
Project Administration	10%	of Construction		$137,600
Total Cost				**$1,769,400**

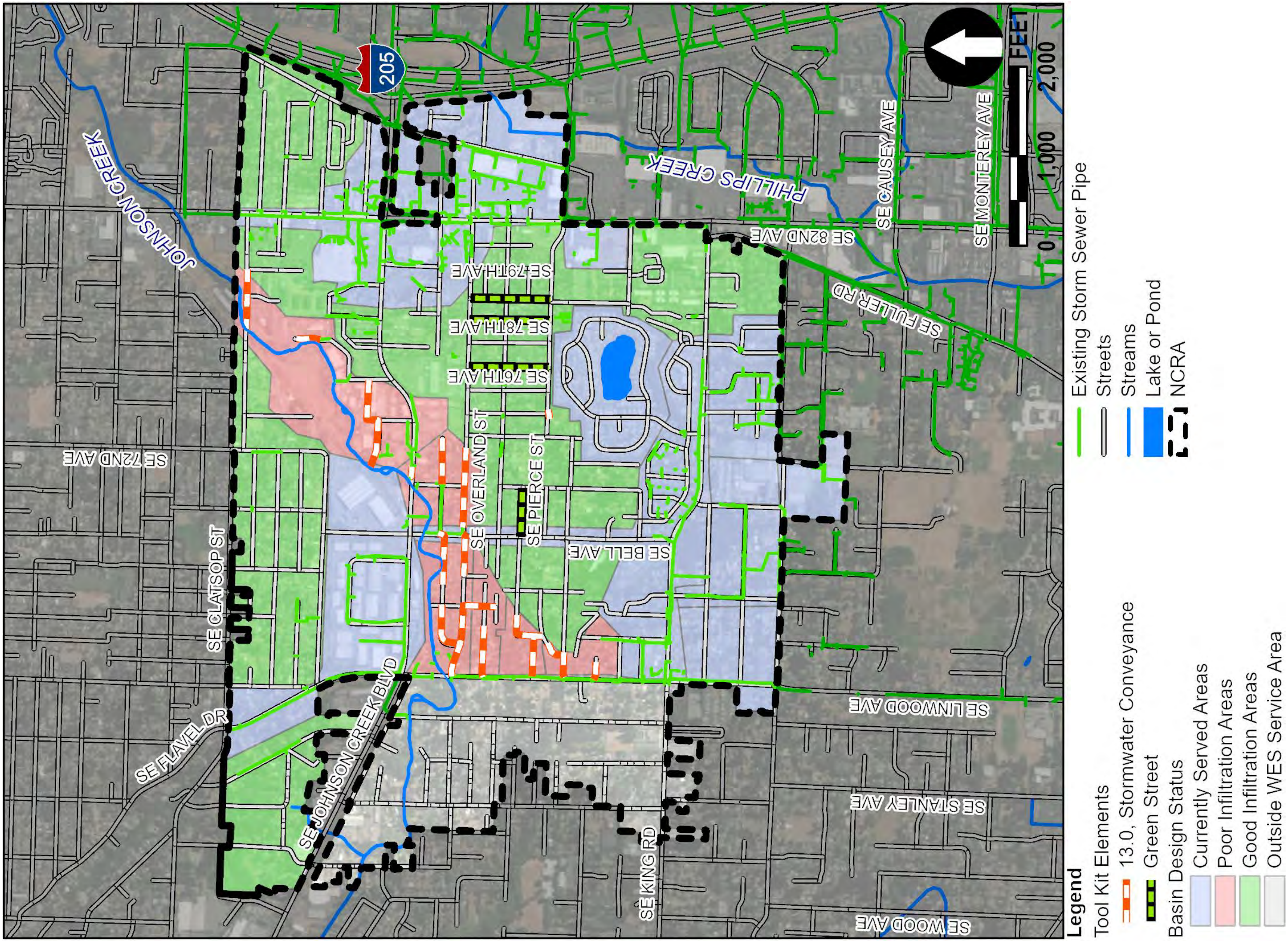
Cost Estimate – Area-wide Green Streets*				
Construction	Qty	Unit	Price	Amount
Stormwater Planter	9000	SF	$130	$1,170,000
Curb and Gutter	450	LF	$50	$22,500
Mobilization	10%	of Construction		$183,700
Erosion and Sediment Control	2%	of Construction		$36,700
Temporary Water Management				$0
Construction Subtotal				***$1,412,900***
Construction Contingency	30%	of Construction		$423,900
Total Construction Cost				**$1,836,800**
Other		Assumption		
Design	15%	of Construction		$275,500
Basic Permitting				$50,000
Project Administration	10%	of Construction		$183,700
Total Cost				**$2,346,000**

Cost Estimate – Pilot Green Street*				
Construction	Qty	Unit	Price	Amount
Stormwater Planter	3300	SF	$130	$429,000
Curb and Gutter	165	LF	$50	$8,250
Mobilization	10%	of Construction		$67,400
Erosion and Sediment Control	2%	of Construction		$13,500
Temporary Water Management				$0
Construction Subtotal				***$518,150***
Construction Contingency	30%	of Construction		$155,400
Total Construction Cost				**$673,550**
Other		Assumption		
Design	15%	of Construction		$101,000
Basic Permitting				$50,000
Project Administration	10%	of Construction		$67,400
Total Cost				**$891,950**

Cost Estimate – NCRA Stormwater Master Plan			
Master Plan			
NCRA Stormwater Master Plan			$125,000
Total Construction Cost			**$125,000**
Other		Assumption	
Project Administration	10%	of Costs	$12,500
Total Cost			**$137,500**

* Costs are estimated for the storm system costs portion of projects only.

Grand Total: $5,144,850


Legend
Tool Kit Elements
13.0, Stormwater Conveyance
Green Street
Basin Design Status
Currently Served Areas
Poor Infiltration Areas
Good Infiltration Areas
Outside WES Service Area
Existing Storm Sewer Pipe
Streets
Streams
Lake or Pond
NCRA
FEET
0
1,000
2,000
205
JOHNSON CREEK
PHILLIPS CREEK
SE 82ND AVE
SE CAUSEY AVE
SE MONTEREY AVE
SE FULLER RD
SE 79TH AVE
SE 78TH AVE
SE 76TH AVE
SE OVERLAND ST
SE PIERCE ST
SE BELL AVE
SE 72ND AVE
SE CLATSOP ST
SE FLAVEL DR
SE JOHNSON CREEK BLVD
SE KING RD
SE LINWOOD AVE
SE STANLEY AVE
SE WOOD AVE

Appendix H

Stormwater Tool Kit Factsheets

Otak

Tool Kit Fact Sheet

Stormwater Pond

Creating depressions to store and/or infiltrate stormwater

Description

Stormwater Pond can provide water quality treatment, infiltration, and flow control. Stormwater Pond is created by excavating a depression to temporarily store stormwater or expand an existing pond.

Temporarily storing stormwater and controlling the rate of the flow leaves the pond and into the pipe or stream, reduces flooding, erosion, and sedimentation.

Stormwater Pond use drain rock to provide infiltration of stormwater into the native soil and uses plants, engineered soil media, and matting to incorporate water quality treatment.

Stormwater Pond is a good choice where there is a large contributing drainage area, adequate space to integrate the facility into landscaping, and access for maintenance.

Uses

Stormwater Pond is often used to:

- Reduce flooding from storms
- Slow down stream flows to prevent erosion
- Allow sediment to settle out of dirty water before it releases to a stream

Benefits

The benefits of Stormwater Pond include:

- Protect stream channels
- Easy to see if it's working
- Some can look like natural ponds
- Infiltration and groundwater recharge
- Remove pollutants from stormwater runoff

Costs

Design Unit

The unit of measurement for design of Stormwater Pond is **cubic feet (CF) of storage**. Costs do not include outlet structure, ditch inlets, or outfall protection.

Cost Assumptions Per Unit

The cost assumption was developed for a hypothetical 200,000 CF pond.

Item	Qty	Unit	Price	Amount
Excavation	7223	CY	$37	$267,251
Water Quality Mixture (18-in depth)	3150	CY	$55	$173,229
Drain Rock (18-in depth)	2406	CY	$50	$120,297
Drain Pipe (6-in dia)	208	LF	$40	$8,320
Bark Mulch (3-in depth)	525	CY	$50	$26,247
Geotextile	6299	SY	$6	$37,794
Small Shrub (1-gal)	2268	EA	$22	$49,890
Large Shrub/Small Tree (2-gal)	1701	EA	$27	$45,921
Dec. Trees (1" cal.)	134	EA	$305	$40,828
Ground Cover (SP #4)	65,197	EA	$2	$130,394
Seeding	1.30	AC	$7,500	$9,761
Temporary Irrigation ($0.50/SF)	1	EA	$28,347	$28,347
Total				**$938,280**

Price per CF of Storage (rounded) **$4.70**

Effort

Permitting – up to six months

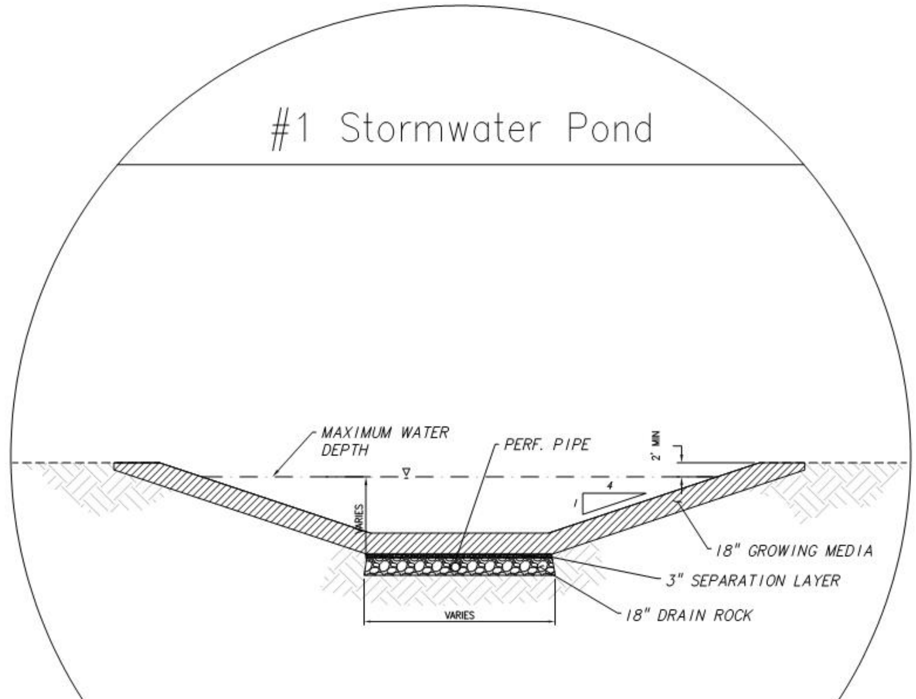
Permitting varies depending on the location of the pond. Stormwater ponds are often constructed away from stream banks and wetlands. Local permits from the Clackamas WES almost always required. Work in a stream or wetland requires permits from State and Federal agencies. Work in the floodplain will require compliance with the county’s no-rise floodplain ordinance.

Implementation – medium effort

Stormwater Pond requires design by an engineer. Construction requires extensive earthwork and revegetation. Plant establishment will take two to three years.

Maintenance – medium effort

Maintenance typically requires vegetation management multiple times per year. Sediment should be removed from the outlet structure as needed. An annual inspection is recommended to check for erosion, filling of the outlet structure, and standing water. Eventually, accumulated sediment must be removed from the pond bottom.



Pond designs vary based on site conditions, purpose, and secondary purpose, if any. Follow applicable minimum standards.

Otak

Tool Kit Fact Sheet

Bioengineered Slope

Stream bank reconstruction with natural materials

Description

A bioengineered slope is one tool for reconstructing a stream bank that has eroded or been subject to landslide or slumping.

The eroded or slumped stream bank is excavated and terraced. The bank slope is reconstructed and stabilized using a combination of rocks, logs, vegetation, biodegradable textiles, and soil.

Where vegetation is used, a bioengineered slope may look like a natural stream bank after plants have matured.

Uses

Bioengineered slopes are often used in the following situations:

- Landslide into a stream
- Eroded stream bank on the outside of a bend in the stream

Benefits

The benefits of a bioengineered slope include:

- Green solution
- Aesthetics
- May improve stream habitat
- Low ongoing maintenance cost

Costs

Design Unit

The unit of measurement for design of Bioengineered Slope is **square feet (SF) of restored slope**, calculated by multiplying length of the bank by height of the slope.

Cost Assumptions Per Unit

The cost assumption was developed for a hypothetical 100-ft long, 1.5-ft tall Bioengineered Slope with one soil lift and a toe protection log.

Item	Qty	Unit	Price	Amount
Excavation	30	CY	$37	$1,110
General Fill (Re-use Native)	38	CY	$50	$1,900
Coir Woven (staked)	167	SY	$8	$1,336
Coir Non-woven (staked)	167	SY	$6	$1,002
Native Seeding	75	SY	$2.50	$188
Willow Stakes	75	EA	$5	$375
24-in X 24-ft Toe Protection Log	4	EA	$2,300	$9,200
Total				$15,111

Price per SF of Bioengineered Slope (rounded) **$101**

Effort

Permitting – up to six months

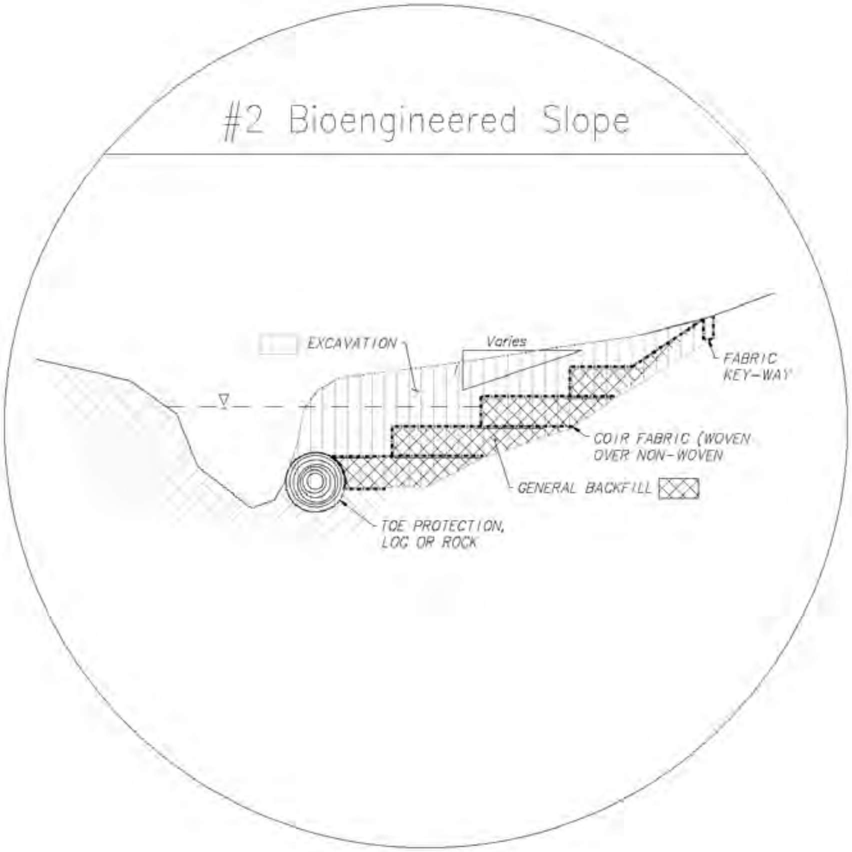
Permitting requires a permit from the Oregon Department of State Lands, the Army Corps of Engineers (ACOE), and a Water Quality Certification from Oregon DEQ. Endangered Species Act Consultation will be required on some streams in Clackamas County but can often utilize a programmatic biological opinion. Local permits from Clackamas County WES are also required.

Implementation – medium effort

Construction or implementation of this tool requires work during the established in-water work period, when fish are less likely to be impacted by grading and equipment in the channel. Work area isolation measures are necessary to manage flows and sediment to protect water quality during construction. Not as many contractors have work crews with good experience building bioengineered slopes.

Maintenance – low effort

Vegetation management and establishment during the first 2 to 5 years are important for long-term success. After a 5-year period a bioengineered slope requires little ongoing maintenance.



Tool Kit Fact Sheet

CLACKAMAS WATER ENVIRONMENT SERVICES

Outfall Extension or Tightline

Discharge stormwater closer to a stream, river, or wetland

Description

An outfall is the location where stormwater leaves WES's drainage system to enter a stream or other surface water body. An outfall is often a pipe.

An outfall located too far away from the water body allows stormwater to flow over unprotected ground. An outfall at the top of a hill can contribute to landslides on a steep slope. An unprotected outfall near a stream can lead to erosion of the steam bank.

An outfall extension is a pipe that conveys flows past an eroded area of the stream bank. A tightline is a long pipe on the surface of a hill to conveying flows down the hill.

Uses

An outfall extension or tightline is used to:

- Reduce erosion of a streambank
- Protect hillslope from erosion, gully-formation, and landslide
- Reduce sediment entering a stream or water body

Benefits

The benefits of using the outfall extension or tightline tool are:

- Often a simple fix
- May improve stream habitat
- Low ongoing maintenance cost

Costs

Design Unit

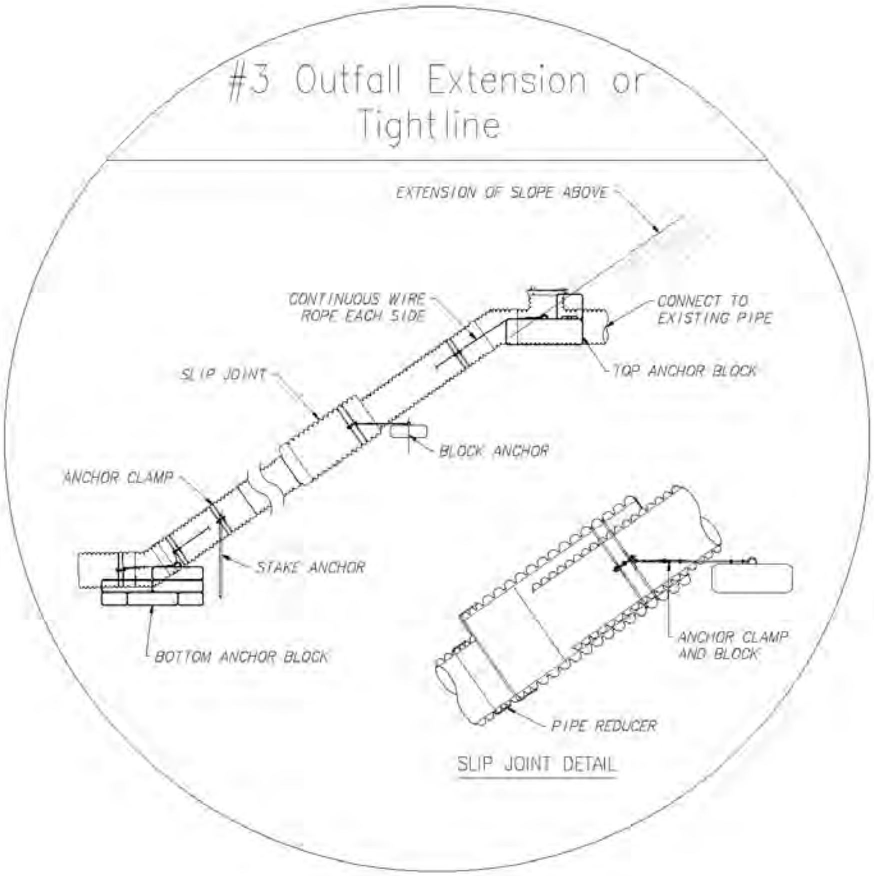
The unit of measurement for design of an outfall extension or tightline is **linear foot (LF) of pipe**.

Cost Assumptions Per Unit

The detailed cost assumption was developed for a hypothetical 18-in diameter 250-ft tightline. Price per unit is also given for a 12-in and a 24-in tightline.

Item	Qty	Unit	Price	Amount
Pipe	250	FT	$18	$4,500
Connect to Existing Outfall	1	EA	$1,190	$1,190
Upper Anchor Block	1	EA	$5,950	$5,950
Pipe Cleanout	1	EA	$2,975	$2,975
Slip Joint	1	EA	$2,380	$2,380
Pipe Anchors (cable, bands, stakes)	12	EA	$893	$10,716
Elbow	1	EA	$298	$298
Tee End	1	EA	$595	$595
Total				**$28,604**

Price per LF 12-in Pipe (rounded)	**$115**
Price per LF 18-in Pipe (rounded)	**$135**
Price per LF 24-in Pipe (rounded)	**$165**



Effort

Permitting – up to six months

Local permits from the Clackamas County WES will be required. If work below ordinary high water (OHW) is required, then permits from the Oregon Department of State Lands, the Army Corps of Engineers, and a Water Quality Certification from Oregon Department of Environmental Quality will be required. Endangered Species Act (ESA) Consultation will be necessary on some streams in Clackamas County. The design should minimize work below OHW so that programmatic permits and ESA Consultation can be utilized.

Implementation – medium effort

Construction typically requires work on hillsides and stream banks with difficult access. Heavy equipment may be required for some of the work.

Maintenance – low effort

Maintenance is similar to other storm sewer pipe or storm outfall, and may include jetting the pipe, re-securing anchors, and replenishing scour protection materials.

Otak

Tool Kit Fact Sheet

Floating Treatment Wetland

Floating vegetation islands that provide water quality treatment

Description

A Floating Treatment Wetland (FTW) is a fabricated small island with wetland plants.

The roots of the plants dangle in the water and trap particles. The plants and associated microorganisms can remove metals and nutrients from the water.

Floating Treatment Wetlands may be installed in stormwater ponds and in natural lakes and ponds.

A FTW is typically secured to the side of the pond or may be anchored to the bottom. Because the island floats, the plants are rarely inundated.

A FTW may cover 20% of the pond surface area.

Uses

A FTW may be used to:

- Enhance treatment in existing stormwater wetponds or basins
- Provide treatment in natural or dammed ponds that are impacted by urban runoff
- Enhance treatment in deeper pools of constructed treatment wetlands

Benefits

The benefits of a FTW include:

- Green solution
- Aesthetics
- Innovative
- May provide wetland habitat
- Few other natural technologies effectively remove metals

Costs

Design Unit

The unit of measurement for design of FTW is **square foot (SF)**.

Cost Assumptions Per Unit

The cost assumption was developed for a hypothetical 4,032 SF FTW constructed by County crews of foam boards and wood trim with 1-gal plants. A second option is given for a proprietary system installed by a contractor.

Item	Qty	Unit	Price	Amour
Materials	1	EA	$42,840	$42,84
Installation	320	HR	$119	$38,08
Total				**$80,92**

Price Per SF – County-installed (rounded) **$20**
Price per SF – Contractor-installed (rounded) **$150**

Effort

Permitting – up to six months

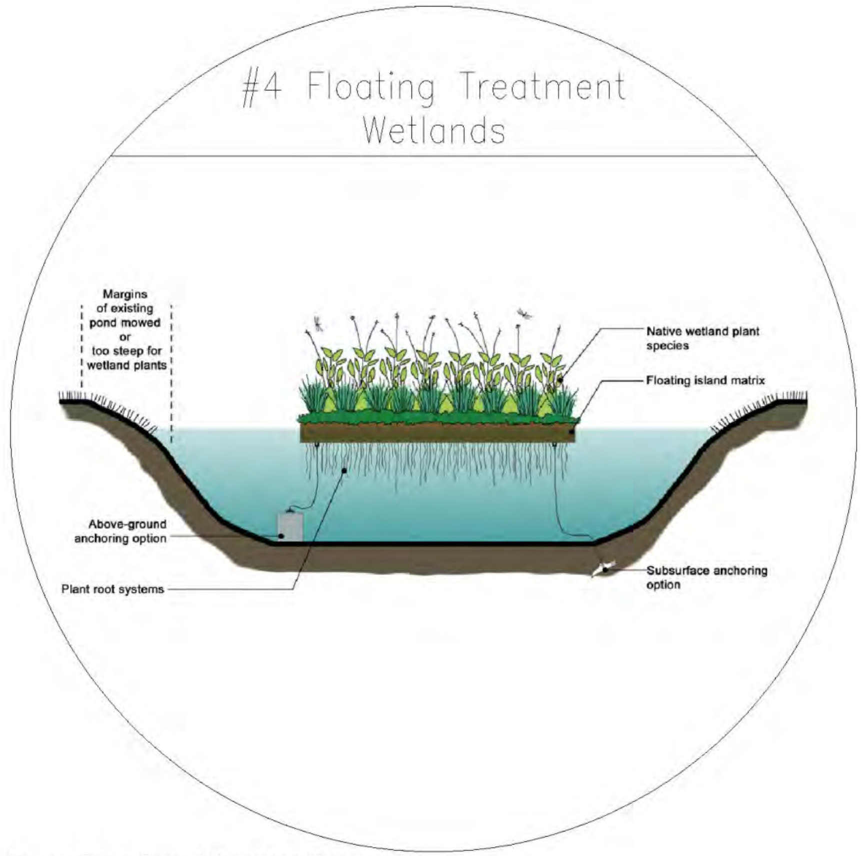
Permitting requires a permit from the Oregon Department of State Lands, the Army Corps of Engineers, and a Water Quality Certification from Oregon Department of Environmental Quality. Endangered Species Act Consultation may be required in some locations but likely can use a programmatic biological opinion. Local permits from Clackamas County WES are also required.

Implementation – medium effort

FTWs may be constructed by in-house resources using readily available materials. There are a few proprietary products on the market that can be purchased, but the cost may be significantly greater.

Maintenance – low effort

Expect one to two years of vegetation management to establish the plant community. Little maintenance after the first couple of years is required. Portions of the FTW may need to be replaced due to damage from wildlife, weather, or vandalism. Replacement interval will depend upon the quality of materials used in the initial construction.



Source: Texas Coastal Watershed Program
http://tcwp.tamu.edu/floating-wetland-islands/

Tool Kit Fact Sheet

Light Touch Grade Control

Create small obstructions in moderately sloped portions of streams

Description

Light Touch Grade Controls are small wooden structures installed in moderately sloped stream channels that experience moderate flows.

Light Touch Grade Controls create small pools upstream, slow down flow, reduce erosion, and protect the stream channel. They can be installed to create or protect a drop of up to six inches.

One type uses live fascines. Fascines are long bundles of live stakes such as willow or alder. The long bundles are placed perpendicular to span the entire channel.

Another type mimics a beaver dam and is made of wooden posts driven into the streambed. Posts hold cobbles and organic matter to form an upstream pool.

Uses

Light Touch Grade Control is often used in the following situations:

- Small streams with moderate flow
- Eroded stream bed and bank in moderately sloped streams
- Stream channels that are not subject to high flows

Benefits

The benefits of a Light Touch Grade Control include:

- Green solution
- Aesthetics
- May improve stream habitat
- Low ongoing maintenance cost
- May be installed by County crews

Costs

Design Unit

The unit of measurement for design of Light Touch Grade Control is **linear foot (LF) of grade controls**. The length of grade control is calculated as the width of the stream multiplied by the number of grade controls needed.

Cost Assumptions Per Unit

The cost assumption was developed for a 15-ft length of 7-ft to 8-ft wide stream channel.

Item	Qty	Unit	Price	Amount
2-in x 8-ft Round Stakes	10	EA	$36	$360
Coir Logs	25	LF	$10	$250
0.5-in Diameter Woody Debris	2	CY	$119	$238
Willow Stakes	6	EA	$5	$30
Total				**$878**

Price per LF (rounded) **$60**

Effort

Permitting – up to six months

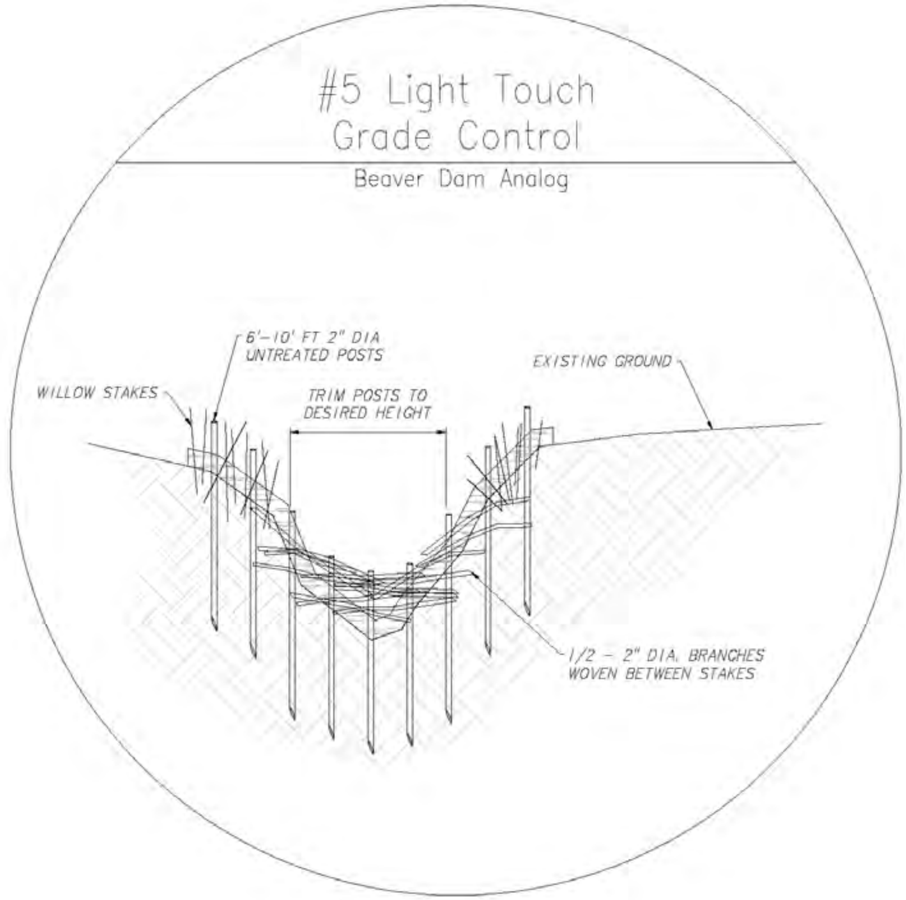
Installation of Light Touch Grade Control requires in-water work. However, when installed on their own the volume of material placed below ordinary high water of a stream may be small enough that the work is covered under a programmatic permit from both the Oregon Department of State Lands and the Army Corp of Engineers. Local permits from the Clackamas County WES are also required.

Implementation – low effort

The design needs to be "field directed" by someone that understands stream hydraulics. Construction of Light Touch Grade Control can be accomplished by County crews using hand tools. Multiple grade controls can be constructed in one day. Benefits begin immediately after installation. Minimize the hydraulic drop across each installation. Consider benefits and risks associated with increased water elevations under a range of flood flow scenarios.

Maintenance – low effort

Ongoing maintenance of Light Touch Grade Control can be done by County crews. Effort may include periodic inspection. Maintenance activities typically include replacement of material lost, or additional material to expand the size or length of the structures.



Tool Kit Fact Sheet

Flow Control Modification

Improve storage in stormwater ponds or flow into culverts by preventing blockages that cause water to overflow

Description

The inlets to and outlets from stormwater ponds and culverts can become blocked by debris and sediment. Blockages of the inlet can prevent water from entering the pond or culvert. Blockages of the outlet (also known as the flow control structure) can cause water to overflow using the surface overflow.

Ponds that are overflowing or bypassing stormwater can lead to downstream erosion and sedimentation and flooding downstream or upstream.

Flow control modifications to prevent these problems include debris gates or trash racks on inlets, debris gates or trash racks before the outlet structure, and improving the outlet by installing a flow control manhole.

Uses

Flow Control Modification is often used in the following situations:

- Retrofit an existing stormwater pond
- Culvert inlet susceptible to debris accumulation
- Pond with flow control structure prone to clogging
- Flow control structure with difficult maintenance access

Benefits

The benefits of a Flow Control Modification include:

- Upgrade performance of existing infrastructure
- Reduce future maintenance cost of pond
- Allow pond to fill and drain properly
- Prevent erosion, sedimentation, and flooding

Costs

Design Unit

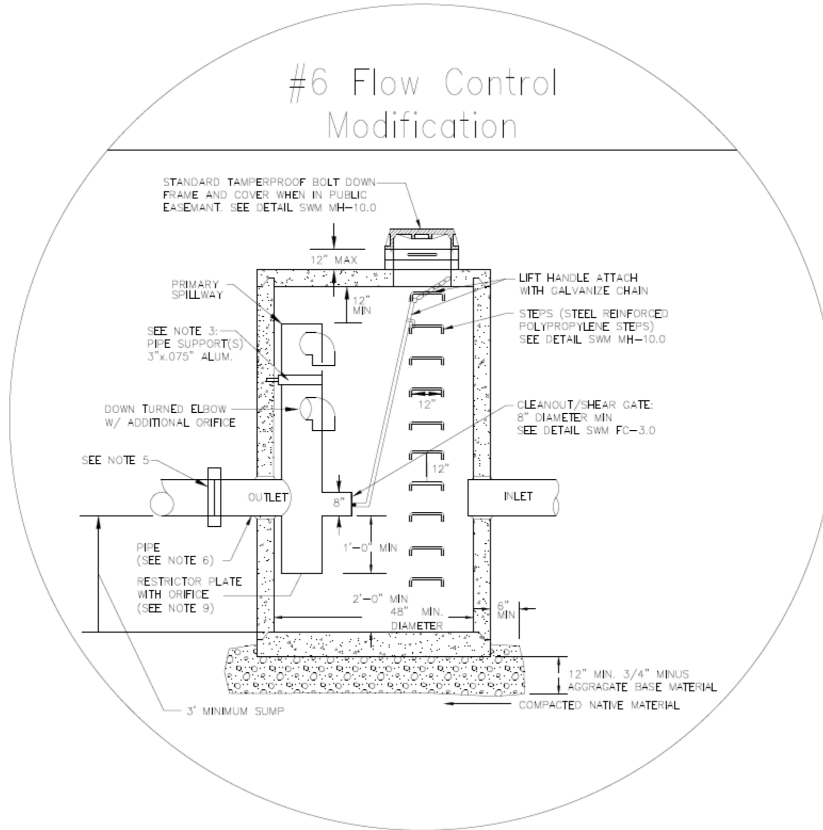
The unit of measurement for design of Flow Control Modification is **per pond**. There are several types of flow control modifications.

Cost Assumptions Per Unit

The cost assumption includes three different options: 1) a retrofitted large debris grate at a pipe or culvert entrance, 2) a 48-in diameter manhole with birdcage top used as an overflow, and 3) a 72-in diameter flow control manhole. The detailed estimate is shown for option 1.

Item	Qty	Unit	Price	Amount
Excavation	4	CY	$37	$148
Min Weight Bar Grate with Frame	282	SF	$84	$23,688
Concrete Sill (Reinforced)	4	CY	$119	$476
Total				**$24,312**

Price Per Debris Grate Special/Large (rounded)	**$24,500**
Price per Overflow Manhole	**$6,500**
Prince per Flow Control Manhole	**$14,500**



Source: Clackamas WES Standard Drawing SWM MH–6.0, December 2021

Effort

Permitting – up to six months

Permitting typically requires local permits from Clackamas County WES.

Implementation – medium effort

Flow control modification structures require engineering. Installation typically requires excavation and equipment to place a pre-cast concrete manhole. There can also be lead time for steel fabrication. Some concrete manholes or sills may be poured on location. Equipment and hand tools are used to place and secure grates.

Maintenance – low effort

Flow Control Modification on an existing pond typically reduces frequency of need to maintain it. Maintenance activities include removing debris from grates manually with hand tools or with Vactor equipment and using Vactor equipment to remove sediment from the manhole. Maintenance should be performed whenever debris or sediment buildup begins to affect performance of the structure.

Tool Kit Fact Sheet

CLACKAMAS WATER ENVIRONMENT SERVICES

Open Channel Excavation

Remove sediment from water quality facilities or to create floodplain storage

Description

Open Channel Excavation is dredging the accumulated sediment from the bottom of a water quality pond or swale or to create floodplain storage.

Water quality facilities can fill with sediment. Removing the sediment from a water quality facility can increase conveyance capacity of the facility and can restore its ability to remove sediment from runoff.

This tool can be used to increase the capacity of a water quality facility that is undersized for the drainage basin. This tool can also be used to excavate other surface areas, including ditches and natural channels.

Open Channel Excavation can reduce flooding and improve water quality.

Uses

Open Channel Excavation is often used in the following situations:

- Water quality pond or swale filled with sediment
- Water quality pond or swale with that is too small for the flows it handles

Benefits

The benefits of Open Channel Excavation include:

- Reduce flooding
- Improve water quality
- Reduce future ongoing maintenance

Costs

Design Unit

The unit of measurement for design of Open Channel Excavation is **cubic yards (CY) of excavation**.

Cost Assumptions Per Unit

The cost assumption was developed using ODOT's average bid prices for 2018 and applying an inflation factor. It is an average of unit prices awarded for excavation quantities ranging from 50 CY to 18,000 CY.

Item	Qty	Unit	Price	Amount
Excavation	1	CY	$37	$37
Total				**$37**

Price per CY **$37**

Effort

Permitting – up to six months

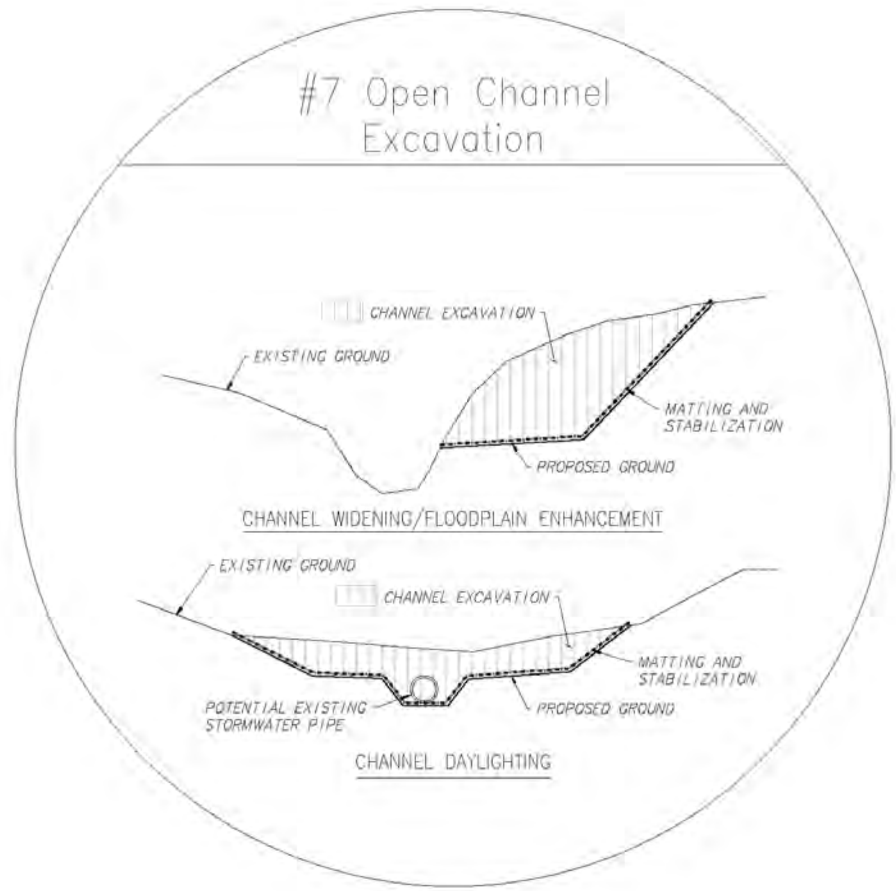
Permitting varies depending on the location of the facility. Stormwater facilities are often constructed away from stream banks and wetlands. Local permits from the Clackamas County WES are almost always required. Excavation in a stream or wetland requires permits from State and Federal agencies.

Implementation – high effort

Design of Open Channel Excavation requires engineering to determine the final depth and grade of the facility or floodplain. Open Channel Excavation requires heavy equipment for brushing, excavation, and grading. Site access can be on weak soil conditions and needs to be planned for and included in the permits. Flows to the facility must be diverted during the construction period. Work is best done during the summer when weather conditions are dry. Temporary erosion and sediment control are required during construction. Replanting may be required.

Maintenance – moderate effort

Once a water quality facility has been restored using Open Channel Excavation, maintenance needs are likely to decrease compared to its previous condition. Routine maintenance of water quality ponds includes trash removal, brushing and mowing, weed control, and removal of sediment from the forebay. An annual inspection is recommended to check for sediment accumulation in the facility, erosion at inlets and outlets, and evidence of piping through berms.



Otak

Tool Kit Fact Sheet

Outfall Scour Protection

Protect stream bank or stormwater facility slope from high flow discharges

Description

Where pipes or culverts discharge high-velocity flows to streams, rivers, or stormwater facilities, the bank can erode away (called “scour”).

Outfall Scour Protection uses rock pads, gabions, larger wood, or cement pads as a barrier to protect soils from high flows. Outfall Scour Protection also reduces the energy of flows by spreading them out and and creating roughness in the flow path.

A common Outfall Scour Protection technique is placement of riprap, loose angular stones of various sizes, around and above the outfall pipe and extending to the opposite side of the bank. Riprap is typically placed over geotextile, which provides additional protection for the soil.

Uses

Outfall Scour Protection is often used in the following situations:

- Stream channels eroding from high velocity discharges or flows
- Erosion at downstream end of culvert
- Prevention of erosion problems at any location where a storm pipe or culvert discharges to stream

Benefits

The benefits of Outfall Scour Protection include:

- Proactive solution to prevent problems
- Effective retrofit to halt existing problems

Costs

Design Unit

The unit of measurement for design of Outfall Scour Protection is **diameter of pipe**.

Cost Assumptions Per Unit

The detailed cost assumption was developed for a hypothetical 24-in diameter 8-ft outfall pipe buried 2-ft deep. Prices per unit are given for various ranges of pipe sizes: less than 30-in diameter, 30-in to 48-in diameter, and greater than 48-in diameter.

Item	Qty	Unit	Price	Amount
Riprap (ODOT Class 100)	9.3	CY	$150	$1391
Riprap Geotextile	19	SY	$8	$155
Excavation	9.3	CY	$37	$343
Total				**$1,889**

Price per Pipe: Less than 30-in Dia. (rounded)	**$1,900**
Price per Pipe: 30-in to 48-in Dia.	**$5,300**
Price per Pipe: Greater than 48-in Dia.	**$11,200**

Effort

Permitting – up to six months

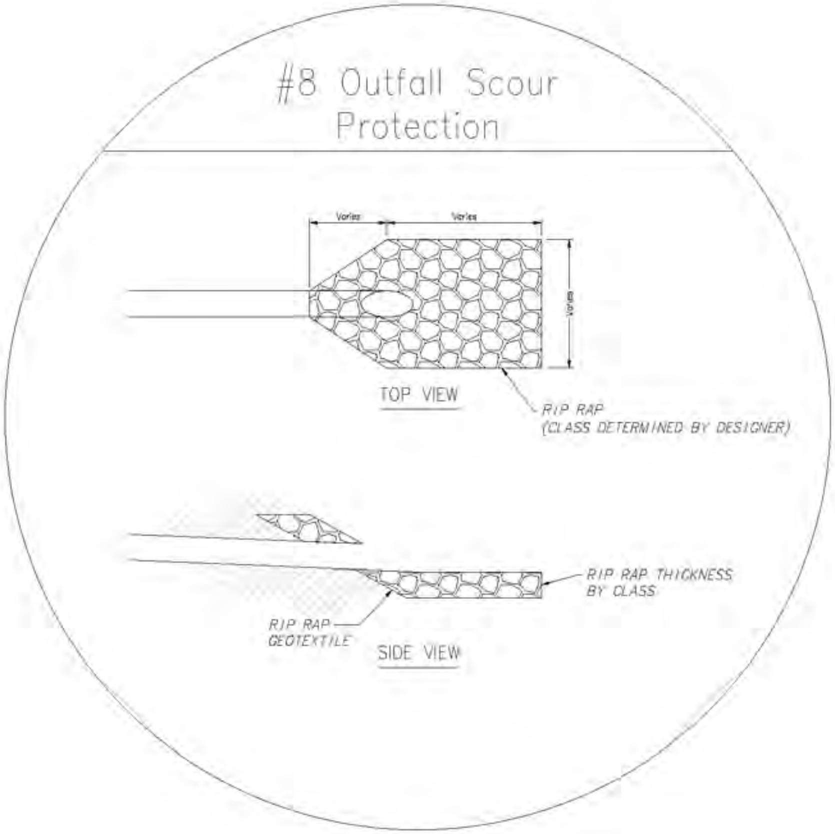
Some Outfall protection can be installed just above ordinary high water (OWH) which only requires limited permitting from Clackamas County WES. Work below OHW requires a permit from the Oregon Department of State Lands (DSL), the Army Corps of Engineers (ACOE), and a Water Quality Certification from Oregon Department of Environmental Quality. Endangered Species Act Consultation will be required on some streams in Clackamas County but can often use a programmatic biological opinion. Some installations below OHW may be small enough that the work is covered under a programmatic permit from both the Oregon DSL and ACOE.

Implementation – medium effort

Outfall Scour Protection requires varying engineering design effort. Construction below OHW usually needs to occur during the established in-water work period. Construction equipment is needed for excavation and placement of riprap.

Maintenance – low effort

Maintenance of Outfall Scour Protection is low. An annual inspection is recommended to look for signs of exposed geotextile, soil erosion, and loss of riprap material. Trash and sediment should be removed as needed.



Tool Kit Fact Sheet

Real Time Control

Optimizing stormwater pond levels using real-time data forecasts and adjustable orifice

Description

Real Time Control (RTC) uses data to predict the optimal water level in a stormwater pond. If a rainstorm is expected and the pond is full, the operator can release water in advance of the storm. If dry weather is expected, the operator can maintain the water level in the pond for the optimal amount of time to remove pollutants and protect receiving waters.

Equipment located at the pond tracks water levels and controls valves at the outlet.

Software at an operations center compiles various data and recommends when to open and close the valves. An operator opens and closes valves remotely.

Uses

RTC may be used in the following situations:

- Existing stormwater ponds contributing to downstream flooding, erosion, or sedimentation
- Retrofit detention ponds to add water quality functions
- New stormwater ponds

Benefits

The benefits of RTC include:

- Reduce downstream flooding, erosion, and/or sedimentation
- Can be used in new or retrofit situations
- Optimize performance without increasing pond size

Costs

Design Unit

The unit of measurement for design of RTC is **each pond where RTC is installed**.

Cost Assumptions Per Unit

The cost assumption was developed for a hypothetical large existing stormwater pond.

Item	Qty	Unit	Price	Amount
Installation and Software	1	EA	$95,200	$95,200
Total				**$95,200**

Price per RTC	**$95,200**

Effort

Permitting – up to six months

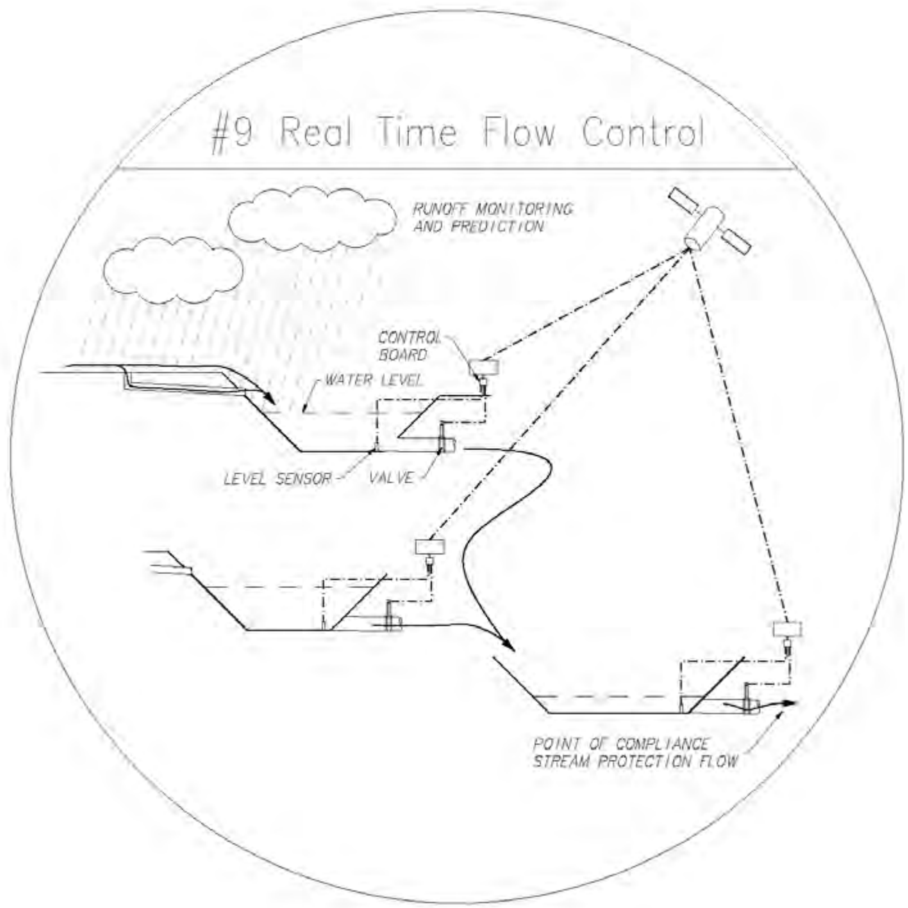
Permitting typically requires local permits from Clackamas County WES. A mechanical or utility permit for electrical service will also be required.

Implementation – medium effort

Design of RTC requires both engineering and technical expertise in remote monitoring equipment, telemetry, remote control equipment, and software configuration. Construction requires moderate effort to install electronic sensing equipment and electronic equipment to control mechanical valves in existing or new ponds. Electrical service must be brought to the site.

Maintenance – moderate effort

RTC implementation requires ongoing monitoring of software at an operations center, which is a level of routine interaction that exceeds most stormwater infrastructure that functions without constant human operation. Maintenance activities could include troubleshooting data transfer issues, electronics troubleshooting, valve operations or maintenance, and protecting equipment against vandalism. Maintenance also could include software upgrades and software troubleshooting.



Tool Kit Fact Sheet

Retaining Wall

Stabilizing steep slopes using walls

Description

Retaining Walls are used to stabilize bank slopes in narrow stream corridors. They can be installed to hold back nearly vertical slopes. Different wall types are used depending on wall height and slope stability.

Walls up to 10-ft may be precast large modular cement blocks, or gabions, which are wire baskets filled with rocks.

Walls up to 15-feet may be held by I-beams driven into the ground (soldier piles), or up to 25-feet with the addition of tiebacks to undisturbed soils.

Walls up to 25-feet may be mechanically stabilized earth (MSE) with prefabricated modular block facing.

Uses

Retaining Walls are often used in the following situations:

- Urban streams with development in the floodplain
- Stabilize steep slopes above streams
- Pair with grade control to stabilize streambanks
- Create additional storage volume in an existing stormwater pond

Benefits

The benefits of Retaining Walls include:

- Minimal space needed for wall
- Solution works for urban streams
- Many design and construction options
- Low ongoing maintenance cost

Costs

Design Unit

The unit of measurement for design of Retaining Walls is **square foot (SF) of wall**. Wall costs vary widely by type.

Cost Assumptions Per Unit

The detailed cost assumption was developed for a hypothetical 8-ft tall and 50-ft long modular block gravity wall. Costs are also given for cantilever soldier pile wall and an MSE wall with prefabricated modular blocks.

Item	Quantity	Unit	Price	Amount
Excavation	276	CY	$37	$10,209
General Backfill (Re-use Native)	148	CY	$30	$4,444
Granular Backfill	33	CY	$90	$3,000
Modular Block	93	CY	$120	$11,111
Mitigation	425	SF	$5	$2,125
Total				**$28,765**

Price per SF: Modular Block Gravity Wall (rounded)	**$75**
Price per SF: MSE with Prefab Modular Block (rounded)	**$75**
Price per SF: Cantilever Soldier Pile Wall (rounded)	**$210**

Effort

Permitting – up to one year

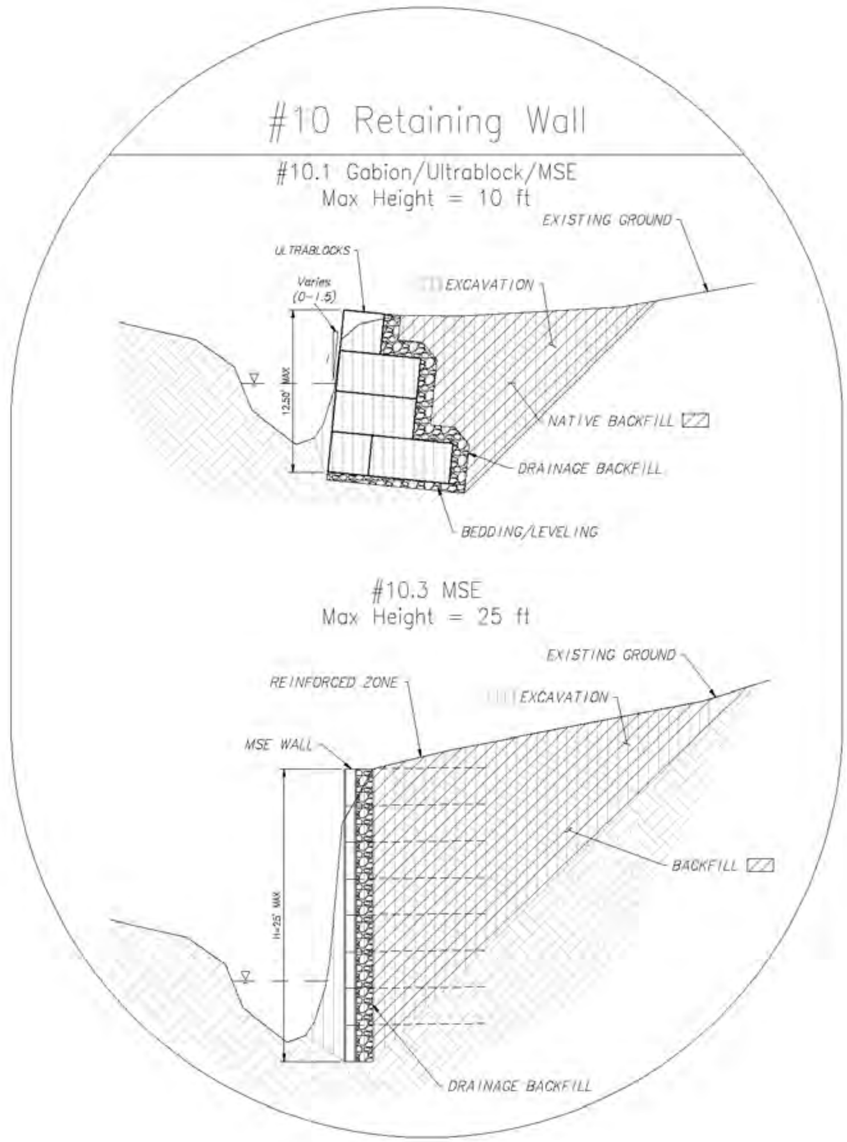
Retaining Wall requires a building permit. Within a stormwater facility Retaining Wall may require local permits from Clackamas County WES. Below the ordinary high water (OHW), Retaining Wall requires a permit from the Oregon Department of State Lands, the Army Corps of Engineers, and a Water Quality Certification from Oregon Department of Environmental Quality. Endangered Species Act Consultation will be required on some streams in Clackamas County but can often utilize a programmatic biological opinion. Construction below OHW should expect to require mitigation.

Implementation – high effort

Design of Retaining Wall requires geotechnical and structural engineering. Construction requires heavy equipment. Work below OHW needs to occur during the established in-water work period. Walls in streams are prone to scour.

Maintenance – low effort

Ongoing maintenance of Retaining Wall is low. An annual inspection is recommended to check for deformation, leaning, and erosion at the base.



Otak

Tool Kit Fact Sheet

CLACKAMAS WATER ENVIRONMENT SERVICES

Rock Buttress

Stabilize moderately steep slopes of streambanks

Description

Rock Buttress is an engineered support made of rocks used to stabilize an eroding or sliding streambank. It provides support to moderately steep slopes between 3H:1V (33%) and 1.5H:1V (67%).

Rock Buttress is formed by excavating benches, or terraces, in an eroding or sliding slope. Large rocks are placed to form a supportive buttress against the slope.

Typically, Rock Buttresses may be used in place of the Retaining Wall tool when the stream corridor is wider and/or the bank is not tall. Rock Buttress may be used on a steeper bank than the Bioengineered Slope tool.

Uses

Rock Buttress is often used in the following situations:

- Landslide into a stream
- Eroded stream bank on an outside turn
- Moderately steep slope

Benefits

The benefits of Rock Buttress include:

- Low initial cost
- Low ongoing maintenance cost

Costs

Design Unit

The unit of measurement for design of Rock Buttress is **square foot (SF) of buttress**. Square footage is calculated by multiplying the length and height of the buttress.

Cost Assumptions Per Unit

The cost assumption was developed for a hypothetical 100-ft long and 8-ft tall Rock Buttress.

Item	Qty	Unit	Price	Amount
Excavation	248	CY	$37	$9,181
Stone Embankment	148	CY	$56	$8,296
Embankment Geotextile	200	SY	$4.50	$900
Total				**$18,378**

Price Per SF **$23**

Effort

Permitting – up to two years

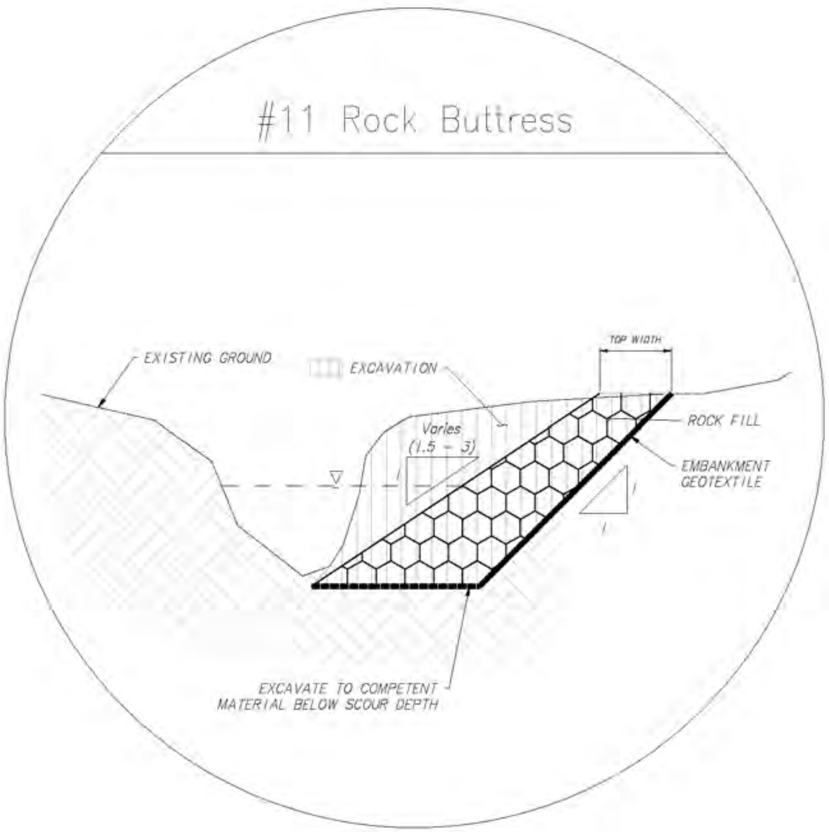
If extending below ordinary high water, permits from the Oregon Department of State Lands and the Army Corps of Engineers are required, as well as a Water Quality Certification from Oregon Department of Environmental Quality. Endangered Species Act Consultation will be required on some streams in Clackamas County but can often utilize a programmatic biological opinion if bioengineering is incorporated with the rock buttress. Local permits from Clackamas County WES are also required.

Implementation – high effort

Design of a Rock Buttress requires geotechnical engineering. Construction or implementation of this tool requires work during the established in-water work period, when fish are less likely to be impacted by grading and equipment in the channel. Work area isolation measures are necessary to manage flows and sediment to protect water quality during construction. Heavy equipment is often necessary. Sites are usually in areas with difficult access. Construction access and staging should be planned and included in the permits. Pair this tool with other bioengineering techniques to mitigate for impacts.

Maintenance – low effort

Routine ongoing maintenance of Rock Buttress is low. An annual inspection is recommended to check for exposed geotextile, movement of rock materials, erosion, and evidence of sliding.



Tool Kit Fact Sheet

Pre-settling Basin

Small basin, vault, or manhole that allows some sediment to settle out of runoff

Description

Pre-settling Basin is a small basin, chamber, or manhole preceding either a stormwater facility or an outfall to a stream or river. It allows larger sediment particles and trash to settle out of piped runoff before it enters a facility or stream.

Pre-settling Basin improves the treatment performance of a water quality facility, and it extends the length of time before the main facility must be excavated to remove sediment (see the Open Channel Excavation tool).

It improves water quality at an outfall.

Pre-settling Basin is easy to access and is generally easy to clean using hand tools and/or Vactor equipment.

Uses

Pre-settling basins are often used in the following situations:

- Where piped stormwater enters a water quality facility or stream
- New water quality facilities
- Retrofit existing water quality facilities for longer life

Benefits

The benefits of a Pre-settling Basin include:

- Increase ease of facility maintenance
- Improve water quality
- Low ongoing maintenance cost

Costs

Design Unit

The unit of measurement for design of Pre-settling Basin is **each Pre-settling Basin**. Cost varies considerably based on size of the structure to serve the contributing area.

Cost Assumptions Per Unit

The detailed cost assumption was developed for a simple screened vault serving a medium-sized drainage basin of 5 to 15 acres and designed to manage 20 cubic feet/ 1.0 CFS flow up to the 25-year flow. Prices per basin are also given for a 60-in diameter water quality manhole serving a small basin and a complex screened vault serving a basin 15-ac or greater.

Item	Qty	Unit	Price	Amount
Vault (8-ft x 18-ft)	1	EA	$18,445	$18,445
CDS Screen	1	EA	$7,140	$7,140
Installation (@ 50%)	1	EA	$12,793	$12,793
Total				**$38,378**

Small Drainage Basin (Less than 5 Acres) (rounded)	**$11,200**
Medium Drainage Basin (5-15 Acres) (rounded)	**$38,500**
Large Drainage Basin (15+ Acres) (rounded)	**$70,500**

Effort

Permitting – up to six months

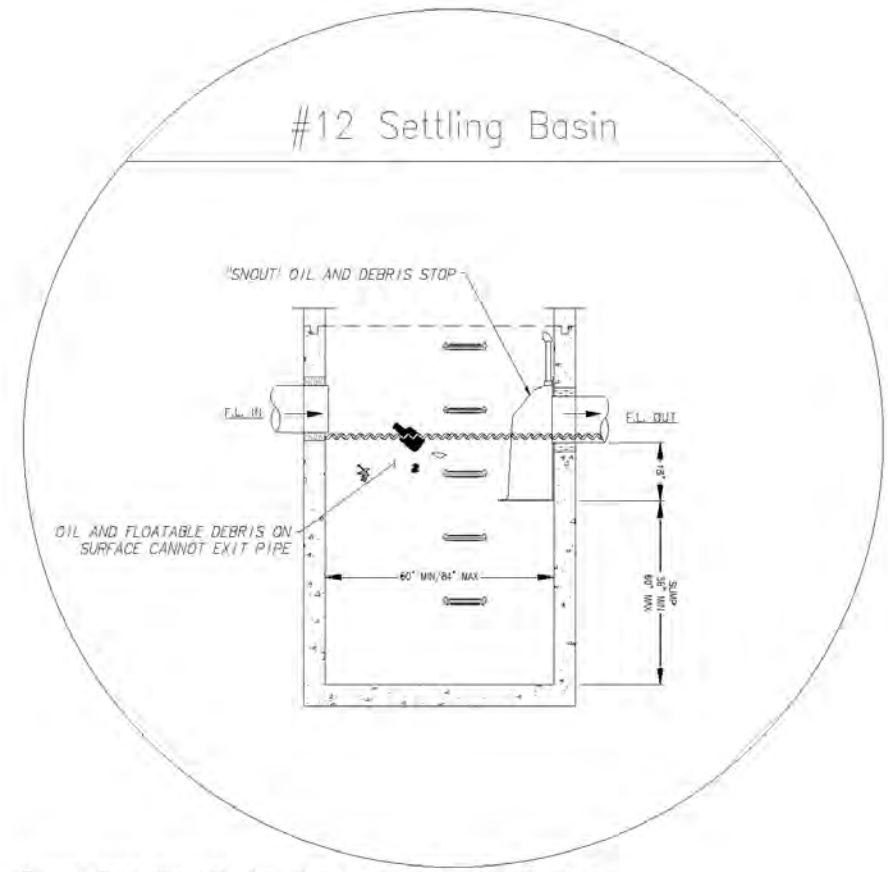
Permitting Pre-Settling Basin before an existing water quality facility typically requires local permits from Clackamas County WES

Implementation – medium effort

Pre-Settling Basin requires engineering design. Construction requires heavy equipment for excavation and placing the manhole or vault. These devices should be located for easy maintenance access, so construction access should also be easy. Plant establishment may be required for non-structural Pre-settling Basin.

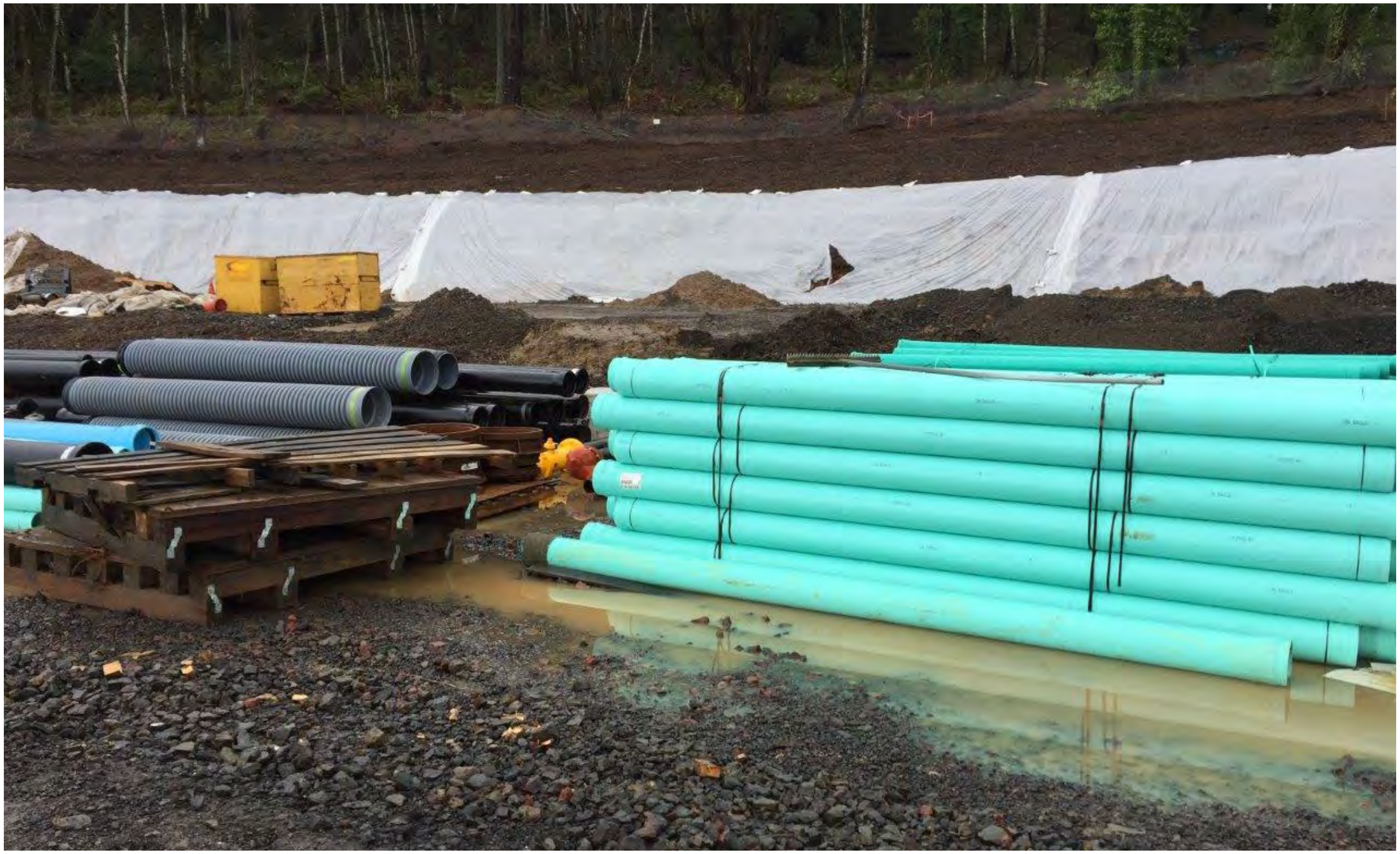
Maintenance – low effort

Ongoing maintenance of this tool is low and reduces frequency of major maintenance needed for the primary water quality elements of the facility. The need for confined space entry should be minimized but planned for with the design. Typical maintenance activities include trash removal, sediment removal using Vactor equipment, and vegetation control in vegetated basins.



Source: Clean Water Services Design and Construction Standards
Adapted from Standard Drawing 250

Tool Kit Fact Sheet



CLACKAMAS WATER ENVIRONMENT SERVICES

Storm Sewer Pipe

Pipe for conveying stormwater underground

Description

Storm Sewer Pipe is laid underground and is used to convey runoff as part of the drainage system or within a stormwater facility.

The size of pipe depends on the flow of stormwater expected. Using the correct size and placement of pipe can reduce local flooding and prevent degradation of nearby infrastructure (e.g. roads).

Uses

Storm Sewer Pipe is often used in the following situations:

- Convert open drainages to underground drainage
- Replace aging pipes
- Replace pipes that are too small

Benefits

The benefits of Storm Sewer Pipe include:

- Reduce flooding
- Protect infrastructure
- Create space for other development

Costs

Design Unit

The unit of measurement for design of Storm Sewer Pipe is **linear foot (LF) of pipe**. Storm Sewer Pipe is available in a variety of diameters, and installation costs depend on buried depth.

Cost Assumptions Per Unit

The detailed cost assumption was developed for a hypothetical 600-ft 24-in diameter pipe buried to 6 feet installed with manholes and inlets.

Item	Qty	Unit	Price	Amount
24 inch pipe	600	FT	$180	$108,000
Manhole	3	EA	$5,200	$15,600
Inlet	6	EA	$2,700	$16,200
Total				**$139,800**

The total price for the detailed cost estimate averages $235 per linear foot for a complete and installed storm system. The per linear foot costs below include pipe, manholes, and inlets.

Per LF of 18" Pipe	**$195**
Per LF of 24" Pipe	**$235**
Per LF of 36" Pipe	**$300**

Effort

Permitting – up to six months

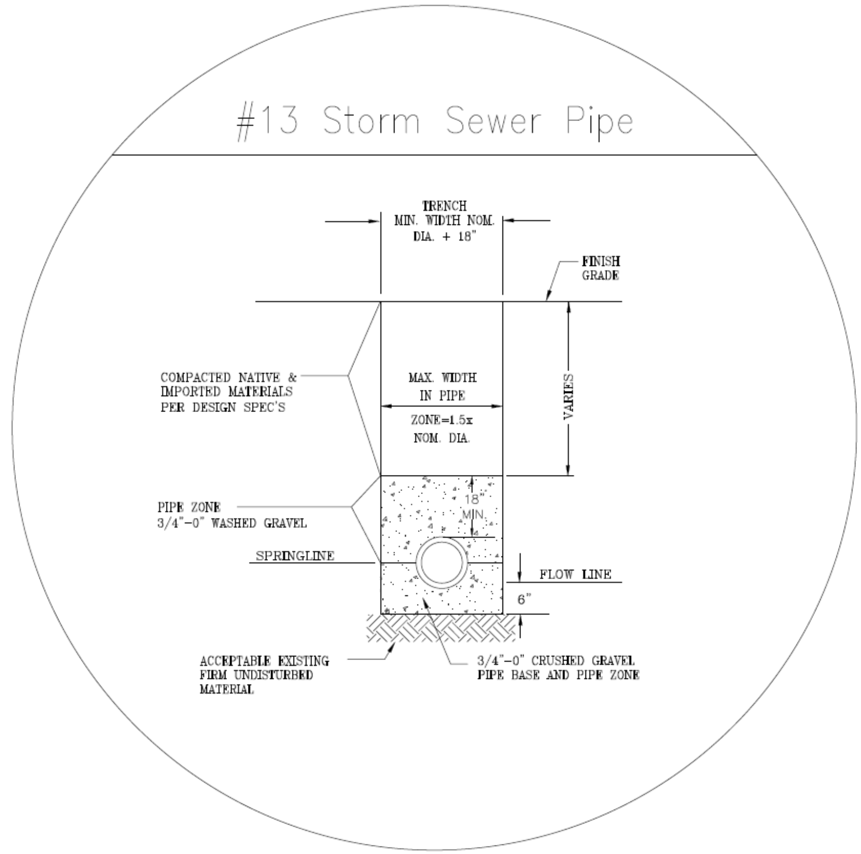
Permitting of Storm Sewer Pipe depends on location of the pipe. A pipe installation along an urban roadway or connecting to existing stormwater facilities generally will require local permits from Clackamas County WES.

Implementation – medium effort

Design of Storm Sewer Pipe requires engineering to calculate the optimal pipe size, depth, and placement. Construction requires equipment for trenching and placing pipe underground. Shoring of trenches may be required. In urban areas, construction may require traffic management when Storm Sewer Pipe is placed under or near a roadway. Restoration of surface material is required.

Maintenance – low effort

Maintenance of Storm Sewer Pipe is low. Television camera inspection and pipe jetting may be performed at a scheduled frequency or when a blockage is suspected.



Source: Clackamas WES Standard Drawing SWM ST-2.0, December 2021

Otak

Tool Kit Fact Sheet

CLACKAMAS WATER ENVIRONMENT SERVICES

Streambed Fill

Adding lost material to streambeds in order to aggrade the channel to reconnect with floodplain or reduce bank height

Description

Streambed Fill is rocks or other materials placed in the stream channel and on the banks. Fill may restore an incised channel, prevent further erosion, and protect streambanks from slope failure due bank height and/or undercutting the toe.

Streambank Fill is often used with a Grade Control tool (shown in the photo), which helps the fill stay in place.

Streambed Fill may be used to restore the elevation of a channel closer to its natural condition.

Streambed Fill may improve habitat for aquatic species.

Uses

Streambed Fill is often used in the following situations:

- Incised stream (formation of steep-sided channel)
- Streambank instability
- In combination with Grade Control to hold material in place

Benefits

The benefits of Streambed Fill include:

- Green solution
- Aesthetics
- May improve stream habitat
- Low ongoing maintenance cost

Costs

Design Unit

The unit of measurement for design of Streambed Fill is **volume of fill in cubic yards (CY)**.

Cost Assumptions Per Unit

The cost assumption was developed by averaging the ODOT bid award for three Streambed Fill projects from 2016 and applying an inflation factor.

Item	Qty	Unit	Price	Amount
Fill	119	CY	$99	$11,781
Total				**$11,781**

Price Per CY (rounded) $100

Effort

Permitting – up to nine months

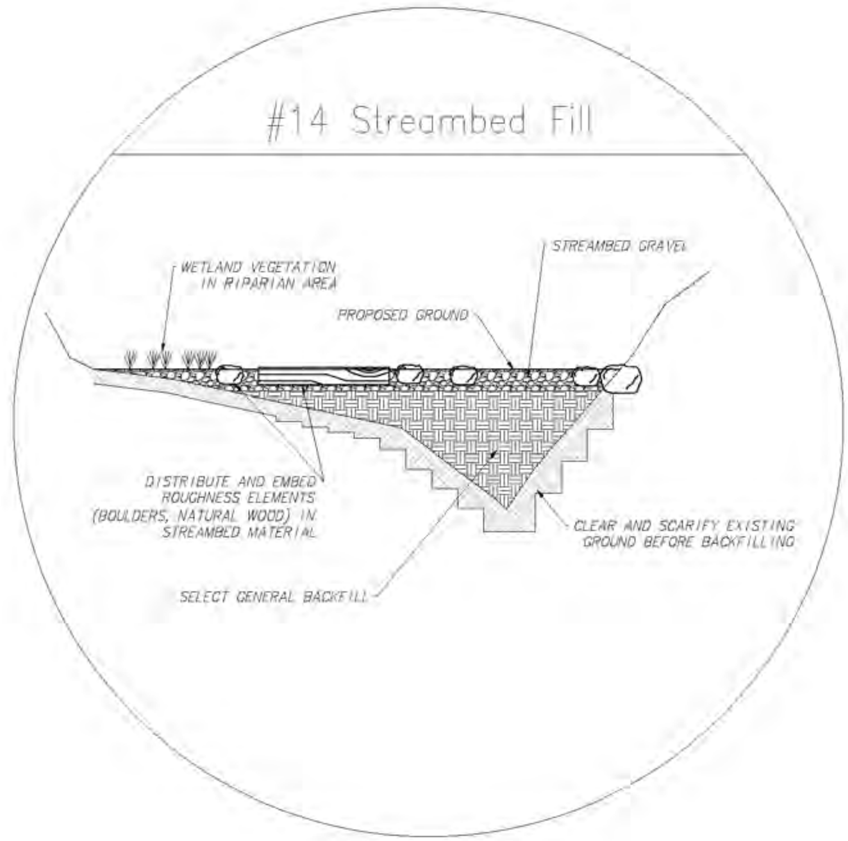
Streambed Fill requires permits from the Oregon Department of State Lands and the Army Corps of Engineer as well as a Water Quality Certification from Oregon Department of Environmental Quality. Endangered Species Act Consultation will be required on some streams in Clackamas County but can often utilize a programmatic biological opinion. Local permits from Clackamas County WES are also required.

Implementation – high effort

Construction or implementation of this tool requires work during the established in-water work period, when fish are less likely to be impacted by grading and equipment in the channel. Work area isolation measures are necessary to manage flows and sediment to protect water quality during construction. Heavy equipment is often necessary. Sites are usually in areas with difficult access. Construction access and staging should be planned and included in the permits. The fill materials and construction must be engineered so the stream flow stays at the surface.

Maintenance – low effort

Maintenance of Streambed Fill is expected to be low. Inspection following large flow events and annual inspection is recommended to check for stability of the streambed. Materials transported out of the streambed as the new channel adjusts may need to be replenished. Success of this tool may be dependent on the successful establishment and maintenance of grade control structures and streambank restoration implemented in combination.



Tool Kit Fact Sheet

CLACKAMAS WATER ENVIRONMENT SERVICES

Structural Grade Control

Slow or eliminate channel lowering through placement of an engineered hard point in a stream channel. May also be used to raise the elevation of an already degraded stream bed.

Description

Structural Grade Control is the use of large rocks, large logs, or other obstructions to prevent or slow channel lowering. Obstacles should be keyed into the stream banks, so flow does not go around them. They should be engineered to withstand high flow conditions and also be able to pass fish.

Structural Grade Controls should be spaced to maintain a water surface drop of 6 to 12 inches.

Uses

Structural Grade Control is often used in the following situations:

- Large channels experiencing erosion
- Erosion in channels that experience flows that are too high for the Light Touch Grade Control tool
- Stabilize an area of a stream or river that has an abrupt change in grade

Benefits

The benefits of Structural Grade Control include:

- Green solution
- Aesthetics
- Low ongoing maintenance cost

Costs

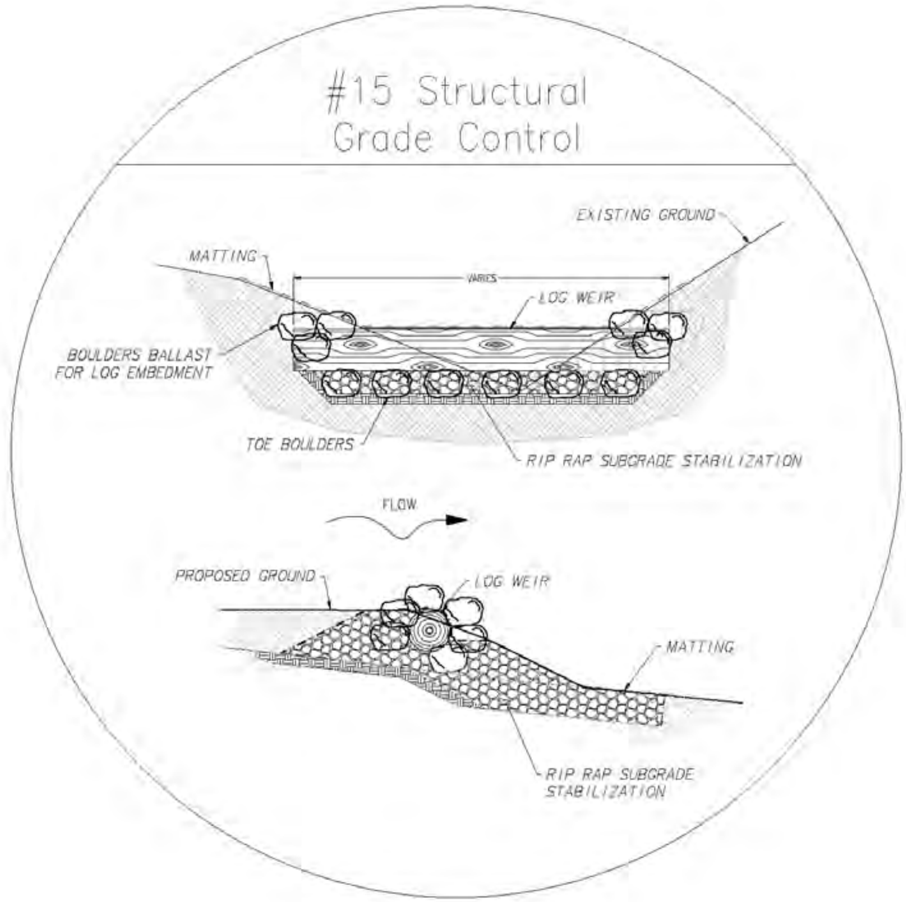
Design Unit

The unit of measurement for design of Structural Grade Control is **linear foot (LF)** of grade controls, calculated my multiplying channel width by number of controls.

Cost Assumptions Per Unit

The cost assumption was developed for a hypothetical 24-ft wide grade control.

Item	Qty	Unit	Price	Amount
Excavation	24	CY	$37	$888
Riprap	30	CY	$110	$3,300
General Fill (Re-use Native)	8	CY	$50	$400
Anchor Boulders	5	EA	$200	$1,000
Coir Matting (Woven)	67	SY	$8	$536
Native Seeding	67	SY	$2.50	$168
Willow Stakes	133	EA	$5	$665
24-in Diameter x 24-ft Log	1	EA	$2,300	$2,300
Total				**$9,257**
Price Per Linear Foot (rounded)				**$385**



Effort

Permitting – up to nine months

Grade controls require permits from the Oregon Department of State Lands and the Army Corps of Engineers as well as a Water Quality Certification from Oregon Department of Environmental Quality. Endangered Species Act Consultation will be required on some streams in Clackamas County but can often utilize a programmatic biological opinion. Local permits from Clackamas County WES are also required.

Implementation – high effort

Construction or implementation of this tool requires work during the established in-water work period, when fish are less likely to be impacted by grading and equipment in the channel. Work area isolation measures are necessary to manage flows and sediment to protect water quality during construction. Heavy equipment is often necessary. Sites are usually in areas with difficult access. Construction access and staging should be planned and included in the permits.

Maintenance – low effort

Ongoing routine maintenance of Structural Grade Control is expected to be low. Annual inspection and inspection following large flow events is recommended to check for stability of the structure. Materials transported out of the structure may need to be replenished periodically.

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Tool Kit Fact Sheet

CLACKAMAS WATER ENVIRONMENT SERVICES

Underground Storage

Pipes, chambers or vaults to temporarily store stormwater during storms

Description

Underground Storage is created by installing large underground pipes, chambers, or vaults to temporarily store stormwater runoff.

Temporarily storing runoff slows down the flow of water through pipes and streams, and can help reduce downstream flooding, erosion, and sedimentation.

Underground Storage may be used under parking lots, parking structures, roads, and in other highly developed locations where there is not much room for a stormwater pond.

Uses

Underground Storage is often used in the following situations:

- New urban development with limited space for Aboveground Storage
- Add detention in an existing system to address downstream flooding, erosion, or sedimentation

Benefits

The benefits of Underground Storage include:

- Saves space
- Can be used to retrofit urban areas developed prior to use of adequate stormwater controls

Costs

Design Unit

The unit of measurement for design of Underground Storage is **cubic foot (CF)** of storage volume.

Cost Assumptions Per Unit

The cost assumption was developed for the hypothetical storage of 200,000 CF of runoff in a proprietary system manufactured by Contech.

Item	Qty	Unit	Price	Amount
Contech Chambers (40 rows x 65 cha	100,000	CF	$5.00	$500,000
Excavaction	13,061	CY	$37	$483,269
Drainage rock	6,760	CY	$30	$202,800
Installation 25%	1	LS	$175,700	$175,700
Total				**$1,361,769**

Price Per CF (rounded) **$13**

Effort

Permitting – up to six months

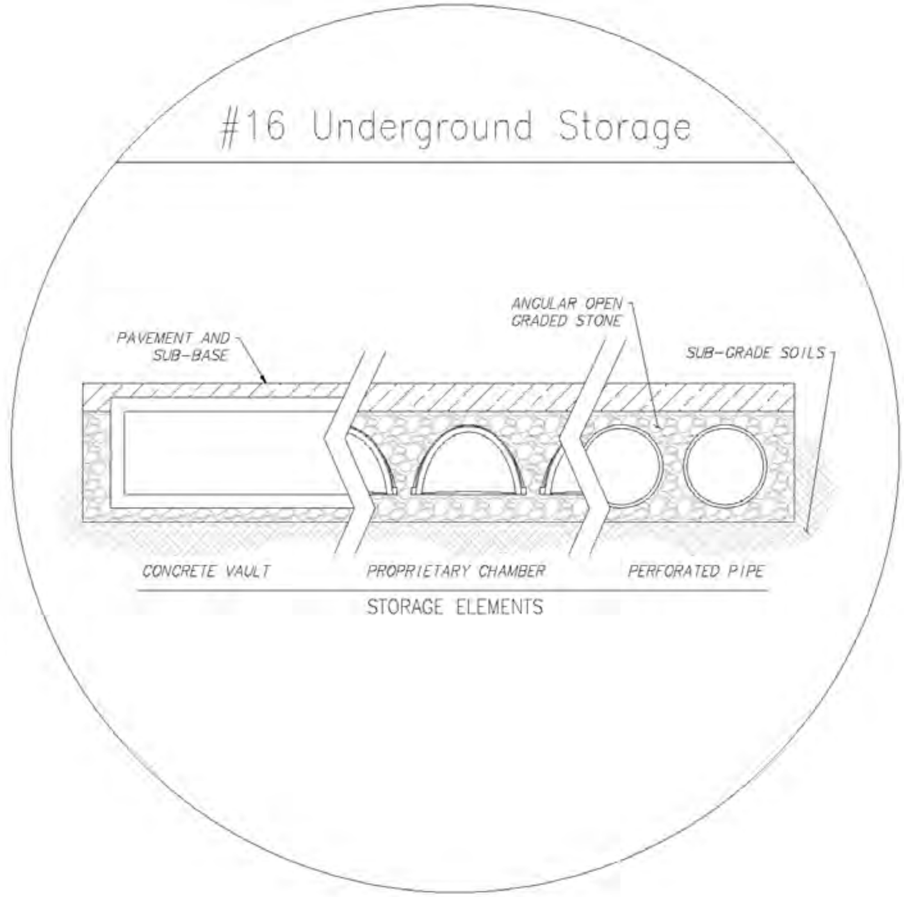
Permitting typically requires local permits from the Clackamas County WES. In some cases, a building permit may be required.

Implementation – medium effort

Construction or implementation of this tool typically requires work in a developed urban area, which may result in scheduling issues and the need for traffic control. Construction requires considerable excavation. Heavy equipment is needed for excavating, filling, and for placing some of the prefabricated structural components in the ground. Restoration of the surface (roadway, parking lot, plaza, lawn, etc.) is required.

Maintenance – medium effort

Maintenance of Underground Storage requires routine inspection to monitor sediment build-up in the structure. In some systems, sediment may be removed directly from the structure using Vactor equipment. In other systems, sediment may be pushed into an access structure or manhole using water-jetting equipment and then removed using Vactor equipment. The control structure, which manages how quickly stored runoff is released, must also be monitored for build-up of sediment and floatables that may impede the discharge of water.



Tool Kit Fact Sheet

CLACKAMAS WATER ENVIRONMENT SERVICES

Vegetation Restoration

Replant where plants have been removed from streambanks, floodplains, riparian areas or stormwater facilities

Description

Vegetation Restoration is replanting after construction activities have removed vegetation from stream banks or stormwater facilities.

Vegetation helps stabilize soils and prevents erosion of the stream banks and side slopes of stormwater facilities. Vegetation protects facilities and stream channels from sedimentation.

New plantings are generally stabilized by matting or geotextile.

Plants may be grasses, groundcover, shrubs, or trees.

New plantings typically require temporary irrigation for one or two years.

Uses

Vegetation Restoration is often used in the following situations:

- Streambanks denuded by excavation for grade control, retaining walls, or other tools
- Re-graded side slopes or channels of stormwater facilities

Benefits

The benefits of Vegetation Restoration include:

- Green solution
- Aesthetics
- Prevent erosion of streambanks and stormwater facilities

Costs

Design Unit

The unit of measurement for design of Vegetation Restoration is **square foot (SF) of area** to be revegetated.

Cost Assumptions Per Unit

The detailed cost assumption was developed for restoration of vegetation in a water quality facility with 11,000 SF bottom area and 9,000 SF side slope area. A price per unit is also given for restoration of a greenway.

Item	Qty	Unit	Price	Amount
Geotexile	2222	SY	$6	$13,332
Bark Mulch (3-in depth)	185	CY	$50	$9,250
Small Shrub (1-gal)	800	EA	$22	$17,600
Large Shrub/Small Tree (2-gal)	600	EA	$27	$16,200
Dec. Trees (1" Cal.)	90	EA	$305	$27,450
Ground Cover (SP #4)	23,000	EA	$2	$46,000
Seeding	0.46	AC	$7,500	$3,444
Temporary Irrigation	20,000	SF	$0.50	$10,000
Total				**$143,276**

Price Per SF Water Quality Facility Rest	**$7**
Price Per SF Greenway Restoration (rou	**$9**

Effort

Permitting – minimal to none

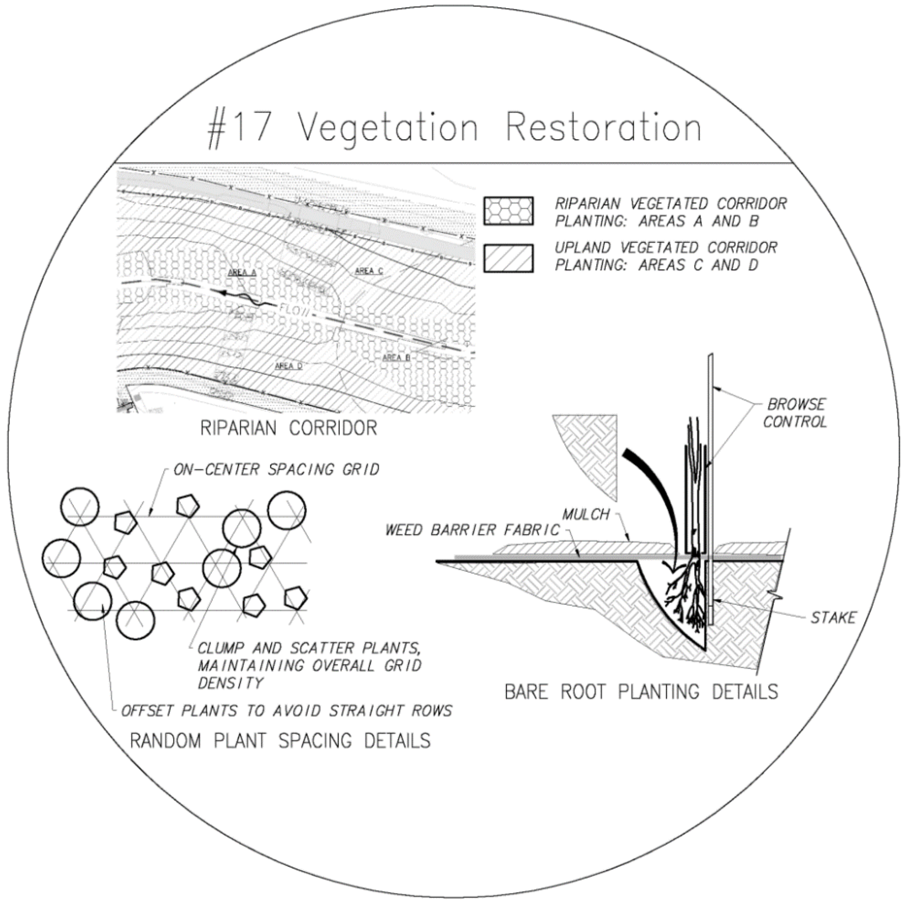
Vegetation Restoration is likely permitted as part of a larger project. On its own, only local permits from Clackamas County WES may be required.

Implementation – medium effort

Vegetation Restoration is typically done manually using hand tools and low-cost laborers. A temporary irrigation system is usually recommended for the first couple of years. Most failures of this tool occur during the establishment period, so proper planning and allocation of resources is necessary to ensure a successful outcome.

Maintenance – low to medium effort

Ongoing routine maintenance of vegetation in a water quality facility is typically required at least two times per year. Mowing or weed whacking are typical methods of vegetation control in facilities. Hand tools may also be required since herbicides should be avoided in water quality facilities. Maintenance of greenway areas usually involves control of invasive plants and requires minimal effort after establishment.



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Tool Kit Fact Sheet

CLACKAMAS WATER ENVIRONMENT SERVICES

Drywell

Underground detention and infiltration structure

Description

A drywell is an underground perforated manhole that temporarily detains stormwater runoff before it infiltrates into the surrounding soil. The drywell's rate of infiltration is dependent on the ability of the surrounding soil to absorb water. Some drywells have an emergency overflow that connects to a storm conveyance system. Others are standalone structures.

Structures may be cast in place or pre-cast.

Drywells reduce flows in the storm system and recharge groundwater. Drywells do not provide water quality treatment, so they must be paired with treatment facilities upstream.

Drywells are regulated as "Class V Injection Wells" under the federal Safe Drinking Water Act.

Uses

Drywells are best used in the following situations:

- Areas with good soil infiltration rates (greater than 2.0 inches per hour)
- Locations where there is no space for surface detention
- Locations outside of source water wells areas

Benefits

The benefits of drywells include:

- Reduce flooding from storms
- Groundwater recharge
- Limit maintenance obligation
- Allow development where a municipal storm conveyance system is lacking

Costs

Design Unit

The unit of measurement for design is **per drywell**. A standard drywell has a 48" diameter and is 20' deep. An oversized drywell has a 72" diameter and is 20' deep.

Cost Assumptions Per Unit

Cost assumption were developed for standard and oversized drywells based on ODOT 2018 standard bid tabs. The detailed cost assumption is for a standard depth pre-cast drywell.

Item	Qty	Unit	Price	Amount
Excavation	27	CY	$35	$945
Drain Rock	11	CY	$50	$550
Backfill	3	CY	$40	$120
Drywell	1	EA	$10,500	$10,500
Geotextile Fabric	40	SY	$6	$240
Total				**$12,355**
Price Per Standard Drywell (rounded)				**$12,500**
Price Per Oversized Drywell				**$15,500**

Effort

Permitting – up to six months

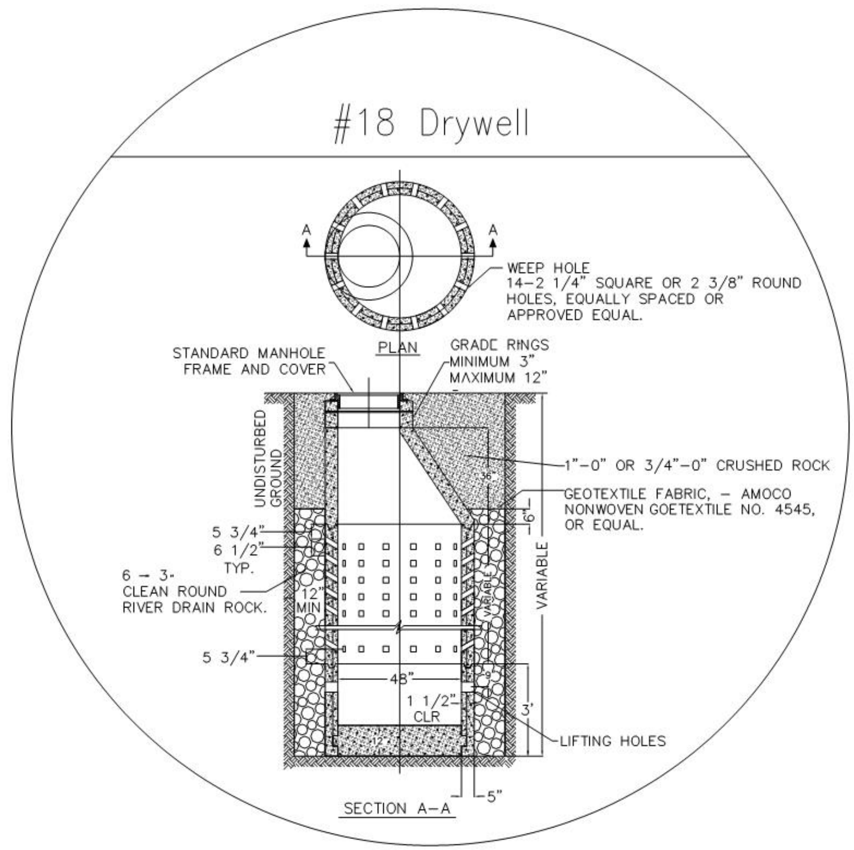
Drywells require permitting from the State of Oregon DEQ and must follow state and federal requirements as an Underground Injection Control facility. Drywells also need permitting from Clackamas County WES.

Implementation – medium effort

A drywell requires engineering design and compliance with Clackamas County WES Stormwater Standards. All drywells will require water quality treatment upstream. Pretreatment is required as well for non-residential areas.

Maintenance – low effort

Maintenance needs for drywells are limited. Periodic inspection is recommended to ensure proper function. Typical maintenance includes removing debris and unclogging inlets and emergency overflow.



Tool Kit Fact Sheet

Stormwater Planter

Creating a walled basin to store and/or infiltrate stormwater

Description

Stormwater Planter is a walled basin that temporarily stores and treats stormwater runoff though a combination vegetation and engineered soil mix. Stormwater planter is a good choice where space is limited.

Often Stormwater Planter is constructed between the sidewalk and roadway and collects runoff from the adjacent road and sidewalk, or it is constructed between a building and sidewalk and collects roof runoff.

Stormwater Planter can be used for flow control when designed with infiltration or an underdrain with controlled outlet. Controlling the rate of flow leaving the planter and into a pipe or stream reduces flooding, erosion, and sedimentation.

Uses

Stormwater Planter is often used to:

- Reduce flooding from storms
- Slow down stream flows to prevent erosion
- Allow sediment to settle out of dirty water before it releases to a stream

Benefits

The benefits of Stormwater Planter include:

- Protect stream channels
- Easy to see if it's working
- Infiltration and groundwater recharge
- Remove pollutants from stormwater runoff

Costs

Design Unit

The unit of measurement for design of Stormwater Planter is **square feet (SF) of planter**.

Cost Assumptions Per Unit

The cost assumption was developed for a hypothetical 4-foot wide by 30-foot long flow though planter (120 SF) located between a sidewalk and road.

Item	Qty	Unit	Price	Amount
Excavation	24.00	CY	$46.00	$1,104.00
Water Quality Soil	7.00	CY	$80.00	$560.00
Depth of Rock, 3/4 Inch - 1/4 Inch	1.00	CY	$163.00	$163.00
Depth of Rock, 1-1/2 Inch - 3/4 Inch	6.00	CY	$132.00	$792.00
6" Underdrain Pipe	27.00	LF	$45.00	$1,215.00
Impermeable Liner	14.00	SY	$10.00	$140.00
Beehive inlet	1.00	EA	$2,350.00	$2,350.00
Thickened Curb and Gutter	30.00	LF	$54.00	$1,620.00
Modified Curb	38.00	LF	$81.00	$3,078.00
Curb Cut	2.00	EA	$925.00	$1,850.00
Flow spreaders	2.00	EA	$750.00	$1,500.00
Planting	120.00	SF	$7.00	$840.00
Irrigation	13.00	SY	$40.00	$520.00
Total				**$15,732.00**

Price per SF of Planter (rounded) **$130**

Effort

Permitting – up to three months

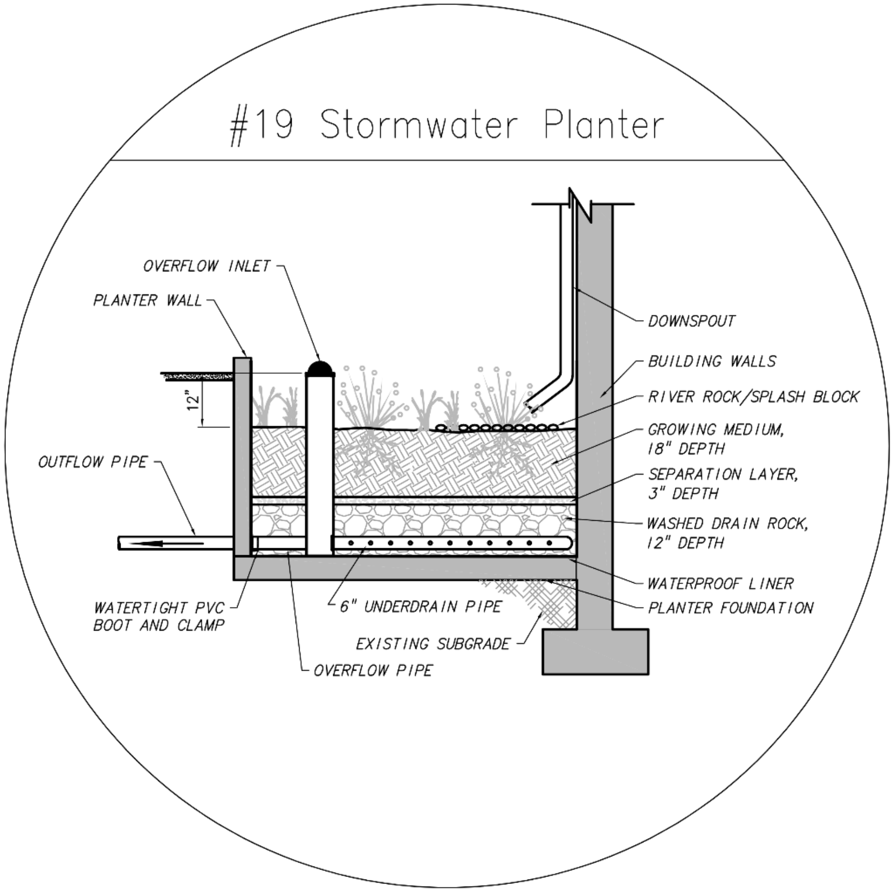
Local permits from Clackamas County WES are required. A right-of-way permit may be required.

Implementation – medium effort

Stormwater Planter requires design by an engineer. Construction requires earthwork and revegetation. Plant establishment will take two to three years.

Maintenance – medium effort

Maintenance typically requires vegetation management multiple times per year. Sediment should be removed from the overflow structure as needed. An annual inspection is recommended to check for erosion, filling of the overflow structure, and standing water. Eventually, accumulated sediment must be removed from the planter bottom.



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Appendix I

Program Factsheets

Program Recommendation Fact Sheet

Restoration and Property Acquisition Program

Restore, revegetate, and acquire critical habitat and riparian areas within the Planning Area

Problem Statement

As an organization, WES puts a high value on stream restoration, habitat improvement, and floodplain management and sees these actions as part of its mission to protect and improve water quality. These projects maximize the ecological and stormwater benefits of properties and support numerous local and regional environmental goals.

According to watershed action plans for Rock Creek and Kellogg/Mt. Scott Creeks, the main challenges for these waterbodies include poor fish passage, changes to aquatic habitat conditions, flooding risks, lack of riparian vegetation, in-stream erosion and down cutting, and water quality concerns.

The key causes of the challenges include poor streamside practices, changes in land use, bridge and culvert crossings, agriculture runoff, increased stormwater runoff, channel modifications, and riparian clearing. Together these problems degrade water quality, habitat, and riparian zones, and can increase risks of flooding and property damage.

In response, the watershed and waterway may experience:

- Increased flow volume and duration during storm events
- Channel instability including bank erosion and channel widening
- Flooding affecting infrastructure
- Lower flow during summer
- Exceeding water quality standards for temperature, bacteria, or other pollutants
- Reduction in populations of sensitive aquatic species
- Reduced aquatic habitat quality through fine sediment accumulation and loss of in-stream structure such as deep pool habitat and large woody debris
- Increase in non-native invasive species

Thirteen stream locations experiencing these types of impacts were identified throughout the Planning Area. Sites were identified from the latest WES CIP and reports from staff.

Program Recommendation

The SSMP recommends grouping these similar projects into their own program so they can be prioritized against each other and not compete with other large capital projects that may be needed for NPDES permit compliance. Within the program, restoration-type projects are organized into four main categories: in-stream restoration, property acquisition, riparian revegetation, and culvert replacement or repair.

In-stream habitat improvement projects typically include channel enhancements or stabilization, floodplain reconnections, or culvert/fish barrier removal. It also includes tree planting in areas where it supports regulatory compliance. Priority is given to projects that directly benefit streams where the Oregon Department of Environmental Quality (DEQ) has established Water Cleanup Plans to address elevated water temperatures.

In-stream habitat improvements are prioritized based on cost-benefit, applicability to recovery plans, and the degree to which the project complements other planned stormwater projects within a drainage area. Revegetation projects typically have a fairly constant per-acre cost across all projects, so a cost/benefit analysis does not provide significant basis for prioritization.

WES already manages various public and grant programs that enhance public and private properties with native vegetation, including trees. It also has funding for current capital projects have restoration components to them, such as the Carli Creek project.

To fund these projects, the SSMP recommends an annual baseline funding allocation to put toward restoration, revegetation, and culvert efforts, as well as an allocation of funding spread across a five-year period for property acquisition that would support restoration efforts. With many project specifics unknown, this was the preferrable way to estimate costs

In-Stream Habitat – Restoration

In-stream habitat improvement typically improve habitat for fish and aquatic invertebrates by slowing stream velocity, creating or restoring habitat for spawning such as gravel channels, creating refugia and deeper pools by reconnecting side channels or installing permanent obstructions like large wood. The projects typically include channel enhancements or stabilization, floodplain reconnections, or culvert/fish barrier removal. Habitat improvement projects are usually very cost-effective methods to improve stream habitat and function where past impacts have been significant. In-stream habitat improvement projects often rely on the availability of grant funding or use remaining budget after regulatory requirements have been met.

The stream channel and floodplain Known Issues analyzed for the SSMP included a list of highly varied projects. Some appeared to be relatively small and others were potentially several reaches long with more complex challenges. Some projects looked to be highly constrained between residential properties. Specific scope information for the potential projects was not available.

Property Acquisition

Streamside property acquisition can protect existing valuable habitat from alteration. The Program would continue WES's process for property acquisitions, which are prioritized and pursued as opportunities are available. When possible, WES seeks to leverage capital funds with grant and partnership funds such as from parks and open space programs. Selection and prioritization of property acquisitions is coordinated through various performance partners including WES sanitary sewer utilities, parks and open space programs, and watershed councils.

Occasionally, WES will purchase sites with existing high-quality habitat along streams, in wetlands, or in forested upland areas. Preservation of these areas provides significant long-term watershed benefits, including stormwater control. Property purchases are often costly and are dependent on the availability of willing sellers; however, preventing stormwater problems before they occur is among the most cost-beneficial means of managing stormwater impacts.

Culvert Replacement or Repair

Culvert replacement or repair can re-introduce habitat to fish that had been previously cut off due to culverts that prevented passage. The Program would evaluate and prioritize culverts for a stormwater program nexus. Culverts reaching end of life, culverts that have structural issues necessitating earlier repair, or new culvert construction would require installation of fish-passage friendly culverts.

Riparian Revegetation

Revegetation of streamside properties improves habitat for fish and aquatic invertebrates by shading the stream, reducing water temperatures. The Program would continue to support WES's efforts to enhance public and private properties with native vegetation, including trees. These projects maximize the ecological and stormwater benefits of the properties, supporting numerous local and regional environmental goals, including regulatory compliance in some areas.

Tree planting projects provide stormwater benefits that often qualify for permit required controls, so they may be included in stormwater capital plans; however, these projects represent only a subset of the overall restoration program.

Recommended Program Budget

Cost Estimating Methodology

The cost estimating method for this program utilized the Stormwater Toolkit for the revegetation and box culvert costs, and a baseline funding approach for in-stream restoration and property acquisition. The baseline funding approach assumed that over a five-year period WES would fund 1-5 large-scale in-stream restoration projects and that the typical costs for each of those projects is between $1-$2 million. Similarly, for the property acquisition the SSMP assumes that WES may need to acquire property to support habitat and restoration projects. The SSMP recommends allocating $750,000 to meet this need.

Associated costs include project management, mobilization, traffic control, erosion controls, and surface restoration. All costs are presented in 2020 dollars.

Program Recommendation

The estimated cost for this program over five years is $4,977,088. This would cover five box culvert replacements, about an acre of revegetation, a $500,000/year allocation for instream restoration, and $750,000 for property acquisition over a five-year period.

In-Stream Restoration

The in-stream restoration costs assume an annual baseline funding that can used annually or banked for larger projects. The SSMP assumed that larger projects typically cost between $1-$2 million. In a five-year budget, $500,000 annually or $2.5 million total would be allocated for in-stream restoration projects. This type of funding will give WES the ability to plan for critical projects as well as take advantage of property acquisitions that can ensure the long-term watershed benefits. This allocation is inclusive of management and administration costs.

Project Type	Annual Allocation	Total 5-Year Program
Restoration Construction Cost	$500,000/year	**$2,500,000**

Property Acquisition

Property acquisition varies widely depending on current and future land uses. The SSMP recommends $150,000 baseline funding for this purpose to support watershed and habitat projects. This allocation is inclusive of management and administration costs.

Project Type	Annual Allocation	Total 5-Year Program
Property Acquisition	$150,000/year	**$750,000**

Riparian Revegetation

Costs for revegetation work used estimates from the Stormwater Toolkit and assumed 20,000 square feet of planting. The Toolkit estimates that revegetation work costs approximately $3.00 per square foot. The program assumes two, almost half-acre projects in the total costs. The total costs assume 10% of construction costs for design and 10% for associated costs.

Cost Per 20,000 SF	Assumption	Amount
Average Construction Cost	Toolkit/Recent Bid	$60,000
Design	10% of construction	$6,000
Management & administration	15% of construction	$9,000
Associated costs	10% of construction	$6,000
Per Project Total		**$81,000**
Program Costs	**1 acre**	**$162,000**

Culvert Replacement or Repair

Costs for new box culverts assumed 60-foot length and 10-foot height of the headwalls, and 3 feet of cover over the culvert. The 12 x 7 box culvert unit price was based on a recent bid from 2020 from Oldcastle. The program assumes 5 culvert projects as part of the total costs. The total costs assume 25% of construction costs for design and 20% for associated costs.

Cost Per Culvert	Assumption	Amount
Average Construction Cost	Toolkit/Recent Bid	$ 195,636
Design	25% of construction	$48,909
Management & administration	15% of construction	$29,345
Associated costs	20% of construction	$39,127
Per Project Total		**$313,018**
Program Costs	**5 Projects**	**$1,565,088**

Program Recommendation Fact Sheet

CLACKAMAS
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SERVICES

Small Drainage Project Program

To address small drainage issues in the Planning Area that cost less than $100,000

Problem Statement

Nuisance issues in the stormwater system are common and expected. They include blockages of small pipes by roots, degradation of small pipes, and minor flooding due to clogged or degraded inlets or missing small pipes. Minor repairs and upgrades to the storm system exceed routine maintenance requirements and are an important part of proper asset management.

The following nuisance issues have been identified: 32 instances where a new inlet or manhole could reduce clogging and minor flooding and three instances of roots blocking small pipes. It is assumed that 3,000 linear feet annually of 18" or smaller pipe could be installed to address some flooding and ponding.

Program Recommendation

Projects correcting nuisance issues and estimated to cost less than $100,000 each are grouped together into the Small Drainage Project Program. The projects will improve drainage issues when flooding is caused by WES's stormwater infrastructure and would support WES's goal of proactively addressing performance deficiencies or enhancements and decreasing the number of customer service requests.

The Small Drainage Project Program is intended to provide steady annual funding so that WES can both reactively and proactively address small flooding and drainage issues in a timely manner. Without this program, damage to roadways or public and private property could result, and public complaints could rise.

The Small Drainage Project Program is expected to be carried out by WES field staff or contractors as the issues arise or once staff identifies a problem area. Three types of small drainage projects are described below.

New Birdcage Inlets and Manholes

Because some inlets frequently clog with debris and cause minor flooding, this program recommends upgrading 32 inlets and manholes with a large birdcage inlet or manhole. This type of inlet will help to reduce clogging and debris accumulation at these locations that have been problematic in the past.

Root Removal/Pipe Lining

There were several Known Issues that mentioned root intrusion into stormwater drainage pipes. Many of those were also part of larger conveyance projects and did not meet the criteria for a Small Drainage Project. However, smaller pipes that are 18" diameter or less also have root intrusion that can cause issues in the surrounding pipe network. Roots are removed by auguring, and pipes are lined using a cured-in-place plastic to reduce future intrusions.

Small Pipe Conveyance

Small pipe conveyance funding will allow WES to address and mitigate reoccurring ponding or flooding across the Planning Area. Our assessment is that this category of flooding is not necessarily widespread but often needs immediate attention. An annual funding allocation will allow WES to respond when necessary.

Program Cost Estimate

Cost Estimating Methodology

A planning-level cost estimate has been prepared for each component of the program as described below. The estimate is presented as the cost to complete all currently identified issues in this program.

Associated costs include project management, mobilization, traffic control, erosion controls, and surface restoration. All costs are presented in 2020 dollars.

Program Costs

Total program cost estimate is $971,906 to complete 32 inlet or manhole replacements, five small pipe projects, and three root removal/pipe lining projects.

Annual Program Estimate	Assumption	Amount
Large Birdcage Inlet or Manhole	32 Replacements	$276,480
Small Pipe Conveyance	5 Projects @ 600 LF each	$567,000
Root Removal/CIPP	3 Projects @ 600 LF each	$128,426
Program Cost		**$971,906**

Project Cost Estimates

New Large Birdcage Inlet or Manhole

Using the Stormwater Toolkit, the birdcage manhole or inlet is priced per installation with associated costs. Design costs are not included in this estimate.

Cost Per Unit	Assumption	Amount
Average Construction Cost	Stormwater Toolkit	$ 6,400
Design	-	-
Management & administration	15% of construction	$960
Associated costs	20% of construction	$1,280
Per Project Total		**$8,640**
Program Cost	**32 Units**	**$276,480**

Small Pipe Conveyance

Costs for small conveyance were established by assuming 600 linear feet (LF) of 18” per project. The program assumes 18” pipe as the maximum diameter considered “small pipe.” The 600 linear feet assumption is based on approximate length of to two residential blocks. No design costs were assumed as part of this estimate.

Cost Per 600 LF	Assumption	Amount
Average Construction Cost	Toolkit	$ 84,000
Design	-	-
Management & administration	15% of construction	$12,600
Associated costs	20% of construction	$16,800
Per Project Total		**$113,400**
Program Cost	**5 Projects (3000 LF total)**	**$567,000**

Root Removal/Pipe Lining

Costs for root removal by cured-in-place-pipe (CIPP) were established by assuming 600 linear feet (LF) of 18" per project. The program assumes 18" pipe as the maximum diameter considered "small pipe." The 600 linear feet assumption is based on approximate length of to two residential blocks. No design costs were assumed as part of this estimate.

Cost Per 600 LF	Assumption	Amount
Average Construction Cost	Estimate from recent project bid	$ 31,710
Design	-	-
Management & administration	15% of construction	$4,757
Associated costs	20% of construction	$6,342
Per Project Total		**$42,809**
Program Cost	**3 Projects (1800 LF Total)**	**$128,426**

Program Recommendation Fact Sheet

CLACKAMAS
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Stormwater Pond Repair and Rehabilitation Program

Provide for repair and rehabilitation for WES owned/operated stormwater ponds

Problem Statement

WES owns or operates 620 vegetated stormwater ponds that provide the critical function of reducing pollutants in stormwater runoff and/or controlling flows prior to discharge to a natural drainage, wetland, stream, or river. They also help reduce erosive runoff, or hydromodification, in stream channels.

Based on information gathered from WES and Happy Valley, and verified by some cases by inspections, 58 of those currently need repair or rehabilitation.

Repairs and rehabilitations such as these are required by the municipal stormwater permit issued to WES and the cities it covers with stormwater services by Oregon Department of Environmental Quality.

WES currently has allocated $250,000 per year through FY 2023 for the Detention Facility Repair/Rehab project type in the Surface Water CIP. This typically funds five to six facility rehabilitations per year, which are bid to contractors. Generally, these facilities need routine inspection and maintenance, as well as eventual rehabilitation to their original design function, to ensure functionality and maximize their useful life.

New development within the WES service districts will generate more stormwater facilities, adding to this asset management category. In the future, WES may encourage regional facilities to reduce the number of stormwater facilities coming online as new development progresses in the District. In the meantime, steady funding for the 620 assets will be needed to ensure a level of service, proper functionality and water quality is being provided.

Program Recommendation

The Stormwater Pond Repair and Rehabilitation Program will provide a clear budget line for required repair of these assets. In order to stay ahead of asset management needs, the SSMP recommends a five-year timeline to complete the known backlog. The SSMP assumes one additional facility per year will degrade in addition to the 58 facilities already identified for a total of 63 facilities.

Rehabilitation a stormwater pond typically includes removal of sediment and invasive species, regrading edges, cleaning orifices and pipes and other related activities. Stormwater pond repair can include several activities or types of work. In some cases, hard features such as weirs, orifices, inlets, pipes, or other parts of the system may need to be replaced. Also, maintenance access to the ponds may need repair to allow proper equipment near the site or allow field staff to work near the site safely.

Program Cost Estimate

Cost Estimating Methodology

A planning-level cost has been estimated based on WES's previous bid tabs for detention pond repair. The estimate assumes that 50% of each pond's area needs repair or rehabilitation. Using the footprints of the 58 known ponds, a total rehabilitation footprint of 264,000 square feet for 63 ponds was estimated.

Bids from five previous repair projects were used to calculate a construction unit cost. The sum of the five reference projects was divided over the total rehabilitated area, resulting in $10.17/square foot construction cost.

Associated costs include project management, mobilization, traffic control, erosion controls, and surface restoration. All costs are shown in 2020 dollars.

Program Estimate

Assuming a cost of $10.17/square foot plus design and associated costs, the program total is $4,114,951 over five years.

WES could continue this funding beyond the five-year timeline and provide funding for repair and rehabilitation of 10% of all facilities every five years.

Cost Estimate for 63 Facilities	Assumption	Amount
Average Construction Cost	$10.17/SF for 264,000 SF	$2,837,897
Design	10% of construction	$283,790
Management & administration	15% of construction	$425,685
Associated costs	20% of construction	$567,579
Program Cost		**$4,114,951**

Program Recommendation Fact Sheet

CLACKAMAS WATER ENVIRONMENT SERVICES

UIC Decommissioning and Retrofits

Decommission or retrofit a pre-determined list of underground injections control (UIC) systems

Problem Statement

Underground Injection Controls (UICs) are systems that place fluids below the ground. The most common UICs in Oregon are stormwater drywells, which are usually found on large parking lot surfaces, according to the Department of Environmental Quality (DEQ). UICs for stormwater are most commonly used where connections to storm system infrastructure are not available.

Decommissioning or retrofitting UICs is necessary where the system is a known threat to groundwater quality. Under state regulatory requirements, WES has identified UICs with risk of polluting groundwater.

In December 2000, an inventory of all known stormwater injection systems within WES service districts (CCSD #1 and SWMACC) was provided to DEQ. This inventory was subsequently revised and re-submitted on several occasions in the following years. The most recent inventory was provided to DEQ in April 2015. Since that time seven drywells were discovered or constructed by WES.

In 2018, WES submitted the “System-Wide Assessment for: Clackamas County and WES-owned and/or operated stormwater injection devices, including drywells” to DEQ. This assessment satisfied a Water Pollution Control Facility (WPCF) permit requirement and provided an inventory and conditions as required. For those drywells whose depth is known, the determination of direct discharge status was based on data contained within the following USGS Scientific Investigations Report (2008-5059): "Estimated Depth to Ground Water and Configuration of the Water Table in the Portland, Oregon Area".

Thirty drywells were identified in the 2018 report, which were believed to intersect highest seasonal groundwater on at least one day per year, and 20 of them were subsequently decommissioned with authorization from DEQ in the 24 months from June 2011 to June 2013.

The remaining 10 drywells that intersect groundwater are the focus of this Program.

Program Recommendation

The recommendation for this Program is to continue the ongoing work WES has already begun. There are also private property UICs and/or UICs near drinking water wells that WES may want to retrofit, for instance if a rain garden can be installed on upstream public property to provide treatment.

WES previously developed cost estimates for the decommissioning or retrofitting of these 10 UIC locations. The SSMP recommends continuing this work and funding the 10 projects.

Some UIC retrofit projects may also satisfy municipal stormwater permit requirements for the retrofit strategy. UIC retrofits are prioritized based on cost-benefit and the results of the risk analysis.

Typically, decommissioning a UIC entails filling the vault with concrete and removing the manhole cover. The area around the manhole will be restored to match the directly adjacent surfaces, either lawn or pavement.

Typically, retrofitting a UIC entails filling it with one to two feet of concrete so that the total depth is greater distance from seasonal high groundwater levels. It could also entail installing low impact development (LID) practices upstream of the UIC inlet to treat the runoff before it enters the UIC.

Program Cost Estimate

Cost Methodology

In 2018, WES estimated design and construction costs for retrofitting or decommissioning the ten UICs. The SSMP represents these costs in 2020 dollars and includes 15% of construction costs for management and administration costs.

Program Estimate

The total estimated cost for the 10 UIC projects is $528,412. The annual costs will depend on the timeframe to complete the projects. In a five-year budget, approximately $106,000 per year would be required to complete the UIC work.

UIC - < 0’ Groundwater Separation	Assumption	Amount
WES Estimated Construction Costs for 10 Sites	2017 Estimate Escalated to 2020 Dollars (12.2%)	$528,412
Program Total		**$528,412**

Program Recommendation Fact Sheet

CLACKAMAS WATER ENVIRONMENT SERVICES

Water Quality Retrofits Program

Retrofit impervious areas to address water quality concerns

Problem Statement

Within the Planning Area, water quality has been significantly degraded from pre-development conditions in some areas due to land use changes, hydromodification, and untreated runoff from impervious surfaces.

Based on watershed assessments within the Planning Area, some of the key water quality issues affecting creeks and streams include the following:

- Stream temperatures exceed water quality criteria for summer conditions.
- Benthic macroinvertebrate and fish population surveys indicate moderately to severely impaired biological communities.
- Elevated levels of E. coli bacteria have been found.
- Elevated levels of total phosphorus (TP) and pesticides have been observed.

In addition, expected future development in a watershed can pose a high risk for in-stream sedimentation.

Water quality retrofits generally include new facilities in unserved areas or enhancements which add or increase water quality treatment within existing stormwater infrastructure. New facilities serving existing impervious surfaces may be placed in the right-of-way or on public property. Enhancements of existing facilities could include installation of cartridge filter systems, conversion of swales to rain gardens or wet ponds, and other improvements to stormwater facilities or conveyance systems where water quality treatment is either inadequate or can be significantly improved.

The National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit requirements may change in the future and require additional water quality monitoring and retrofits to the existing storm system to improve water quality.

Program Recommendation

Currently, WES implements water quality retrofits primarily in areas that have been urbanized for many years, as the focus is on areas with no treatment, followed by those with outdated treatment facilities. These retrofit projects are prioritized based on the severity of the project need and the results of the cost/benefit analysis. In the WES CIP published prior to this SSMP, the Water Quality Retrofits budget category has limited funding allocated.

Under the SSMP, a list of Known Issues is categorized as water quality retrofits, including nine retrofit projects that would treat runoff from streets as well as large parking lots. These projects are in locations where WES staff have observed that retrofits would be beneficial to a nearby stream or river and where space exists to place a facility.

The Water Quality Retrofit Program would add a new water quality retrofit where a clear benefit to a nearby stream has been identified. The program recommendations include implementation of three types of retrofits: large stormwater ponds, stormwater planters in the right of way, and vegetated swales.

Retrofit projects help meet WES's NPDES permit requirements, support water quality goals, and support WES's goals to be good stewards of the environment.

Large Stormwater Ponds

Large stormwater ponds can treat or manage stormwater runoff from an extensive tributary area. These systems are typically landscaped depressions that allow stormwater to collect, infiltrate and slowly release into a downstream waterway or pipe. Ponds provide treatment for stormwater as well by filtering out sediment and other pollutants carried by stormwater runoff. Several water quality retrofit opportunities were documented in a 2013 Retrofit Strategy report conducted on behalf of WES. WES has identified a retrofit site for a large stormwater pond within a retail parking lot at a Burlington Coat Factory store, and this type of project was used as the basis for the large stormwater pond cost estimate below.

The land requirements for a large stormwater pond are high, so relatively few of these retrofit types are proposed.

Vegetated Swale

Vegetated swales are elongated water quality treatment facilities that can be installed adjacent to a roadway. They could be grassed, like the example above, or contain other vegetation. Typically, it will receive sheet flow from the street, or have an inlet directing stormwater runoff to the swale. The swale will detain, filter, and infiltrate the runoff and in more intense storms, overflow to either existing pipe or to an adjacent stream.

There were three locations where a swale retrofit could be utilized along existing roadways and provide a water quality benefit.

Stormwater Planter in the Right-of-Way

Stormwater planters in the right-of-way are walled basins that can be installed on existing streets where space allows, often between the curb and the sidewalk. A right-of-way planter would be installed in the parking lane near an intersection or in a portion of the sidewalk to capture stormwater runoff from an existing street. The planters either infiltrate the runoff or connect to existing conveyance in the street.

The costs of this type of retrofit includes new curbs, utility coordination, and other possible conflicts that may arise with retrofitting existing roadway.

Five Known Issue locations could benefit from a right-of-way stormwater planter.

Program Cost Estimates

Cost Estimating Methodology

Cost estimates for each of the retrofit types were developed using either a recent public sector capital project that installed these project types or Otak's stormwater cost estimating toolkit. The program recommendation includes a planning-level cost estimate for each component as described below. The estimate is presented as the cost to retrofit roadways or other impervious properties similar to the retrofit opportunities included in the Known Issues analysis.

Associated costs include project management, mobilization, traffic control, erosion controls, and surface restoration. All costs are presented in 2020 dollars.

Program Costs

The estimated cost for the program is $1,724,260. The annual costs will depend on the agreed timeframe to complete a similar number and type of projects.

Program Estimate	Assumption	Amount
Large Stormwater Pond Retrofit	1 Project	$1,080,288
Stormwater Planter in the ROW	5 Projects	$236,250
Vegetated Swale	3 Projects	$407,722
Program Cost		**$1,724,260**

Detailed costs for each project type are presented below.

Project Cost Estimates

Large Stormwater Pond Retrofit

The opportunity to retrofit a big box retail parking lot located at SE King Road near Phillips Creek was assessed as part of WES's Retrofit Strategy, and costs were developed using Stormwater Pond unit costs from the Stormwater Toolkit, which were based on recent bids from other water quality projects. Assumptions for this estimate include:

- The pond treats approximately 20 impervious acres.
- The pond footprint is 2.4% of the total impervious area treated.

The sizing factor above was calculated using the WES BMP Tool. Once a pond size was determined for the treated acreage, the cost of $0.80/square foot from the Stormwater Toolkit was applied. Design and associated costs each are assumed to be 20% of construction costs.

Cost Estimate	Assumption	Amount
Construction	Pond Toolkit	$696,960
Design	20% of construction	$139,392
Management & administration	15% of construction	$104,544
Associated costs	20% of construction	$139,392
Program Cost	**1 Project**	**$1,080,288**

Stormwater Planter in the Right-of-Way Retrofit

The cost estimate for the stormwater planter in the right of way (ROW) retrofits was developed using bid costs from a similar retrofit. Estimating a hypothetical drainage basin from existing roadway surface resulted in a 3000 square foot drainage basin. Using the WES BMP Tool and assuming that the stormwater planter would fit in existing right of way widths (no acquisition needed), a 4% sizing factor was used to calculate a 120-square foot stormwater planter. While the Stormwater Toolkit estimated costs for new construction, retrofitting in existing development would require additional costs for field fitting inlets and outlets to maximize drainage and detention. Design and Associated costs each are assumed to be 25% of construction costs.

Cost Estimate	Assumption	Amount
Construction	Engineer's Estimate/WES BMP Tool	$27,000
Field-fitting and testing	10% of construction	$2,700
Design	25% of construction	$6,750
Management & administration	15% of construction	$4,050
Associated costs	25% of construction	$6,750
Total per Planter		**$47,250**
Program Cost	**5 planters**	**$236,250**

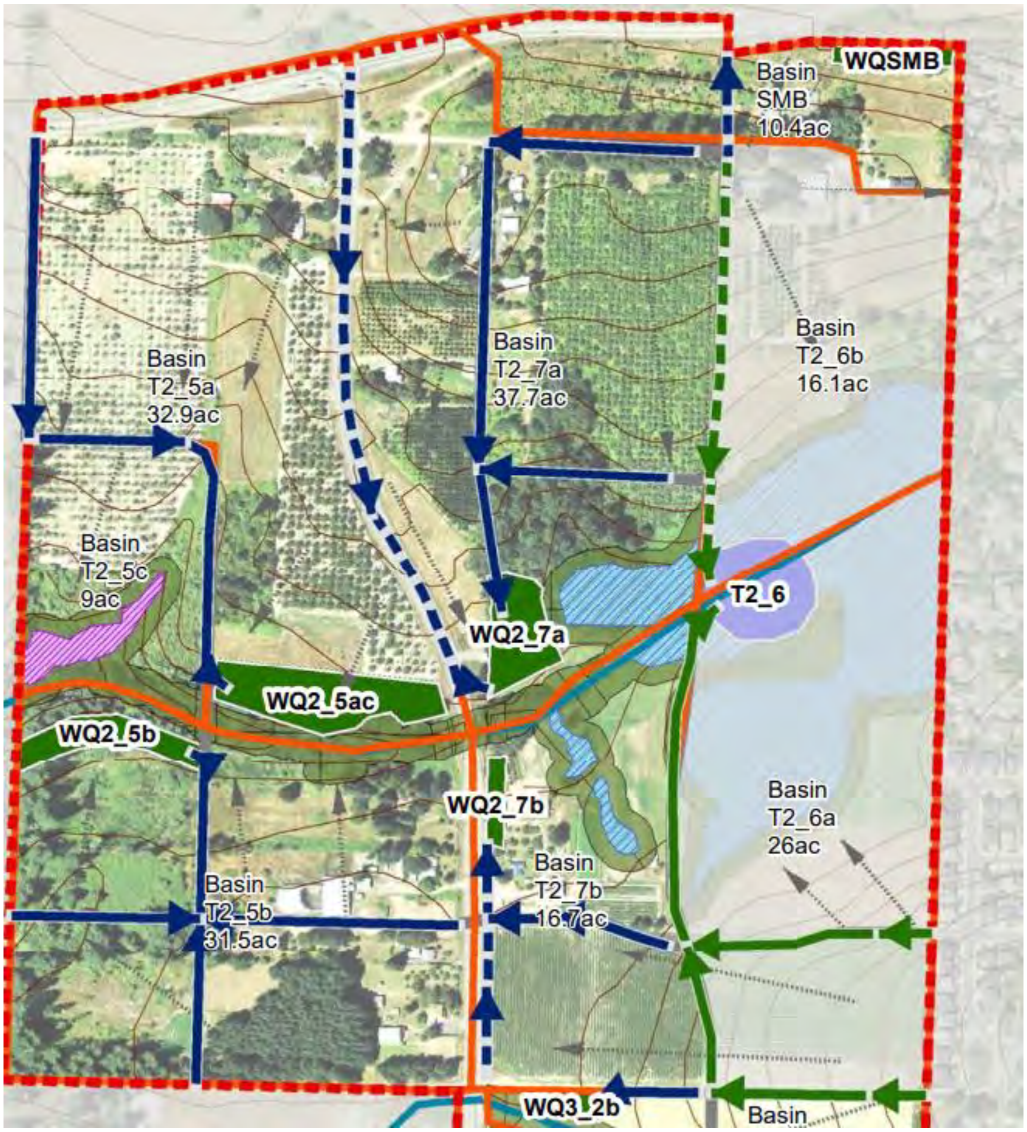
Vegetated Swale Retrofit

The cost estimate for a vegetated swale water quality retrofit assumes that the retrofit practice is designed to treat one acre using a 5% sizing factor. The sizing factor was calculated using the WES BMP Tool. Once that was determined, the cost per square foot treated was developed using the Stormwater Toolkit for an estimated cost of $1.95/square foot treated. Design and Associated costs each are assumed to be 20% of construction costs.

Cost Estimate	Assumption	Amount
Construction	Engineers Estimate/Toolkit	$84,942
Design	25% of construction	$21,236
Management & administration	15% of construction	$12,741
Associated costs	20% of construction	$16,988
Total per Retrofit		**$135,907**
Program Cost	**3 Projects**	**$407,722**

Appendix J

Policy and Planning White Papers



River Terrace Community Plan – Regional Stormwater Facilities

Clackamas Water Environment Services
Storm System Master Plan

Regional Stormwater Facilities White Paper

Final

Submitted to:

Clackamas County
Water Environment Services
150 Beavercreek Avenue
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June 2022

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Project No. 19109

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Section 1. Introduction

Background

In recent years, regional stormwater facilities have been widely used in the Pacific Northwest and in the Portland metropolitan area to meet post-construction requirements or local development codes for mitigating impacts from stormwater runoff. Regional facilities can provide water quantity control, water quality treatment, or a combination of both.

The purpose of this white paper is to provide a summary of the tools and the necessary building blocks that jurisdictions could employ when considering regional stormwater facilities for their communities. It will also review key considerations for planning and implementing regional stormwater facilities based on discussions with jurisdictions in the Portland metropolitan area and provide links to resource documents.

A regional stormwater facility is typically described as a large stormwater management solution strategically situated and designed to serve multiple properties or subdivisions in order to optimize stormwater management as part of a development project. The term could also refer to a single facility for an individual catchment area resulting in several regional stormwater facilities in a larger development.

In some cases, alternatives to ponds can be used and can provide a similar benefit such as an in-stream enhancement project, wetland expansion or creation, subsurface detention, a combination system (including ponds, swales, low impact development approaches (LIDA), and in-stream stormwater management), or other alternatives to manage runoff in a consolidated manner as opposed to site-by-site. Other terms for regional facilities may be *centralized facilities, large-scale detention*, or *neighborhood-scale facilities*.

Why Consider Regional Stormwater Facilities?

There are many reasons a jurisdiction would consider regional stormwater facilities, but often maintenance and operations resources are the determining factor. If a jurisdiction is responsible for maintaining detention ponds already and several new developments are in planning stages, the possibility of taking on four to five new assets versus dozens of new assets may be appealing. If the developer or private entity will maintain the assets, fewer sites will be more cost-effective for them as well.

The front-end planning effort may take time, but the construction and maintenance are often less costly overall. Additionally, many jurisdictions and developers see the opportunity to create community amenities when designing these facilities, offering the community more than just a large stormwater pond.

Several advantages that make regional stormwater facilities attractive to jurisdictions and developers include:

- **Lower design and construction costs.** One or two regional stormwater facilities could be much more cost-effective to implement than multiple individual onsite structural controls.
- **Reduced operation and maintenance costs.** Jurisdictions can more cost-effectively manage operations and maintenance for fewer facilities. Fewer sites also increase the likelihood that maintenance activities are carried out regularly for both public and private operators.
- **Visibility.** Regional stormwater facilities have high visibility due to their size making them more likely to be maintained. This also engages the community to understand the purpose and benefits of the regional stormwater facility, and stormwater management in general.

- **Higher utilization of developable land.** Developers can maximize the developable land by minimizing the land normally set aside for the construction of stormwater controls. Each stormwater facility may have minimum design requirements for setbacks, maintenance access, or other structural elements that may add to the overall “footprint” of a stormwater facility. This total area, while not providing direct stormwater management functionality, would be not available for developable land. Reducing the total number of stormwater facilities would increase the ratio of potentially buildable land.
- **Community benefits.** Well-designed regional stormwater facilities can serve as educational, recreational, ecological, and aesthetic amenities for a community.

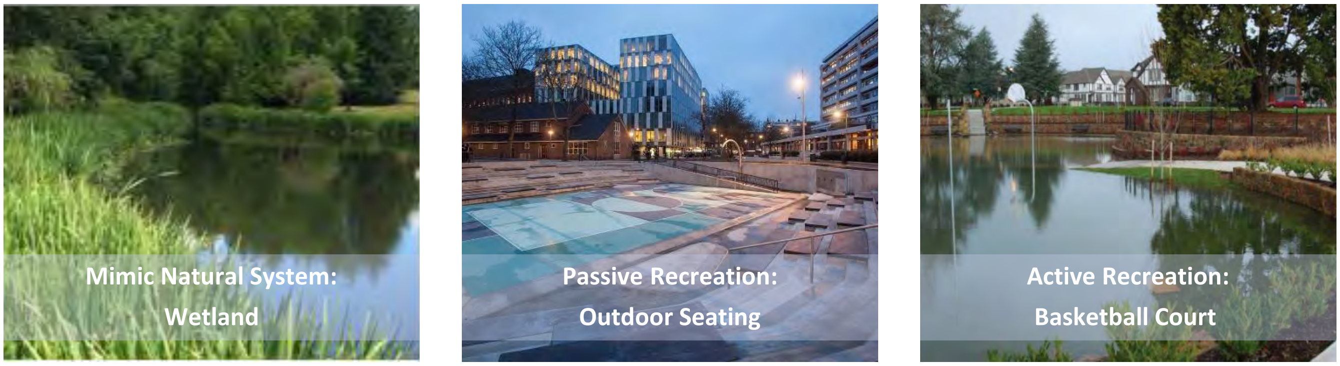


Figure 1. Examples of Regional Stormwater Facilities

Alternatively, some potential challenges that may arise when considering regional stormwater facilities include:

- **Size and Siting.** One or several regional stormwater facilities may be difficult to site depending on the size, and particularly in infill development.
- **Sequencing and Funding.** Coordinating the regional stormwater facility and related conveyance systems can be complicated depending on the number of property owners and developers involved, as well as the topography.
- **Time and Schedule.** Successfully implemented regional stormwater facilities typically completed rigorous planning, as well as reviewed options for funding, and possible permitting requirements. Additionally, land acquisition or easements must be in place before development can begin.

Section 2. Building Blocks for Implementation

Discussions with local Portland area jurisdictions revealed key lessons learned including the benefits of creating stormwater plans, writing codes that encourage regional facilities, and providing developers with guidelines and minimum standards. Without these building blocks, it can be difficult for a jurisdiction to successfully implement a regional approach for stormwater management.

Typically, jurisdictions that created targeted stormwater master plans for new growth areas or urban revitalization areas were able to work through many of the questions related to regional stormwater management prior to the new development. These plans laid the groundwork for codes and design standards that followed.

Depending on the size and type of land being developed, the planning process and stakeholders can vary. Table 1 below shows a sample of development projects near Portland that conducted planning for regional facilities and the development’s approximate size.

Table 1. Sample Development Projects and Sizes

Location	Greenfield or Infill Development	Development Size
Reeds Crossing	Greenfield	464 acres
North Bethany	Greenfield	800 acres
River Terrace	Greenfield	500 acres
Downtown Beaverton	Infill	90 acres (treated)

As mentioned above, the planning effort can require long lead times to prepare and to conduct the various studies that might be needed. For example, the River Terrace development in Tigard, Oregon was a new growth area where the City intended to utilize regional facilities. Here is the general timeframe for that planning effort:

Table 2. Sample Project Timeline for River Terrace, Tigard

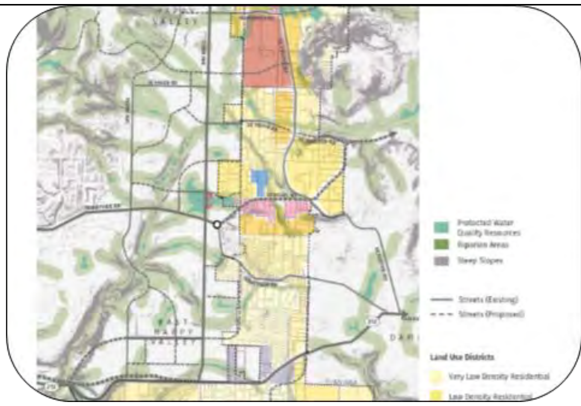
River Terrace Planning – Overall Timeline	
Added to Urban Growth Boundary	2002/2011
River Terrace Community Plan	2012-2014 (adopted)
Stormwater Master Plan	2014 (adopted)
Public Improvement Design Standards – Stormwater Management	2015 (adopted)
Development Start	2015

Planning for Success

Beginning with stormwater planning can help determine general feasibility and provide a transparent public document that describes the road map for achieving stormwater goals. A critical element to be determined early in the process will be the responsibility for operation and maintenance of these assets - the jurisdiction or the developer. If the former, the planning process can indicate that design standards will be developed, the types of components a jurisdiction is able to operate or require the developer to provide manuals and training for operational staff. This will drive several decisions during planning, codes drafting, design standards, and implementation of the projects.

Stormwater plans can also help piece together multiple services into broader vision through a regional stormwater planning approach. For instance, the greenway plan in Reeds Crossing in South Hillsboro is one example. This greenway provided active and passive recreation, wildlife habitat, natural areas to enhance views and aesthetics as well as stormwater management for the development. Creating multi-beneficial infrastructure can often enhance a development, as well as meet multiple stated community goals.

Figure 2 (next page) describes the key components to properly assess whether a regional stormwater approach would be feasible and compatible with future development sites.

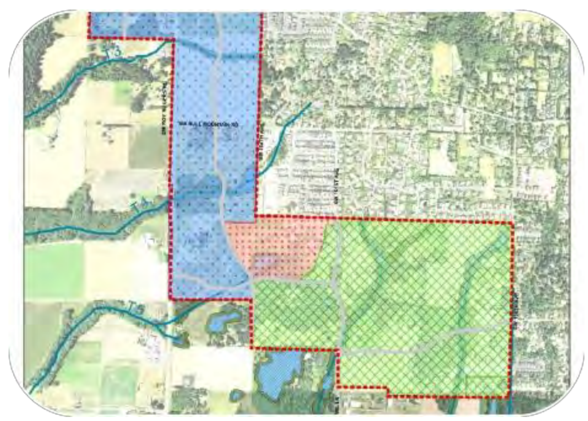


Determine Options/Understand Site Conditions

- Are regional facilities an option for this site?
- Conduct a GIS analysis to identify low points and other features such as streams, wetlands, steep slopes, and other major characteristics of the study area
- Delineate floodplains and vegetated corridors/ riparian zones
- Locate where water quality issues, erosion, or other problematic areas exist

Develop Stormwater Strategy

- Determine multiple options for siting regional facilities including specific types, locations and estimated size
- Note open space, park, or other amenity plans and goals and discuss if integrating those with regional stormwater facility would be added benefits for the community
- Estimate construction costs
- Consider future maintenance and operation access and costs



Prepare for Land Acquisition/Easements

- Identify properties not publicly owned but required for regional stormwater facility
- Begin discussion with elected officials early about land acquisition and/or easements
- Secure necessary approvals and budget before reaching out to property owners
- Prepare solid arguments about why it's in their best interest to sell or allow easements

Estimate Size/Location

- Begin to estimate how much stormwater needs to be detained to meet regulatory or code requirements and create conceptual designs for the facilities.
- If multiple facilities are required, create conceptual plan for the entire site including temporary facilities and conveyance infrastructure
- Show community amenities if applicable

Figure 2. Key Components of Planning for Regional Stormwater Facilities

Greenway Park and Regional Stormwater Facility at Reeds Crossing, South Hillsboro
(Photo Credit: GreenWorks, PC)

Developing Code that Serves Goals

Once a plan has shown how the regional stormwater facilities will be integrated into the new development, drafting development codes and ordinances that build on that vision will facilitate the implementation. The codes should speak to the specifics of the landscape and vegetation design as well as to the technical and performance aspects of the stormwater systems. If protecting streams, habitat, and riparian areas are needed, consider restricting development in floodplains. Also, consider requiring LID onsite to supplement the regional stormwater facility and provide resiliency into the system.

Jurisdictions can begin this effort during or after the planning process by:

- Reviewing existing stormwater codes and determining if updates or additions can be made, or if entire new sections, chapters, or ordinances are needed.
- Determining what regulatory requirements must be met and if the new codes will support and streamline that process, and include enforcement and reporting requirements in that review to ensure all information can be gathered easily.
- Identifying how to protect or restrict sensitive, degraded, and/or hazard areas within the watershed. Alternatively, encouraging placement of facilities in or adjacent to sensitive areas or riparian buffers that need improvement in order to leverage project funding for restoration. For example, regional stormwater facilities could be sited adjacent to or in water quality resource areas or vegetated buffers but also sited to avoid jurisdictional wetlands.
- Clearly stating the minimum requirements for approval and include detailed guidance for sizing
- Requiring site-scale LID to provide stormwater quality and, in some cases, additional quantity reductions.
- Reviewing potential funding mechanisms and developing any code necessary to implement the regional approach as envisioned.

Building flexibility into the code and policies is recommended such as creating a process for alternative proposals and being prepared for unanticipated outcomes. A regional stormwater facility may be a large pond, or it may end up becoming a wetland, or it may be bigger than originally expected. The codes will need to be flexible to accommodate challenges and constraints as the design phase progresses. Many pieces will need to align for the ideal outcome to be realized but the reality may look more like a mix of regional and distributed facilities. Codes that anticipate alternative ideas will reduce delays in plan review and approvals.

See Section 4 for an example of planning documents for a regional stormwater approach from North Bethany, Hillsboro, Tigard, and Beaverton.

Regional Stormwater Facility, Washington County

Funding Regional Facilities

Numerous funding options exist and can generally be divided into revenue generated from private development and public funding raised through bonds or fees. Many jurisdictions utilize system development charges, fee-in-lieu, or capital funds to fund stormwater infrastructure.

System development charges (SDC) are one-time fees charged to developers to help pay for infrastructure or facilities (such as street and sewer systems) that are required to meet growth-related needs for that jurisdiction. SDCs are paid at the time that a development permit is issued. SDC's could also be created specifically to fund regional stormwater facilities as Clean Water Services did with their Regional Stormwater Management Charge (RSMC).

Fees-in-lieu are allowed and collected per local codes to allow developments to move forward when physical constraints or other major obstacles prevent them from complying with the code as written. The revenue from these fees typically build over time and the amount of funds can vary depending on how quickly the jurisdiction uses those funds for already identified projects. Therefore, using fee-in-lieu for regional facilities may require a specific earmark to ensure the funds can be used for those projects.

Stormwater fees are collected as part of water and sewer service utility revenue and used specifically for surface water quality, stormwater conveyance, and repairs and upgrades to the storm drainage system.

Capital funding is funding raised through municipal bond sales to fund large public infrastructure improvements for example water and wastewater, roads and bridges, and public transit.

Typically, development code language would describe how these funding mechanisms would be integrated into the implementation of the regional stormwater facility. The funding solutions will vary by jurisdiction based on the circumstances of the new development, if capital funds are available, and how revenue is collected. For instance:

- If greenfield development with one property owner and one developer, the developer would ideally be following the codes and manual for incorporating regional stormwater facility along with funding/payment mechanisms outlined in the code. Or the jurisdiction could employ other tools to incentivize the developer or cost share with them to build the regional stormwater facility along with conveyance infrastructure.

- If infill development with several property owners and multiple developers, a SDC, a fee-in-lieu, or the establishment of a reimbursement district or local development district could be options. Each of these present pros and cons related to timing, process, and complexity. One key concern is the timeline for each development and any lags in connecting to the regional stormwater facility would extend timeline for reimbursements to either the jurisdiction or the initial developer who builds the regional stormwater facility.

Ultimately, the Public Works and Budget staff will need to review the scope of work, the results from the stormwater planning, cost estimates, and align it with the ultimate vision for the regional stormwater facility. Creating a new funding mechanism may be necessary to facilitate the regional facility implementation.

Investing in Design Standards

Design standards are often referenced in codes and therefore become requirements with respect to designing and implementing stormwater management controls. For regional facilities, Tigard's *Public Improvement Design Standards for River Terrace (2015)* stands out as a good example for these reasons:

- Allowed for implementation flexibility and exceptions.
  - Provided requirements for interim facilities to manage stormwater prior to the regional stormwater facility construction.
    - In addition to constructing the interim facility, the property owner would be required to contribute its fair share toward the construction of the future regional facility. The interim facility would need to be removed once the regional facility was operational, which would free up the land upon which it was located for development.
  - Includes provisions to allow flexibility for alternative solutions if the minimum requirements and community amenity design guidelines are followed.
  - Allows re-use facilities as a stormwater quantity reduction approach if it meets city approval.
- Funding strategy focused on serving near-term developments with goal of mitigating challenges inherent to the regional stormwater facility approach.
- The city's development review process encourages property owners to coordinate the design of regional stormwater facility with the design and construction of other improvements such as roads, parks, and natural resource mitigation in order to reduce overall costs.
- Easement or land acquisition is encouraged to begin ahead of development so that the location and design of high flow conveyance improvement can be implemented ahead of development or be ready for a developer to construct.
- Maintenance responsibilities are clearly defined in the standards. The City will maintain all regional, neighborhood LIDA, and street LIDA. Property owners and homeowners' associations will maintain site-level LIDA. Operation and maintenance plans are to be prepared for each facility and identifies which city agency or department will be responsible for each part of the facility.
- Clearly laid out process for Land Use, Engineering Plan, and Amenity Report and Landscape Plan approvals.

Section 4 contains resource documents from Tigard, Gresham, and Clean Water Services.

River Terrace Regional Stormwater Facility, Tigard

Section 3. Implementation

Jurisdictions that led with a robust stormwater planning process were more successful at implementing their plans and attracted developers willing to work with the cites to meet stormwater requirements. They were also able to successfully integrate community amenities with the regional stormwater approach.

Once necessary planning, code development, and/or design guidelines have been completed and funding mechanisms are clear, a jurisdiction would typically take the following steps toward implementation:

1. Jurisdiction adopts its stormwater plans and messages to development community that this approach will reduce/eliminate individual on-site stormwater quantity controls in exchange for a regional facility approach.

2. An implementation plan may be developed for larger, publicly led projects, or projects that have regulatory compliance and timeline implications.

3. Depending on how many developers are involved in the new growth area or specific development, the jurisdiction will either fund and build the regional stormwater facility or allow the developer to build the facilities are part of their projects.

4. Sequencing can be worked out with developers and allow for temporary facilities, if needed.

5. Developers will construct the adjacent conveyance infrastructure as part of the development project.

Section 4 has an example of an implementation plan from Redmond, Washington.

Developer-led implementation could also be successful, however it may necessitate certain circumstances that allow it to move forward in a well-coordinated manner. Reimbursement districts, local development districts or similar codes would need to be in place to facilitate this type of implementation.

If a developer wants to initiate the regional facility planning and design effort following typical Reimbursement District codes for example, the following scenarios could occur:

- Single developer sites, builds, and funds regional stormwater facility for the entire development; or
- Developer #1 builds regional stormwater facility and is reimbursed by Developer #2, #3, etc. if multiple developments rely on same regional stormwater facilities.
  - Temporary facilities would need to be allowed if Developer #2 or others' construction timeline were proceeding alongside Developer #1 or in advance of Developer #1.

This approach may be preferred if the jurisdiction is not able to fund construction of regional stormwater facility. While this approach eliminates capital costs to the jurisdiction, it could delay development projects and not necessarily incentivize developers to build regional stormwater facility as the jurisdiction-led process. Additionally, if multiple developers are involved, they would need to agree about the reimbursement structure and development timeline.

Section 4. Reference Documents from Portland Region

Planning for Regional Stormwater Facilities

These plans specifically stated the intent to utilize a regional stormwater management approach in these developments and worked to integrate those goals into the larger vision for the community. They also discussed feasibility, sizing, land uses, funding, and the preferred approach.

North Bethany Stormwater Implementation Plan, October 2013

South Hillsboro Community Plan, December 2014

Beaverton Creekside District Master Plan and Implementation Strategy, November 2014

River Terrace Stormwater Master Plan, December 2015

Development Code for Regional Stormwater Facilities

Below are some examples of code that speak directly to the implementation of regional stormwater facilities including the Washington County ordinance that authorized the various charges and fees that can be used to fund regional facilities.

River Terrace Plan District, Chapter 18.640, Tigard Municipal Code

- Ensured regional stormwater facilities were visible drainage features that mimic natural systems.
- Ensured public access around most of the facilities.
- Required landscape and amenity features that integrated the facilities into the open space design of the development.

North Bethany Alternative Partition Standards, Washington County Development Code

- Laid groundwork for property acquisitions critical to implementing regional stormwater facilities
- Once Clean Water Services had this in place, they were able to estimate budget for land acquisition and approach landowners with the assurance that the County would allow and approve the purchase

Clean Water Services, Ordinance 40, 2013

The purpose of this chapter is to authorize charges, rates and fees for construction of, use of, and discharge to, the public surface water management system.

Clean Water Services Rate and Charges, July 1, 2019-June 30, 2020

Refer to sections:

16. Regional Stormwater Management Charge (RSMC).

17. Fee-In-Lieu of Construction of Onsite Stormwater Management Approaches.

18. Reimbursement District Application Processing and Review Fees.

Design Standards and Guidelines for Regional Stormwater Facilities

Jurisdictions that have developed design standards for regional facility design and implementation in the region are:

Public Improvement Design Standards for River Terrace, City of Tigard, July 2015

Stormwater Management Manual, City of Gresham, October 2019

As a service district, Clean Water Services supports and encourages the use of regional stormwater facilities for water quality treatment and water quantity controls, as well as LIDA at the individual sites.

Clean Water Services Design and Construction Standards, 2019

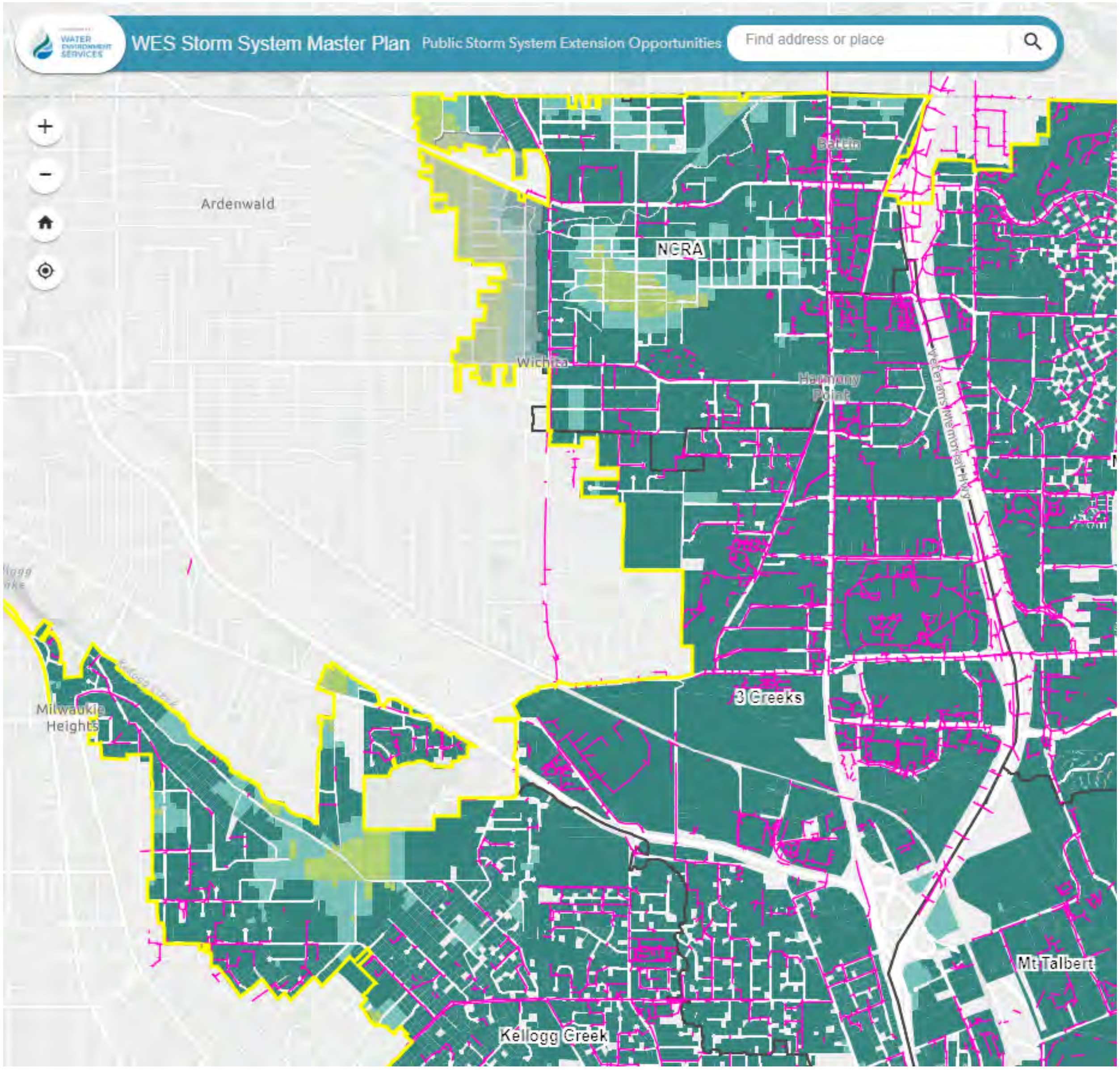
- Chapter 4 – Runoff Treatment and Control

Clean Water Services LIDA Handbook, 2016

Implementation Plans

Often jurisdictions development implementation plans that follow master plan documents. These provide assurances to city officials and regulators that the design and construction of the project(s) will be well considered and that the schedule will meet any compliance dates or other schedule targets.

Overlake Village Stormwater and Park Facilities Conceptual Design, June 2010



Online mapping tool for analysis

Clackamas Water Environment Services
Storm System Master Plan

Identifying Public Storm System Extension Opportunities

Final

Submitted to:

Clackamas County, Water Environment Services
150 Beavercreek Road
Oregon City, OR 97045

June 2022

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Project No. 19109

TABLE OF CONTENTS

Section 1. Introduction

The purpose of this white paper is to identify portions of the Planning Area for the WES Storm System Master Plan (SSMP) that may not have access to public storm system infrastructure. A lack of public storm system conveyances may present a barrier to development or redevelopment by requiring a storm system extension prior to construction. Public streets without public storm systems may drain poorly or not at all, which can impact road maintenance and street quality. The analysis is planning level and likely overestimates individual properties that may otherwise have drainage through private systems. The map may be used to target further investigations to firmly identify areas where a storm system service extension or improvement may be warranted.

Stormwater utilities are increasingly aware of the risks and limitations associated with lack of storm system infrastructure and are seeking ways to rectify immediate concerns while also creating medium- and long-term plans that would address these issues. In order to create plans and budget projections, WES can analyze the service district area and identify areas without storm system service that may be in need of storm system infrastructure.

As a first step, Otak developed a simple web-based mapping tool and methodology so that WES can locate these areas, assess the extent of the issues, and see adjacent infrastructure, as well as land use, zoning, and other helpful data on one map. This tool can be replicated and easily maintained for the District's use to drive policy initiatives, assist community development and planning staff, and prioritize capital projects.

This white paper describes the tool, the methodology, and the result of the initial analysis. It also provides information on how to maintain the map data and further analysis that could be completed in the future. This map encompasses the planning area of the SSMP, including the Service Area #2 (previously named Clackamas County Service District No. 1, or CCSD1) and Service Area #3 (previously named the Surface Water Management Agency of Clackamas County, or SWMACC) as well as specified adjacent planned growth areas. The planning area for the SSMP is non-contiguous and varies in system characteristics.

More details about the operation and maintenance of the web map are given in Section 4.

Section 2. Methodology

Data Sources

The following is a list of data used for the analysis and its source:

Table 1. Data Sources

Layer Name	Source	Year
Planning Area Boundary	Otak	2020
Study Areas	Otak	2020
Analysis Tax lots	Metro/Otak	2022
Planning Area Tax lots	Metro/Otak	2022
WES Service Area	WES	2020
PVNC Planning Area	Angelo Planning Group	2020
Storm Basins (Otak Update)	WES/Otak	2020

Layer Name	Source	Year
Streams	WES	2020
WES SSMP Known Issues (Points)	Otak	2020
SW Pipe	WES	2022
SW Ditch	WES	2020
SW Culvert	WES	2020
SW Inlet	WES	2020
SW Ctrl Vegetated	WES	2020
WES Detention Ponds	WES	2020
Popular Demographics in the United States – Block Group	ESRI	2020
2019 USA Average Household Income	ESRI	2019

Public Storm System Extension Opportunities Defining "Underserved"

For the purposes of this paper, a "public storm system extension opportunity" is defined as a private *residential* property that has a lot line that is more than 200 feet away from a public storm system conveyance.

Using the data listed above, Otak ran several queries to determine proximity from a storm system drainage pipe. The proximity analysis was performed on public storm pipes and sumps and excluded the following components of the system: culverts, inlets, detention and treatment facilities, and ditches. A lack of data relating to private drainage resulted in many properties being classified as a public storm system extension opportunity. Private drainage includes discharge to a waterway or to an onsite system, such as a drywell. The presence of private drainage indicates that offsite drainage *may* not be required in future development situations and any public improvements could continue to be served by direct discharge to a waterbody or by underground stormwater disposal (e.g. drywells). However, future use of private drainage is not assumed, and properties only served by drywells and no other public infrastructure were classified as a public storm system extension opportunity. Ditches were excluded because their ownership status is often not well documented and records regarding sizing and maintenance are not always available. In development situations, existing ditches may need to be upgraded along with street improvements. Presence of a mapped ditch is not an indication of local stormwater service.

Stormwater interceptors and pipes larger than 30 inches were also excluded as these systems do not typically provide local service (lateral connections to individual properties). Also excluded from the proximity analysis were rights of way, parks, and recreation areas as these types of properties and existing uses do not typically need new or expanded stormwater service.

This analysis focused simply on the presence of stormwater conveyance infrastructure and did not assess pipe capacity.

The tax lots were then classified by proximity to a public storm system conveyance system as follows:

- Well Served: Directly served by the existing storm system within 100 feet.
- Adequately Served: Within 100 to 200 feet.
- Potential Public Storm System Extension Opportunity: The nearest storm infrastructure more than 200 feet away.

Otak selected a threshold of 200 feet as distances of under 200 feet can typically be addressed with lateral extensions or minor sewer extensions as a condition of development. Distances beyond 200 feet would require a larger public works improvement to provide sewer within a reasonable distance for a property to be connected by service laterals. This analysis may underestimate storm system infrastructure service in two situations. First, areas identified for future growth may appear as a public storm system extension opportunity, but specific area plan or development requirements will likely address future service needs. Second, stormwater infrastructure in areas of recent development may not yet be reflected in the analysis. The proximity analysis was performed first on data from 2019 and 2020 and was updated with the most recent WES data in May 2022. The classification of potential public storm system extension opportunity areas may be verified through analysis of current stormwater infrastructure data and review of as-builts or other data from recent construction.

Map Description/Functionality

The mapping application was created using ArcGIS Online Web App Builder. The map is hosted online and does not require an ArcGIS license to access or view the map. Currently a password is not required, but password protection may be added.

ArcGIS web maps typically include the following functions that are very similar to the desktop software. These tools and functions help in exploring the data and analysis results and are in addition to the basic functions of the map such as pan, zoom, and search.

- Basemap Selection: Can be used to switch between aerial imagery, road maps, terrain, etc. to provide different basemaps depending on what the user wants to see.
- Selection/Summarize tools: Used to select multiple features at once to run data summary exports. For example, one could select multiple parcels in a given area and the summarize tool will report how many are selected and what attributes they have, etc.
- Layer Selection: This tool allows the user to turn layers on/off, change their transparency, turn their labels on/off, and view details about each layer.
- Print: This tool will print a quick PDF map of the area the map is zoomed to, complete with a title, legend, scale bar, and north arrow.
- Share: This gives a direct, short URL for sharing the map.

Users can also access the following tools:

- Measurement: Allows the user to measure area, distance, and X/Y coordinate locations.
- Editing: Allows the user to edit geometry and attributes of layers in the map. It will also allow the user to add new features to the layers.
- Draw: The draw tool allows the user to markup the map during their current session, leaving the markups until the map is closed. The user can draw points, lines, and polygons as well as place text in the map. It stores these markups in a temporary layer that will not be saved.

Section 3. Results

Key Observations

The mapping analysis revealed that the majority of CCSD1 is well served.

The results highlighted distinct clusters of potential public storm system extension opportunity areas. Four of these areas, listed below, have been identified due to the assumptions used in the analysis yet likely do not need extension of the public storm system.

- Near Scouter Mountain Natural Area (most northeastern cluster of properties), the map analysis captured recreation areas and open spaces (parks and cemeteries) and newer construction. Many of the identified properties are larger properties outside of the service district. These lots are not considered candidates for extension of public storm system at this time.
- An isolated island of properties near Lake Forest is partially outside of the service district. The area consists of large lots with onsite stormwater management, and the streets are served by drywells. This area is not currently a public storm system extension opportunity but could be if future stormwater standards change.
- Along the northwestern edge of the planning area adjacent in the Ardenwald/Lewellen area, most of the properties identified as a public storm system extension opportunity are outside of the service area and are currently served by drywells.
- SWMACC subdistrict areas which consist of large lots with onsite stormwater management. This area is not currently a public storm system extension opportunity but could be if future stormwater standards change.

Two areas are recommended for future study and planning to determine if properties are currently could benefit from extension of the public storm system or if the analysis indicates future risk. Figure 1 shows mapping analysis results and identifies the areas by number.

1. Northern area of the Kellogg Creek basin on the edge of the service district.
   It appears this area is a public storm system extension opportunity due to steep grades and is a densely forested area. This area is approximately 25 acres and includes 24 tax lots that are zoned R10 (residential). Properties may drain via private outfall to creek systems or have onsite drywells. Additional research is recommended to determine how properties are currently managing drainage and stormwater.

2. Western and central areas of North Clackamas Revitalization Area (NCRA).
   This is a known problem area for WES in terms of storm system infrastructure and was an expected result of the analysis. This area is approximately 25 acres and includes 122 tax lots that are zoned R7 (residential). While this result validates the approach and the results, additional research is recommended to determine how properties are currently managing drainage and stormwater.

Public Storm System Extension Opportunity Areas and CIP Rating Criteria

As part of the Capital Improvement Plan (CIP) development for the Storm System Master Plan, potential CIP projects are scored against rating criteria and then the top-rated projects are prioritized according to highest score. One of the rating criteria is whether the potential project provides new drainage or stormwater management to an area identified as public storm system extension. The scoring used a previous iteration of the underserved areas analysis which did not include some areas with new infrastructure. Three potential CIP projects were given a score for this criterion. They are listed below and shown on n Figure 1:

- NCRA Stormwater Plan (CIP ID 1606). Clackamas County hopes to encourage development in NCRA by improving and updating infrastructure. This analysis shows that there is a need for new storm water infrastructure (in addition to the planned retrofitting) in NCRA. If the NCRA Stormwater Plan is selected as a CIP, the public storm system extension opportunity areas analysis will be valuable in determining which areas to focus on providing storm infrastructure. This project would extend public storm systems to those properties.

- 130th/135th Ave Outfall/ Stormwater Treatment Facility (CIP ID 1028). If implemented, the 130th/135th Ave Outfall/ Stormwater Treatment Facility will treat and detain stormwater that discharges into the Clackamas River. The Clackamas River is a vital waterway for fish and other species in the area. The proposed stormwater facility would collect water from a large upstream basin that currently outfalls untreated or detained into the Clackamas River. This project does not extend storm system service.
- SE 172nd Ditch (CIP ID 1322). The SE 172nd Ditch project is an under-capacity ditch in the Pleasant Valley/North Carver area. It is currently outside WES jurisdiction, but it is expected to be annexed into WES in the near future. WES is currently determining the schedule for a planned improvement project for SE 172nd Avenue, which would eliminate the need for the ditch project. As identified in the 172nd/190th Corridor Plan, the new roadway alignment and improvements would increase capacity and includes a bridge replacing the culvert serving Rock Creek. The CIP ditch project would not extend public storm system service, but the planned improvement likely will.

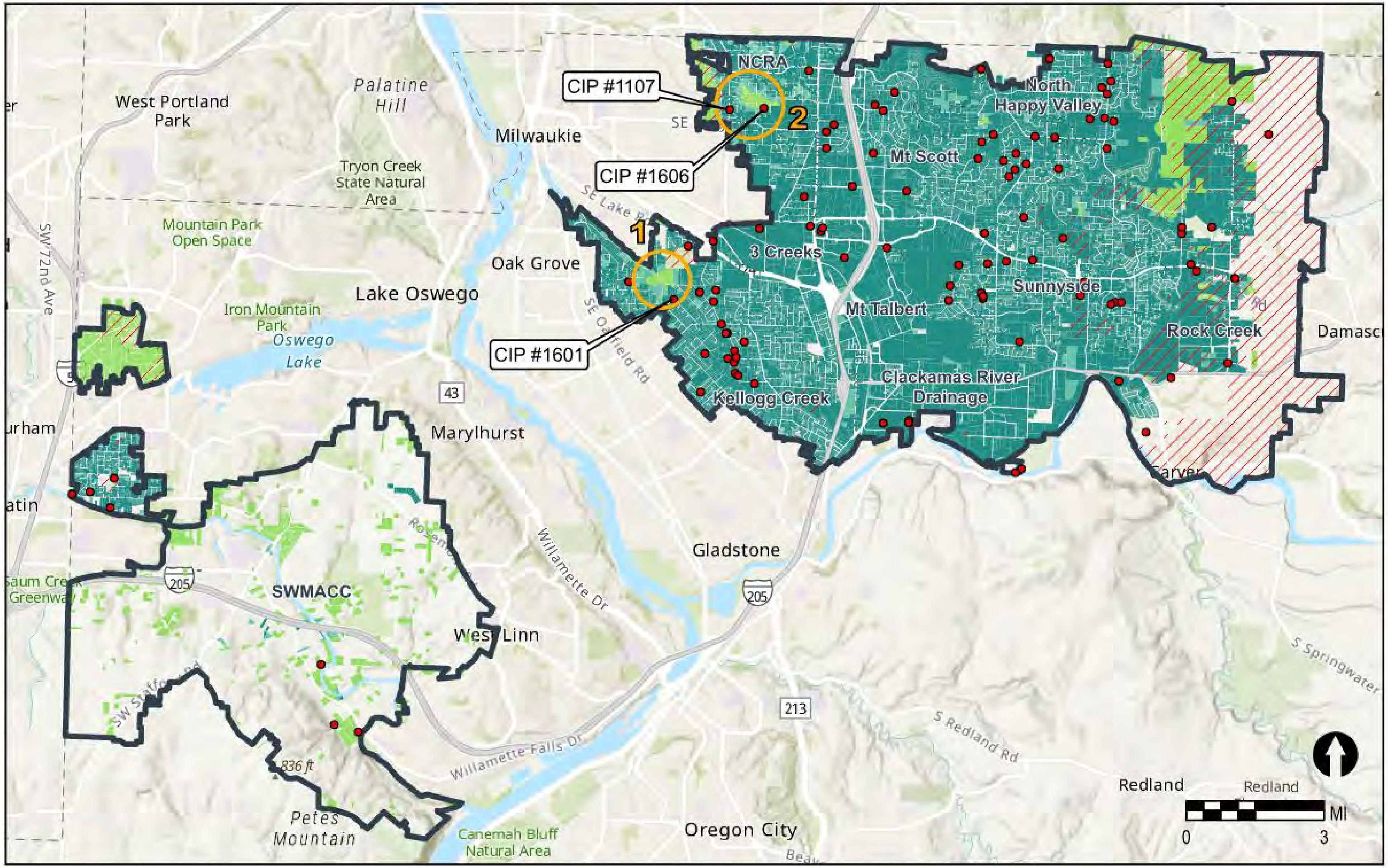

FIGURE 1

STORM SYSTEM EXTENSION OPPORTUNITY AREAS

CLACKAMAS COUNTY WATER ENVIRONMENT SERVICES
STORM SYSTEM MASTER PLAN

CLACKAMAS COUNTY | OREGON

- Potential Public Storm Sewer Extension Opportunity
- Adequately Served
- Well Served
- Confirmed Public Storm Sewer Extension Opportunities
- Planning Area
- Outside WES Service District
- Potential CIP Projects

Otak

CLACKAMAS WATER ENVIRONMENT SERVICES

Section 4. Maintenance and Future Uses of the Web Map

The web map is located online at this address: https://arcg.is/1meWHy0.

Map Maintenance

The web map was created using ArcGIS Online Web App Builder. It is currently hosted on Otak's ArcGIS Online account as a public application (viewable by anyone that has the direct link to the application) and is accessible to WES. The map can be transferred to WES using the ArcGIS Online Assistant so that WES can manage the map.

Requirements to fulfill this transfer are:

- An active ArcGIS Online account.
- Access given to Otak to transfer the application from Otak's account to WES's account.

The Online Assistant will transfer everything "as-is," which will preserve the symbology, labeling, queries, and layouts that you currently see in the application.

The application could live on the ArcGIS Online platform indefinitely and can be made public/private at WES' discretion. To stay active, the application will have to live on a current ArcGIS Online account that is up to date on its subscription. Otak will also keep a copy of the application for three (3) months upon delivery to WES. After three months following delivery, Otak will take down the web map hosted from the Otak account and archive the data and project files.

The data contained in the Public Storm System Extension Opportunities application also will be delivered to WES in geodatabase format.

The analysis data will not be updated automatically. For example, if the storm system data is updated and there are potentially changes to the analysis tax lots, the analysis will need to be done again. The analysis provided is a snapshot in time for when it was conducted.

Additional Analyses Using this Tool

WES will be able to utilize this map as a tool for other analysis with the current data or by easily adding other data. Possible analyses include:

- Distribution of detention ponds related to flooding, erosion, critical reaches, or other issues related to mitigating peak stormwater runoff.
- Parcel level analysis overlaid with demographic data to determine the relationships with various social indicators such as income, race, and age. This data can be added for free via ArcGIS Online and will require a login.
- Modifications to the methodology described here to create a more detailed tax lot-based analysis related to current issues or problem areas or future infrastructure planning.
- This map could easily assist in public outreach purposes to identify stakeholders based on future projects or sub-basin planning.

Clackamas Water Environment Services
Storm System Master Plan

Stormwater Credit White Paper

Final

Submitted to:

Clackamas County, Water Environment Services
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Section 1. Background

Clackamas Water Environment Services (WES) applies stormwater management standards at all development projects that result in 5,000 square feet or more of new impervious surface and/or a modification of existing impervious surfaces. These stormwater management standards include requirements for water quality treatment, infiltration/retention, and quantity/flow control; these requirements apply within Service Areas 2 and 3.

For some transportation projects that exceed the 5,000 square foot threshold, it is often cost prohibitive to design and construct stormwater facilities that meet the standards within the project area. This is most commonly an issue on smaller transportation projects that occur within relatively narrow right-of-way corridors. In such narrow spaces, the existing topography of the area being impacted may not drain to a feasible stormwater facility location. Maintenance projects can aggregate smaller areas into a programmatic improvement, such as curb ramps, where a single curb ramp may not exceed the threshold, but an entire intersection or the total number of curb ramps installed would exceed the threshold. For these projects, the cost to acquire right-of-way from adjacent landowners, the engineering design and construction costs of a stormwater facility, or creating small, dispersed stormwater facilities through the entire project area would likely make the overall project infeasible to complete. Projects that only involve sidewalk or curb ramp improvements are common project types where it can be difficult to meet the current standards.

Clackamas County Department of Transportation and Development (DTD) and the City of Happy Valley (City) are developing transportation projects and working with WES to implement approvable stormwater solutions. WES would like to review approaches for developing a stormwater credit or trading program for DTD and City transportation projects to provide additional flexibility in meeting stormwater management goals. Stormwater credit or trading can help ensure that no net negative impact occurs from project implementation.

While the terms stormwater credits, banking, or trading are often used interchangeably, each term has a distinct meaning. The overall concept recognizes that stormwater facilities have a quantifiable benefit that can be commodified. Stormwater facility capacity, in this case for water quality treatment, is the good being purchased. A stormwater facility with extra capacity generates a benefit, or “credits,” that can be sold, or “credited” to other projects. A project can also purchase stormwater credits prior to a specific stormwater facility being built. Proactive installation of stormwater facilities creates a “bank” of “stormwater credits” (aka “banking”) for future purchase. For example, a transportation project that is unable to meet stormwater requirements within the project extent may purchase stormwater credits to offset the project’s lack of stormwater management. The tracking and documentation of this credit transfer (or “trading”) ensures that the project and the stormwater facility are both eligible given predetermined standards. For the purposes of this white paper, the term stormwater credit will be used to describe the water quality capacity generated by a stormwater facility. The term stormwater banking will describe existing stormwater facilities that have available credits.

The desired outcomes of the stormwater credit program will be to foster development of approvable stormwater management solutions that provide protection to surface waters while reducing the costs of implementation on a specific project basis.

This white paper will provide options and recommendations that could be explored in more detail prior to instituting a formal agreement between WES and DTD/City.

Section 2. Off-site Stormwater Management Approaches

When implementing a stormwater credit program, a key component is allowing for a stormwater facility located outside of the project area to serve as mitigation for the project impacts. There are several approaches that can be taken for developing off-site stormwater facilities. The term off-site is used to describe a location outside of the project extent, such as on a different property or outside the limits of a public improvement project.

These approaches include:

- Oversized Stormwater Facilities: For projects that can more easily accommodate stormwater management facilities, the design can provide additional water quality treatment or flow control in excess of what the standards require. Future projects that are implemented by the same project owner and cannot accommodate on-site stormwater facilities, would be approvable due to the mitigation provided by the previously completed oversized facility.
- Retrofitting Existing Stormwater Facilities: WES, DTD, and the City could identify existing stormwater facilities that could be expanded or modified to accommodate additional stormwater volume or provide additional water quality treatment. This inventory could be used to incrementally improve stormwater facilities and accelerate retrofit or maintenance activities.
- Retrofitting Existing Development*:* WES, DTD, and the City could identify existing properties or sites that could be modified to add stormwater treatment. This could include maintenance yards, parking lots, or buildings and could be addressed as part of regular maintenance work or a small construction project.
- Voluntary Stormwater Facilities: WES project managers could proactively build stormwater facilities, either for projects that would not meet the threshold or to manage existing impervious area. The project would be able to offset the upfront costs by selling credits to future eligible projects. This would create a bank of stormwater credits. Additionally, WES could construct oversize facilities as part of their stormwater retrofit program and use the excess capacity as a stormwater bank.

- Equivalent Area Facilities*:* When stormwater facilities cannot be accommodated within the project extent, stormwater runoff from an equal size of impervious area could be managed by a new facility constructed that gets added to the scope of the project. This approach is already allowed by WES and is being implemented on projects, so equivalent area will not be evaluated further as part of a potential stormwater credit program.

When instituting a stormwater credit program, WES may choose to allow all the various management approaches or choose to prohibit those that do not lead to the desired outcomes of the program.

Special Considerations

There are several special considerations that should be reviewed when implementing the off-site stormwater management approaches listed above. These special considerations include:

- Spatial distance*:* If the stormwater facility is located too far away from the project site, the benefits may not adequately offset the project impact. For example, if the project is in a watershed that suffers from specific water quality or flooding issue, implementing a stormwater facility in a different watershed could lead to the existing problems being exacerbated following project completion.

  Thus, the stormwater credit program must include reasonable limitations in the spatial distance allowed between the project location and the mitigating off-site stormwater facility. A potential way to restrict the spatial distance is to require that the project be located in the same drainage basin (discharging to the same waterbody), as identified by hydrologic unit code (HUC).

  Even with selecting a the smallest HUC unit available (sub-watershed or 12-digit code level), there would still be a risk of a small uncategorized channel being impacted by the project's discharge but not receiving the benefit of the mitigation.

- Timing of impacts and mitigation*:* When federal stormwater regulators have jurisdiction over DTD and City transportation projects, they will require that the stormwater mitigation be constructed before or at the same time as the transportation project. This requires careful planning incorporated into the stormwater credit program. Project planning will need to proactively identify mitigation opportunities for upcoming transportation projects.

- It is likely there will be some risk associated with selecting mitigation opportunities and implementing mitigation projects prior to the completion of projects. For example, if a project changes scope (greater or fewer impacts), loses funding, or proves to be infeasible, then the mitigation project may have been implemented without being supported by credit trading. If that occurs, the facility could be considered a voluntary retrofit and available as a stormwater bank.

- Applicability for flow control: An off-site stormwater mitigation approach may be less feasible for flow control facilities. Unlike water quality limitations, which are typically required only on larger streams, increased flow (flooding, habitat degradation) results in impacts on larger and smaller streams. It will be important for a successful stormwater credit program to build in a requirement to assess capacity limitations in downstream conveyances, as well as assess flooding and habitat impacts in downstream open channels. Projects that are in drainage basins where flooding or habitat issues are identified should not be eligible for implementing off-site mitigation facilities for flow control unless the mitigation occurs in the same drainage basin and would provide mitigation to the same downstream system.

- If a basin has localized capacity issues or if flow control is required, then a project may not be eligible for stormwater credit trading. Often project designs include stormwater facilities that perform both water quality treatment and flow control. Separating these facilities may lead to increased costs. Further, the water quality facilities are usually less expensive and easier to fit into the right-of-way when compared to flow control facilities. These factors may lead to decreased interest in taking advantage of a stormwater credit trading program that cannot accommodate off-site flow control facilities.

- Priority redevelopment areas or goals: WES may be able to identify development and redevelopment goals (low-income housing, social service providers) or locations with physical constraints (soils, topography) where meeting stormwater regulations may add significant design or construction costs. To help spur redevelopment, WES could offer stormwater credits in lieu of building a stormwater facility if sufficient stormwater credits have been banked. Any proactive or publicly available program would need clear eligibility criteria and the development would need transferable conditions of approval.

Section 3. Potential Funding and Credit Trading Accounting Approaches

The following are potential approaches for funding the construction of stormwater facilities for credit banking as well as ways to conduct credit accounting as projects are completed. These approaches assume that WES will require a minimum one to one ratio for stormwater credit trading. This ratio means that for every unit area of impervious surface not treated within the project extent, a unit area of impervious surface is treated within the stormwater facility with available credits.

For these funding and credit accounting approaches, WES would keep track of the credits that are available for purchase (at individual stormwater facilities and within drainage basins) and the project areas that cannot be managed on-site. This tracking would be checked to make sure a ratio of one to one is maintained and that unused or available stormwater credits are available for future projects.

The potential funding and credit accounting approaches include:

- Project Owner Led Funding and Credit Accounting: The Project Owner (DTD or City) would lead the funding and credit accounting for both the project and the stormwater mitigation facility. The funding would be provided upfront by the owner to construct a stormwater management facility to be used as a bank and the credit would be realized by the owner when constructing the project without the need to include on-site stormwater facilities. When the Project Owner has control over both the project and the mitigation project, the mitigation stormwater facility should be constructed before or at the same time as the project to ensure no net negative impact to the drainage basin. In this approach, the Project Owner could include any credit tracking or administration costs in the costs for the project itself.

- WES Led Funding and Credit Accounting: WES would initiate the construction of a facility to be used as a stormwater credit bank using internal funding. This funding could come from a variety of sources including a dedicated use fund or rate payer fees. When a project cannot accommodate stormwater facilities on-site, the project owner would purchase credits from WES. This would allow WES to build up a robust bank of available stormwater credits and use the cost of the credits to support future stormwater facility installation and additional bank credits. WES could determine the stormwater credit eligibility of each individual stormwater facility or the total available credits within a drainage basin. Ideally, WES would have stormwater facilities and credits available for purchase prior to project design. Given careful planning, WES and the Project Owner could work together to construct the project and the stormwater facility concurrently. In this approach, WES could include overhead and administration costs in the value of the credits available for sale.

- Fee-in-lieu Program: Paying a fee instead of constructing a stormwater facility is another way to fund stormwater mitigation for projects that cannot accommodate on-site stormwater facilities. A fee-in-lieu program is a different concept in that the impacting project is constructed first and the collected fee is used to construct a mitigating project later or to purchase credits from an existing stormwater facility with available credits. A fee-in-lieu program could be a viable option for addressing the challenges DTD and the City face when implementing projects that cannot accommodate on-site stormwater. A fee-in-lieu approach can be useful when implemented similar to the WES-led funding and accounting approach and when there is a robust set of existing facilities. A WES-led funding and credit accounting approach could lead to a future fee-in-lieu program that standardizes the fee, eligibility, and application process. However, it is a different concept than stormwater credit banking, which is the primary focus of this white paper. With fee-in-lieu, the project location either needs to be in an area draining to an existing stormwater facility, or there is sufficient stormwater credit banked in the drainage basin for the project to purchase. In this approach, WES could include overhead and administration costs in determining the fee.

See Table 1 of credit trading applicability to each off-site stormwater management approach.

Table 1. Stormwater Facility and Credit Trading Approach Applicability

Approach Applicability	Project Led	WES Led	Fee-in-lieu
Oversized stormwater facilities	Preferred	Yes	Not preferred
Retrofitting existing stormwater facilities	Yes	Preferred	Not Preferred
Retrofitting existing development	Yes	Preferred	Not Preferred
Voluntary Stormwater Facilities	Yes	Preferred	Not Preferred
Equivalent Area Facilities	Yes	Yes	Not Preferred

Special Considerations

There are several special considerations that should be reviewed when implementing the funding and credit accounting approaches listed above. These special considerations include:

- As described above, it was assumed a credit ratio of one-to-one would be used for implementing stormwater credit banking. This is a good initial ratio to provide economic incentive for participation in the program. Other ratios could be considered, such as weighting for drainage basins with water quality limitations or geographic priorities. Similarly, a weighted approach could help provide additional incentive for the off-site mitigation facility to be in the same drainage basin. For example, if a small stream shows existing impacts from erosion, a larger stormwater facility could be built to provide net positive impact to the same drainage basin.

- One of the key challenges for WES to overcome will be the variability of supply and demand. WES will need to obtain the required funding to construct stormwater facilities for credit banking that will meet eligible projects' needs. Additionally, WES will need to determine criteria for when a project would be eligible for credit banking to ensure sufficient eligible stormwater credits remain available for future projects. This can be managed through careful planning with DTD and the City.

- Fee-in-lieu Program Challenges: A key challenge implementing a fee-in-lieu program will be making sure the fees collected are adequate to cover the costs of constructing stormwater facilities. There is an inherent risk associated with allowing the project to be constructed before the stormwater facility is in place. If the costs of implementing the stormwater prove to be higher than planned, WES may need to find additional funding from other sources to meet the stormwater credit obligation.

Section 4. Regulatory Context

When instituting a stormwater credit program, WES will need to take into consideration the requirements of the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit as well as the potential for a federal nexus over the impacting project. The following are stormwater credit program considerations related to these regulations:

- The NPDES MS4 permit includes specific conditions for Post-Construction Site Runoff that WES needs to meet through their stormwater requirements for development and redevelopment projects. Off-site stormwater facilities and stormwater mitigating banking is explicitly allowed as described in in Section 4.f.v. As the permit is renewed and revised, the language relating to off-site stormwater facilities should be reviewed for changes and/or additional restrictions.

- As part of Schedule B in the NPDES MS4 Permit, WES is required to implement a monitoring program to evaluate the stormwater management program effectiveness. This includes evaluation of specific pollutants for water quality limited water bodies that are listed on the Oregon Department of Environmental Quality (DEQ) 303(d) list or have an approved Total Maximum Daily Load (TMDL). For certain streams within the WES service area that are water quality limited and where stormwater credit trading has occurred, WES may need to re-evaluate eligibility criteria or credit trading ratios if the monitoring demonstrates that the previously implemented approach is not achieving intended goals.,

- Projects with a federal nexus will follow the requirements of the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) Endangered Species Act Section 7 Programmatic Conference and Biological Opinion commonly referred to as Standard Local Operating Procedures (SLOPES) for Stormwater, Transportation, or Utilities. When a project uses federal funding or requires federal permitting (Joint Permit Application) then SLOPES requirements will apply, and the stormwater management approach will be subject to NMFS review and approval. This affects a WES stormwater credit program in that WES approaches may not be acceptable to NMFS. As stated in the long form of the SLOPES title, NMFS will be reviewing the stormwater management plan for impacts to species protected under the Endangered Species Act.

Section 5. Approaches Taken by Other Local Jurisdictions

Stormwater credit trading is an approach being slowly adopted nationwide. Programs have been developed with specific goals in mind (phosphorus, sediment, capacity), or in combined sewer areas where subbasins have different flow control needs. Locally, the City of Portland and Washington County implement stormwater credit programs.

City of Portland

The City of Portland Bureau of Environmental Services (BES) implements a stormwater fee-in-lieu program for both public works projects and private development. Public improvement projects and private development projects may apply for a "Special Circumstances," in which they explain why a stormwater management facility is not feasible or needed at that location. BES reviews the request to determine potential downstream impacts, site specific stormwater requirements, and availability of existing infrastructure to manage the stormwater once it leaves the site. If the Special Circumstances is approved, the project pays a fee-in-lieu (the Offsite Management Fee) as part of the project. The fee is adopted every fiscal year as part of the annual budgeting process and is calculated by per square foot of impervious area not being treated for stormwater management.

Additionally, BES and the Portland Bureau of Transportation (PBOT) have negotiated specific categories of transportation and utility projects that do not have to install stormwater facilities. These projects, such as curb ramp installation or safety improvements, may trigger the 500 square foot threshold for stormwater management in total, but given the size or alignment of the work being done, could significantly increase the cost of the project. Given that these projects generally fall in categories of high priority safety (lighting, signals/signs, bike lanes), accessibility (curb ramps), or routine repair and maintenance (sidewalks, curbs) that can generally be done without an extensive engineering design process, PBOT and BES agreed to an approach that can meet needs of both bureaus. PBOT sets aside one percent of construction costs from specific categories of projects and transfers the total to BES at the end of every fiscal year for projects completed during that year. The allocation is known as the Percent for Green Program. The Portland Water Bureau also has a similar arrangement with BES for maintenance projects. This also reduces administrative burden on project managers and designers because the transfer is managed annually by finance staff, not by every project manager.

BES combines the fees received from the Special Circumstances Off-Site Management Fee and the Percent for Green costs and disburses the fees through a competitive grant process (Percent for Green Grants). Public and private projects are eligible to apply and must demonstrate that they are implementing more stormwater management than would be required or are voluntarily installing stormwater management facilities. Portland accounts for these stormwater projects implemented in their annual MS4 report.

Washington County

Washington County has an informal stormwater credit trading program, tracked internally and through a single spreadsheet. Where possible, project managers install more or larger stormwater facilities than required, creating a bank of available stormwater credit. Where stormwater project installation is limited by physical or other constraints, the project manager can consult the tracking spreadsheet to assign stormwater credit from the previously built stormwater facility.

Section 6. Other Program Considerations

As WES evaluates feasibility of a stormwater credit trading program, the following are key considerations and decisions that will help inform program development and implementation.

Project Eligibility

- Are there geographic areas or drainage basins in which a proposed project would not be eligible to request credits?
- Would an entire project be eligible, or just portions of a project?

- Who makes the technical determination that a project is eligible to request stormwater credits?
- Who makes the technical determination that stormwater management facilities are not feasible?
- Is there an appeal process for projects that request credits and are denied, either due to lack of credit availability or a determination that stormwater facilities should be included in the project scope?

Credit Accounting

- Who manages the list of eligible credits available for purchase and how is it accounted for in the MS4 permit?
- Are credits assumed to have a one-to-one ratio from project to mitigation, or will the credit ratio vary due to geography or drainage basin need?
- How is a credit calculated for purchase? Is it a standard fee (average cost of a stormwater facility construction per unit of stormwater management) or a specific facility fee (cost of the stormwater bank facility divided by the unit of stormwater managed)? Is it calculated using construction costs only or for the entire design/construction project?

Stormwater Credit Banking

- Will WES be able to install stormwater facilities proactively to have a bank of credits available, or will WES need to wait for credits to be purchased in order to install a stormwater facility?

Program Funding and Management

- Will each participating agency manage their own stormwater credit trading, or will there be a single point of contact and coordination?
- If so, how will the participating agencies cost-share for program coordination and related overhead?
- What are the various funding sources that will be used to fund the program administration? Will the cost of the credits need to cover overhead or staffing?

Any implementation should have clear goals and be designed to be aligned with stormwater and drainage master planning and permit compliance programs. Future adjustments to design standards and policies may be necessary to help project managers navigate program requirements in a transparent and consistent manner.

Appendix K

Pleasant Valley/North Carver Stormwater Infrastructure Plan

Technical Memorandum

To:	Leah Johanson, WES
From:	Karina Nordahl, PE Teresa Huntsinger, EI
Copies:	Trista Kobluskie; Kevin Timmins; File
Date:	April 9, 2020
Subject:	Pleasant Valley/North Carver Stormwater Infrastructure Plan - Final
Project No.:	19109

Introduction

Otak, Inc. is working with Clackamas County Water and Environment Services (WES) on the Happy Valley Stormwater Masterplan. The Pleasant Valley/North Carver (PVNC) area was recently brought into Happy Valley's urban growth boundary, and a Community Plan for the area must be completed before redevelopment of the area can occur. The City has many creeks and streams that will be impacted by development if stormwater runoff is not carefully managed. As part of the Masterplan development and the Community Plan, potential locations for regional stormwater ponds were identified to provide treatment and detention. This memorandum documents the process that was used to develop proposed locations and sizes for regional stormwater facilities in the Pleasant Valley/North Carver district of Happy Valley in Clackamas County. Adding low-impact development strategies upstream of the regional ponds could reduce their required size but was not included in the analysis.

Stormwater Management Strategy

This memorandum reflects stormwater facility recommendations (size and location) for a stormwater management strategy that relies primarily on the use of regional facilities to serve the future PVNC area. The use of regional facilities is efficient and desirable from an overall land availability and long-term operations perspective but presents certain challenges to implementation. These challenges can include:

- Timing and location of development
- Availability of funding
- Timing of conveyance infrastructure
- Land/easement acquisition

While these challenges have been overcome in other areas, Clackamas County has previously had mixed results at implementing a regional facility approach. New policies and procedures will be required to allow implementation of this regional approach.

Regional stormwater ponds were not added to areas with existing residential developments. In areas that are not shown to be served by regional facilities, stormwater will be managed on a site by site basis as infill redevelopment occurs.

In the North Carver Waterfront District, a new conveyance system will be constructed to discharge stormwater to the Clackamas River. The Clackamas River is large enough that undetained stormwater flows do not significantly impact its channel stability, so flow control is not required. Water quality treatment will still be required and will be provided on a site by site basis in this district.

Design Standards

Development in the Clackamas County Service District No. 1, which includes City of Happy Valley and portions of urban unincorporated Clackamas County, is subject to CCSD No. 1 Stormwater Standards (Clackamas County, 2013), established by WES. WES is currently in the process of updating its design standards and has indicated that its new standards will match those currently used in the WES BMP Tool. The WES BMP Tool was developed in 2010 based on Clackamas County conditions and was adopted by the cities of Wilsonville and Oregon City but has yet to be adopted by Clackamas County. The BMP tool is based off continuous simulation modeling and long-term rainfall data rather than standard (i.e. 24-hour) synthetic design storms. The BMP Tool was used for this conceptual, planning-level stage of design to develop rough estimates of how much land would need to be dedicated to establish regional stormwater facilities. More detailed hydrologic modeling will be required at later stages of facility design.

Following are the design assumptions that were used to size regional stormwater facilities. The facilities were sized to provide both water quality treatment and flow control.

Water Quality Treatment

The WES BMP Tool sizes facilities for treatment of 80 percent of the average annual runoff based on continuous simulation modeling. A 1-inch, 24-hour design storm represents 80 percent of average annual runoff in Clackamas County. The detention pond design in the WES BMP Tool provides water quality treatment as well as detention.

Flow Control

The WES BMP Tool sizes detention ponds such that the flow duration curve from the pond outflow will be equal to or lower than the flow duration curve representing pre-project conditions for flows ranging from 42 percent of the 2-year peak flow to the 10-year peak flow. WES current standards require that the 2-year post-developed runoff rate equal half of the 2-year, 24-hour pre-developed runoff rate.

Pre-Developed Conditions

WES defines pre-developed conditions as the conditions at the site immediately before application for development. Thus, the existing site land uses were used to estimate what portion of each basin was forest, grass, or impervious in existing conditions for the BMP Tool.

Infiltration Standard

WES standards require infiltration of all runoff from storm events up to one-half inch of rainfall in 24 hours. The WES BMP Tool does not have an infiltration standard; however, native soil infiltration rates are taken into account in sizing the facility to meet flow control standards.

Existing and Proposed Conditions

Existing and proposed land use GIS data was received from Angelo Planning Group. The proposed land uses for sizing the regional stormwater ponds were based on Angelo Planning's October 1, 2019 Refined Land Use Designations. In March 2020 the land use designations and zoning were updated and recommended for adoption by the City Council. There are minor discrepancies between the two versions of proposed land use plans. Figure 1 shows the most recent zoning to match the rest of the documentation prepared by Angelo Planning Group. Our calculations are based on the October 1, 2019 land use designations and were not revised because the changes were small and within the accuracy of our previous calculations.

The Pleasant Valley/North Carver Comprehensive Plan Area includes a variety of existing and proposed land uses ranging from agriculture and low density rural residential to a range of residential land use densities and some commercial and employment areas. Portions of the area, particularly to the south, have already been developed to proposed densities, other areas are proposed to remain very low density residential, and still others are proposed to become much more densely developed than current conditions. Regional stormwater ponds have been located in the areas where substantial new development is proposed. In areas where development has occurred recently, it is assumed that stormwater infrastructure is already in place and additional stormwater ponds would be constructed site by site, on an as needed basis.

The study area is transected by many creeks that are tributaries of Rock Creek, which flows south to the Clackamas River. Portions of the area have very steep slopes that have been identified as conservation areas where little to no future development will occur. The study area has Hydrologic Soil Group Type C and D soils which are characterized by moderate to low infiltration rates.

A site visit was conducted to confirm that the proposed pond locations are suitable, and adjustments were made to pond locations as necessary. The pond locations are in gently sloping areas and some have potential for creation of greenspace in addition to the pond. Some locations have existing buildings that will likely be removed as development occurs.

Hydrology

The proposed regional stormwater basins were delineated using existing 10-foot contours and stream locations provided by WES, as well as proposed tax lots and street locations provided by Angelo Planning. Areas where existing development already matches proposed densities were delineated using aerial photography. The proposed regional stormwater basins were created only in areas that are not yet developed to their proposed densities (see Figure 1). Existing and proposed impervious areas of the regional basins are outlined in Table 1.

Table 1—Regional Stormwater Basin Areas

Basin	Existing Impervious Area (ac)	Existing Pervious Area (ac)	Proposed Impervious Area (ac)	Proposed Pervious Area (ac)	Total Basin Area (ac)	Storage Volume* (cf)	Pond Area** (ac)	Pond Percent of Basin Area
A	8.5	123.6	60.2	71.9	132.1	180,209	1.1	0.9%
B	16.3	123.0	74.0	65.3	139.3	333,912	2.0	1.4%
C	2.5	31.2	21.1	12.6	33.6	109,575	0.7	2.2%
D	0.5	34.6	18.8	16.3	35.1	54,739	0.4	1.2%
E	2.4	25.9	17.6	10.7	28.3	52,249	0.4	1.4%
F	7.3	126.5	39.1	94.7	133.8	170,735	1.1	0.8%
G	7.1	134.0	80.4	60.6	141.1	397,080	2.4	1.7%
H	1.9	44.9	29.8	16.9	46.8	68,987	0.5	1.1%
I	12.0	127.8	69.9	69.9	139.7	284,753	1.7	1.2%
J	2.0	36.0	19.3	18.8	38.0	54,936	0.4	1.1%
K	7.7	77.2	45.3	39.6	84.9	178,988	1.1	1.3%
L	2.0	76.7	39.4	39.4	78.7	193,549	1.2	1.6%
M	2.6	22.9	14.0	11.5	25.6	66,782	0.5	1.9%
N	1.0	65.5	27.8	38.7	66.5	132,638	0.9	1.3%

**Storage volume includes the pond volume plus water storage in the three feet of soil media at the bottom of the facility assuming 40% porosity.*
***Pond area includes the pond surface area plus 1 foot of freeboard at 3:1 side slopes and 15% additional area for maintenance access, fencing, etc.*

Existing and proposed impervious areas of each basin were estimated based on the existing and proposed land use types, the average number of residential units per acre associated with those land uses, and corresponding average impervious area percentages.

Land use types were associated with units per acre based on two sources: an impervious area study from Clackamas County, and measurements based on aerial photography of the region. The impervious area study from Clackamas County (Murdock, 2005) was conducted as part of the Damascus area Urban Growth Boundary expansion. Clackamas County analyzed the impervious area percentages of numerous neighborhoods with various units per acre representative of current and future development in the area. Average impervious area percentages were selected from the study for land uses with similar units per acre for this analysis. The data from the study is provided as an attachment. Existing and proposed land uses and their associated units per acre and impervious area percentages are shown in Table 2.

Table 2—Impervious Area and Land Use Density

Land Use Description (Zoning)	Density (units/acre)	Impervious Area Percentage
Existing Land Uses		
Agriculture	0.12	2%
Commercial	N/A	70%
Forest	0.01	1%
Industrial	N/A	60%
Multi-Family Residential	0.5	10%
Rural Residential	0.3	10%
Single Family Residential	1	15%
Vacant	N/A	0%
Road	N/A	1%
Proposed Land Uses (Proposed Zoning)		
Very Low Density Residential (R-15, R-20)	2.5	25%
Low Density Residential (R-7, R-8.5, R-10)	5.2	45%
Medium Density Residential (R-5, MUR-S)	8.7	50%
High Density Residential (MUR-A, SFA)	15	60%
Mixed Use Residential (MUR-M1, MUR-M2, MUR-X)	25	65%
Employment (EC, IC)	N/A	70%
Community Commercial Center (CCC)	24	70%
Mixed Commercial Center (MCC)	24	70%
Institutional and Public Use (IPU)	N/A	30%
Road	N/A	100%

Basins F, H, L and M contain significant areas of steep conservation slope areas that Angelo Planning indicated will be unbuildable (purple areas in Figure 1). However, 2 units per acre may be transferred from conservation slope areas to other developable lands. The methodology for calculating proposed impervious area was modified for these four basins. The conservation slope areas in these basins, which are currently forested, remain forested in proposed conditions. Two additional units per acre of conservation slopes were added to the developable lands in the basin, resulting in a slight increase in density for the developable areas.

Hydraulics

Existing and proposed basin areas were entered into the WES BMP Tool to calculate the minimum detention pond sizes. Detention ponds were designed with 3:1 side slopes and 4 feet of active storage. The WES BMP Tool includes 3 feet of soil media depth, so the total pond depth used in the tool was 7 feet. Pond infiltration rates in the tool were selected based on the NRCS Hydrologic Soil Group (HSG) at the proposed pond location. The output report from the BMP Tool is provided in Appendix B.

Minimum pond surface areas for each basin are provided in Table 1, above. These areas include the freeboard area which is not included in the WES BMP Tool and an additional 15% surface area for maintenance access, fencing, grading to existing surfaces, etc. The pond sizes range from 0.8 percent to 2.2 percent of the basin area, depending on the area's existing conditions, proposed land use, and soil types. For planning purposes, a sizing factor of 2.2 percent of basin area can be used as a rule of thumb to estimate how much land to set aside for regional stormwater facilities.

Cost

A cost estimate was prepared for each of the regional stormwater ponds and the North Carver Waterfront District conveyance system. The cost estimates include work and materials necessary to construct the pond (including plantings), an access road, and flow control structures. Preliminary engineering, permitting, and construction engineering are listed separately and are based on a percentage of the construction cost of the pond. WES recommended a land acquisition cost of $85,000 per acre. The land/easement acquisition, staff time, and appraisal costs are included in the total implementation costs. The storm sewer conveyance system upstream of the stormwater ponds is assumed be developer designed and funded infrastructure. The total estimated cost for regional stormwater infrastructure included for the PVNC area is summarized in Table 3.

Table 3—Regional Stormwater Infrastructure Total Cost Summary

	Costs*
Construction	$15,214,000
Engineering/Permitting	$6,846,000
Land Acquisition	$1,901,000
Total	**$23,961,000**

**Costs have been rounded*

A detailed breakdown of the Regional Stormwater Infrastructure Total Cost Summary is attached.

Conclusions

Preliminary sizes and locations were developed for 14 regional stormwater facilities in the Pleasant Valley/North Carver District using the WES BMP Sizing Tool. The pond sizes range from 0.4 acres to 2.1 acres, including area for maintenance access and freeboard, and they are all less than 2.2 percent of the area of the basin that drains to them. Establishing regional stormwater facility locations during planning for the area will facilitate future development of the area.

References

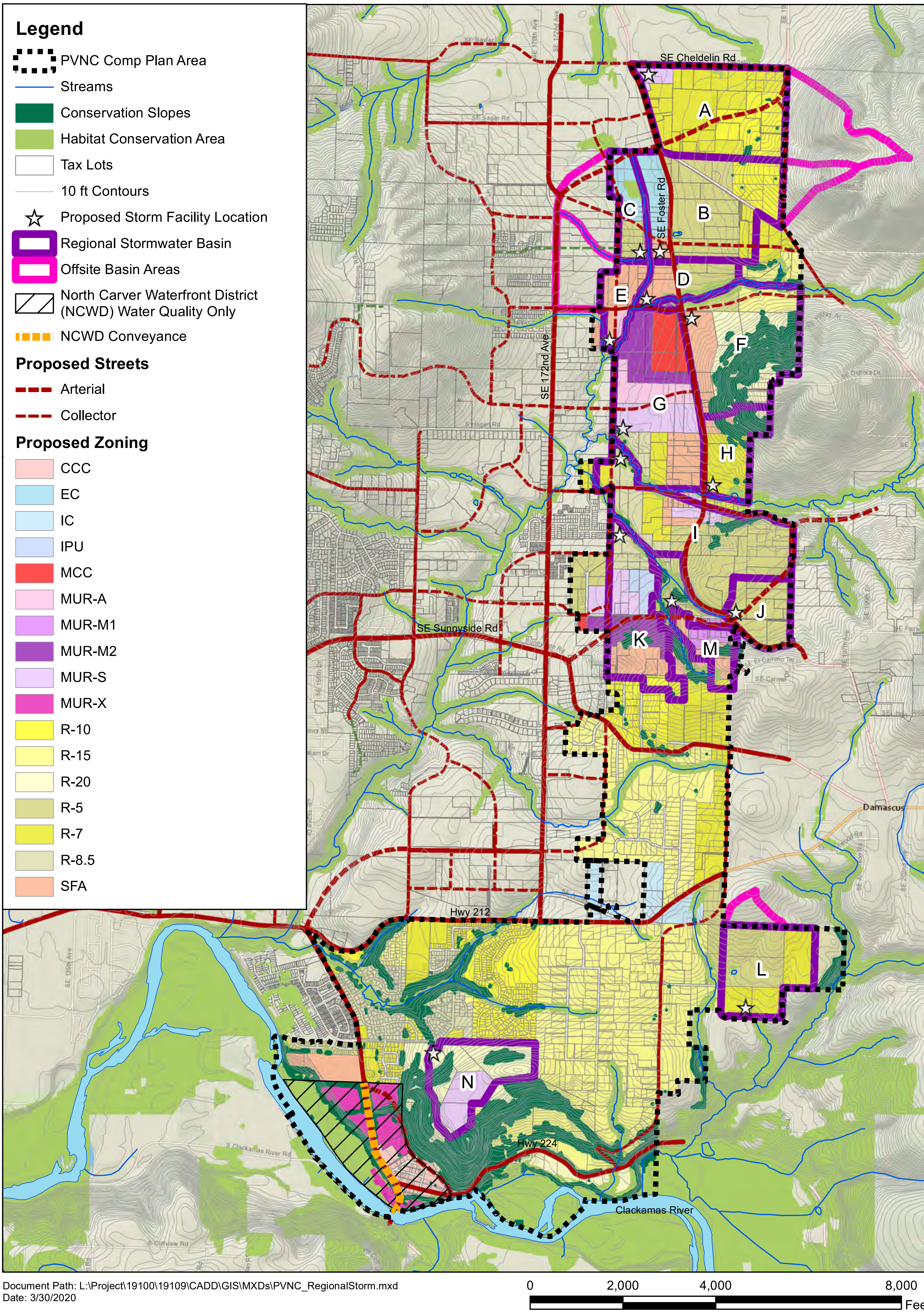
Clackamas County, 2013. *Stormwater Standards: Clackamas County Service District No. 1*. Clackamas County and Water Environment Services. July 1, 2013.

Murdock, 2005. Results of evaluation and analysis of impervious surface and current and future land use types in CCSD#1 and the Damascus UGB expansion area. Memo from Carol Murdock, Clackamas WES to Ted Kyle, Clackamas WES. July 26, 2005.

Wilsonville, 2017. *User's Guide for the BMP Sizing Tool*. City of Wilsonville and City of Oregon City. Revised December 2017.

Attachments

- Figure 1. Pleasant Valley / North Carver Stormwater Infrastructure Plan
- Cost estimates
- Background Information: Clackamas WES impervious surface data
- Hydraulics: WES BMP Tool Sizing Report



Document Path: L:\Project\19100\19109\CADD\GIS\MXDs\PVNC_RegionalStorm.mxd
Date: 3/30/2020

Basin	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Pond Area (ac)	1.1	2.0	0.7	0.4	0.4	1.1	2.4	0.5	1.7	0.4	1.1	1.2	0.5	0.9

Otak

Figure 1. Pleasant Valley / North Carver Stormwater Infrastructure Plan

PLEASANT VALLEY / NORTH CARVER

Regional Stormwater Infrastructure Cost Estimate (prepared in 2020)

ITEM DESCRIPTION	UNIT	UNIT PRICE	REGIONAL PONDS														NCWD Conveyance	TOTALS
			A	B	C	D	E	F	G	H	I	J	K	L	M	N		
MOBILIZATION		10%	$108,093	$190,238	$69,858	$38,466	$38,260	$102,990	$223,771	$47,574	$164,067	$39,763	$107,436	$115,266	$46,353	$82,122	$147,100	$1,521,359
TEMPORARY TRAFFIC CONTROL		2%	$21,619	$38,048	$13,972	$7,693	$7,652	$20,598	$44,754	$9,515	$32,813	$7,953	$21,487	$23,053	$9,271	$16,424	$29,420	$304,272
TEMPORARY EROSION CONTROL		2%	$21,619	$38,048	$13,972	$7,693	$7,652	$20,598	$44,754	$9,515	$32,813	$7,953	$21,487	$23,053	$9,271	$16,424	$29,420	$304,272
CLEARING AND GRUBBING		1%	$10,809	$19,024	$6,986	$3,847	$3,826	$10,299	$22,377	$4,757	$16,407	$3,976	$10,744	$11,527	$4,635	$8,212	$0	$137,426
EXCAVATION & GRADING	CY	$20	$205,527	$379,766	$125,596	$60,883	$60,883	$194,798	$451,438	$79,751	$324,009	$63,910	$204,144	$220,634	$77,265	$151,677	$0	$2,600,280
WATER QUALITY SOIL MEDIA	CY	$45	$108,868	$190,455	$70,217	$37,502	$37,502	$103,746	$223,446	$47,265	$164,603	$39,087	$108,209	$116,055	$45,993	$82,970	$0	$1,375,916
BIODEGRADABLE GEOTEXTILE	SY	$6	$27,386	$48,604	$17,407	$9,417	$9,045	$26,060	$57,218	$11,528	$41,865	$9,447	$27,215	$29,249	$11,203	$20,692	$0	$346,337
DRAIN ROCK	CY	$50	$71,717	$144,414	$39,728	$15,408	$15,408	$67,350	$174,950	$22,250	$120,867	$16,486	$71,153	$77,894	$21,333	$50,008	$0	$908,967
PRE-TREATMENT DEVICE	EA	$11,200	$11,200	$11,200	$11,200	$11,200	$11,200	$11,200	$11,200	$11,200	$11,200	$11,200	$11,200	$11,200	$11,200	$11,200	$0	$156,800
DITCH INLET	EA	$1,800	$1,800	$1,800	$1,800	$1,800	$1,800	$1,800	$1,800	$1,800	$1,800	$1,800	$1,800	$1,800	$1,800	$1,800	$0	$25,200
MAINTENANCE ACCESS ROAD	SF	$4	$16,694	$22,081	$13,407	$9,798	$9,798	$16,297	$23,917	$11,000	$20,528	$10,003	$16,644	$17,237	$10,851	$14,574	$0	$212,829
FLOW CONTROL MANHOLE	EA	$14,280	$14,280	$14,280	$14,280	$14,280	$14,280	$14,280	$14,280	$14,280	$14,280	$14,280	$14,280	$14,280	$14,280	$14,280	$0	$199,920
CONCRETE MANHOLE - 48" W BIRDCAGE TOP	EA	$6,400	$6,400	$6,400	$6,400	$6,400	$6,400	$6,400	$6,400	$6,400	$6,400	$6,400	$6,400	$6,400	$6,400	$6,400	$0	$89,600
6" PERF PIPE	LF	$40	$6,427	$9,120	$4,784	$2,979	$2,979	$6,228	$10,038	$3,580	$8,344	$3,082	$6,402	$6,698	$3,505	$5,367	$0	$79,534
SMALL SHRUB (1-GAL.)	EA	$22	$36,150	$64,157	$22,978	$12,431	$11,939	$34,399	$75,528	$15,217	$55,262	$12,470	$35,924	$38,608	$14,788	$27,313	$0	$457,164
LARGE SHURB/SMALL TREE (2-GAL.)	EA	$27	$33,274	$59,054	$21,150	$11,442	$10,989	$31,663	$69,520	$14,007	$50,866	$11,478	$33,067	$35,537	$13,612	$25,141	$0	$420,799
DEC. TREES (1" CAL.)	EA	$305	$7,528	$9,992	$6,026	$2,668	$4,373	$7,345	$10,832	$4,922	$9,282	$4,467	$7,505	$7,774	$4,856	$4,856	$0	$92,426
GROUND COVER (SP #4)	EA	$2	$94,482	$167,684	$60,055	$32,490	$31,204	$89,907	$197,402	$39,772	$144,435	$32,591	$93,893	$100,908	$38,652	$71,387	$0	$1,194,862
SEEDING	AC	$7,500	$7,073	$12,553	$4,496	$2,432	$2,336	$6,730	$14,777	$2,977	$10,812	$2,440	$7,029	$7,554	$2,893	$5,344	$0	$89,446
TEMPORARY IRRIGATION	SF	$0.50	$20,540	$36,453	$13,056	$7,063	$6,784	$19,545	$42,914	$8,646	$31,399	$7,085	$20,412	$21,937	$8,403	$15,519	$0	$259,753
CONCRETE MANHOLE - 60"	EA	$5,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$45,000	$45,000
24 INCH STORM SEW PIPE, 20 FT	LF	$180	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$266,400	$266,400
30 INCH STORM SEW PIPE, 10 FT	LF	$195	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$288,600	$288,600
36 INCH STORM SEW PIPE, 20 FT	LF	$220	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$325,600	$325,600
CONSTRUCTION CONTINGENCY		30%	$249,445	$439,011	$161,210	$88,768	$88,293	$237,670	$516,395	$109,787	$378,616	$91,761	$247,928	$265,999	$106,969	$189,513	$339,462	$3,510,828
TOTAL CONSTRUCTION COSTS			**$1,080,930**	**$1,902,381**	**$698,575**	**$384,662**	**$382,605**	**$1,029,905**	**$2,237,711**	**$475,742**	**$1,640,669**	**$397,631**	**$1,074,357**	**$1,152,663**	**$463,534**	**$821,225**	**$1,471,002**	**$15,213,590**
PRELIMINARY ENGINEERING		20%	$216,186	$380,476	$139,715	$76,932	$76,521	$205,981	$447,542	$95,148	$328,134	$79,526	$214,871	$230,533	$92,707	$164,245	$294,200	$3,042,718
PERMITTING		5%	$54,046	$95,119	$34,929	$19,233	$19,130	$51,495	$111,886	$23,787	$82,033	$19,882	$53,718	$57,633	$23,177	$41,061	$73,550	$760,680
CONSTRUCTION ENGINEERING		20%	$216,186	$380,476	$139,715	$76,932	$76,521	$205,981	$447,542	$95,148	$328,134	$79,526	$214,871	$230,533	$92,707	$164,245	$294,200	$3,042,718
TOTAL (WITH ENGINEERING & PERMITTING)			**$1,567,348**	**$2,758,453**	**$1,012,934**	**$557,759**	**$554,777**	**$1,493,362**	**$3,244,682**	**$689,825**	**$2,378,970**	**$576,564**	**$1,557,817**	**$1,671,362**	**$672,124**	**$1,190,776**	**$2,132,954**	**$22,059,706**
LAND/EASEMENT ACQUISITION	AC	$85,000	$121,055	$207,257	$79,751	$44,267	$44,267	$115,605	$241,897	$54,935	$180,040	$46,005	$120,354	$128,691	$53,550	$93,431	$0	$1,531,104
STAFFING COSTS	LS	1	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$300,000
APPRAISAL COSTS	LS	1	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$0	$70,000
TOTAL IMPLEMENTATION			**$1,713,403**	**$2,990,709**	**$1,117,685**	**$627,027**	**$624,044**	**$1,633,967**	**$3,511,578**	**$769,760**	**$2,584,009**	**$647,569**	**$1,703,171**	**$1,825,053**	**$750,673**	**$1,309,207**	**$2,152,954**	**$23,960,810**

Impervious Surface Analysis For Existing Land Use Polygons
Recreated From WES Impervious Area Memorandum (July 2005)

ID	DESCRIPTION	TOTAL AC	DWELLINGS PER ACRE	PAVED ROAD	DRIVE/PARK	SIDEWALKS	BUILDINGS	OTHER	TOTAL IA (SF)	TOTAL IA (AC)	PERCENT IA	TOTAL IA NO ROADS	TOTAL IA NO ROADS (AC)	PERCENT IA NO ROADS
1	RESIDENTIAL A/SMALL LOT	62	10.45	131555	575464	91992	619308	34670	1452989	33.36	53.8%	1321434	30.34	48.9%
2	RESIDENTIAL A/ASF	13	14.77	30195	106773	8223	110800	14580	270571	6.21	47.8%	240376	5.52	42.4%
3	RESIDENTIAL B	14	9.57	3668	193492	28766	130441	22642	379009	8.70	62.1%	375341	8.62	61.5%
4	RESIDENTIAL C/VERY LARGE LOT	106	4.29	609255	347950	171086	863147	217085	2208523	50.70	47.8%	1599268	36.71	34.6%
5	RESIDENTIAL C/VERY LARGE LOT	138	4.34	716247	410622	153201	1045434	222733	2548237	58.50	42.4%	1831990	42.06	30.5%
6	SCHOOL	54	0	5687	359646	126923	328951	38304	859511	19.73	36.5%	853824	19.60	36.3%
7	RESIDENTIAL C/LARGE LOT	109	4.98	568762	396184	40120	987192	166069	2158327	49.55	45.5%	1589565	36.49	33.5%
8	LOW DENSITY RES GREEN/VERY LG LOT	43	3.23	55660	140568	3104	186621	37034	422987	9.71	22.6%	367327	8.43	19.6%
9	RESIDENTIAL C/ESTATE LOT	134	2.66	532448	360373	169491	824712	192958	2079982	47.75	35.6%	1547534	35.53	26.5%
10	RESIDENTIAL C/VERY LG LOT	153	3.24	743097	487212	215065	1200609	217366	2863349	65.73	43.0%	2120252	48.67	31.8%
11	VERY LOW EXECUTIVE/ESTATE	95	0.84	145766	202663	29782	212618	80424	671253	15.41	16.2%	525487	12.06	12.7%
12	INDUSTRIAL MIXED EMPLOYMENT/RSIA	135	0	196906	2122245	30986	1703807	84035	4137979	94.99	70.4%	3941073	90.47	67.0%
13	INDUSTRIAL MIXED EMPLOYMENT/RSIA	319	0	647347	5179173	116062	4158609	47791	10148982	232.99	73.0%	9501635	218.13	68.4%
14	INDUSTRIAL	24	0	57315	326744	12146	251693	2899	650797	14.94	62.3%	593482	13.62	56.8%
15	INDUSTRIAL RSIA	161	0	355380	2607384	69053	1745714	105839	4883370	112.11	69.6%	4527990	103.95	64.6%
16	CORRIDOR	37	14.22	125909	334743	53339	384051	76495	974537	22.37	60.5%	848628	19.48	52.7%
17	NEIGHBORHOOD CENTER	207	4.81	1322269	849032	446174	1853472	190557	4661504	107.01	51.7%	3339235	76.66	37.0%
18	EMPLOYMENT 1A/1B/TOWN CENTER	215	0	1679977	3568011	254100	1654172	160367	7316627	167.97	78.1%	5636650	129.40	60.2%
19	EMPLOYMENT 1A/1B	31	0	149945	572815	67246	200898	20213	1011117	23.21	74.9%	861172	19.77	63.8%
20	EMPLOYMENT 1A/1B	32	0	87879	282999	25161	228577	13995	638611	14.66	45.8%	550732	12.64	39.5%
21	EMPLOYMENT 1A/1B	33	0	140478	664324	60309	288063	19444	1172618	26.92	81.6%	1032140	23.69	71.8%
22	EMPLOYMENT 1A/1B	56	0	173956	840236	174700	489090	20962	1698944	39.00	69.6%	1524988	35.01	62.5%
23	LARGE FORMAT RETAIL	183	0	903219	3552945	250183	1681577	175835	6563759	150.68	82.3%	5660540	129.95	71.0%
24	TRAILER PARK	44	7.44	201982	122843	10334	351638	106725	793522	18.22	41.4%	591540	13.58	30.9%
25	APARTMENT/RES A1/MDF	59	25.47	96523	618953	127604	730785	22567	1596432	36.65	62.1%	1499909	34.43	58.4%
26	LOW DENSITY GREEN STREET OLDER/C	169	3.69	842052	688351	45593	1232285	208349	3016630	69.25	41.0%	2174578	49.92	29.5%
27	VERY LOW DENSITY RURAL RES/C	38	3.85	180366	119688	11383	300149	53379	664965	15.27	40.2%	484599	11.12	29.3%
28	HILLTOP B	67	0.98	103969	138507	3082	138447	36481	420486	9.65	14.4%	316517	7.27	10.8%
29	SCHOOL	23	0	0	86422	871	74510	32222	194025	4.45	19.4%	194025	4.45	19.4%
30	VLOWDENSITY RURAL RES/HTA	356	1.91	737104	847087	36664	998834	234628	2854317	65.53	18.4%	2117213	48.60	13.7%
31	VERY LOW DENSITY RURAL RES/ESTATE	205	1.29	401021	477716	23634	454256	127676	1484303	34.07	16.6%	1083282	24.87	12.1%
32	RESIDENTIAL C	105	4.8	623512	394126	190157	1101392	158008	2467195	56.64	53.9%	1843683	42.33	40.3%
33	SCHOOL	43	0	0	268231	28357	222037	39891	558516	12.82	29.8%	558516	12.82	29.8%
34	MIXED USE APART/COMMERCIAL/ASF	10	11.17	11556	153465	20978	112049	3419	301467	6.92	69.2%	289911	6.66	66.6%
35	CORNER STORE	0.3	0	0	4347	0	2754	0	7101	0.16	54.3%	7101	0.16	54.3%
36	NON-URBAN PLAN A	1590	0.25	781701	692195	23035	616141	141300	2254372	51.75	3.3%	1472671	33.81	2.1%
37	PARK	55	0	45048	63273	34501	3934	31329	178085	4.09	7.4%	133037	3.05	5.6%
38	FARM/FOREST	75	0.01	26094	20002	80	19708	1691	67575	1.55	2.1%	41481	0.95	1.3%

WES BMP Sizing Software Version 1.6.0.2, May 2018

WES BMP Sizing Report

Project Information

Project Name	Pleasant Valley / North Carver
Project Type	Addition
Location	
Stormwater Management Area	0
Project Applicant	
Jurisdiction	CCSD1NCSA

Drainage Management Area

Name	Area (sq-ft)	Pre-Project Cover	Post-Project Cover	DMA Soil Type	BMP
A-Ex Imp	369,631	Impervious	Roofs	D	Pond A
A-Per	3,132,095	Grass	LandscapeDsoil	D	Pond A
A- New Imp	2,250,893	Grass	Roofs	D	Pond A
B - Ex Imp	707,975	Impervious	Roofs	C	Pond B
B - Per	2,843,719	Grass	LandscapeCsoil	C	Pond B
B - New Imp	2,516,330	Grass	Roofs	C	Pond B
D - Ex Imp	20,714	Impervious	Roofs	D	Pond D
D - Per	708,122	Grass	LandscapeDsoil	D	Pond D
D - New Imp	800,213	Grass	Roofs	D	Pond D
E- Ex Imp	105,136	Impervious	Roofs	D	Pond E
E - Per	465,864	Grass	LandscapeDsoil	D	Pond E
E- New Imp	661,852	Grass	Roofs	D	Pond E
G - Ex Imp	308,458	Impervious	Roofs	C	Pond G
G - Per	2,641,165	Grass	LandscapeCsoil	C	Pond G
G - New Imp	3,194,740	Grass	Roofs	C	Pond G
I - Ex Imp	520,659	Impervious	Roofs	D	Pond I
I - Per	3,043,579	Forested	LandscapeDsoil	D	Pond I
I - New Imp	2,522,920	Forested	Roofs	D	Pond I
J - Ex Imp	86,899	Impervious	Roofs	D	Pond J
J - Per	818,284	Grass	LandscapeDsoil	D	Pond J
J - New Imp	752,030	Grass	Roofs	D	Pond J
K - Ex Imp	333,435	Impervious	Roofs	D	Pond K
K - Per	1,723,062	Forested	LandscapeDsoil	D	Pond K

K - New Imp	1,640,738	Forested	Roofs	D	Pond K
L - Ex Imp	86,855	Impervious	Roofs	C	Pond L
L - Per	1,714,539	Grass	LandscapeCsoil	C	Pond L
L - New Imp	1,627,685	Grass	Roofs	C	Pond L
F - Forested Slopes	2,169,907	Forested	Forested	C	Pond F
F - Ex Imp	318,247	Impervious	Roofs	C	Pond F
F - Per	1,955,647	Grass	LandscapeCsoil	C	Pond F
F - New Imp	1,385,077	Grass	Roofs	C	Pond F
H - Forested Slopes	656,507	Forested	Forested	C	Pond H
H - Ex Imp	81,596	Impervious	Roofs	C	Pond H
H - Per	739,810	Grass	LandscapeCsoil	C	Pond H
H - New Imp	560,202	Grass	Roofs	C	Pond H
C - Ex Imp	107,899	Impervious	Roofs	C	Pond C
C - Per	547,853	Grass	LandscapeCsoil	C	Pond C
C - New Imp	809,807	Grass	Roofs	C	Pond C
M - Forested Slopes	113,962	Forested	Forested	C	Pond M
M - Ex Imp	114,088	Impervious	Roofs	C	Pond M
M - Per	388,378	Grass	LandscapeCsoil	C	Pond M
M - New Imp	497,219	Grass	Roofs	C	Pond M
N - Forested Slopes	540,410	Forested	Forested	C	Pond N
N - Ex Imp	42,839	Impervious	Roofs	C	Pond N
N - Per	1,144,458	Grass	LandscapeCsoil	C	Pond N
N - New Imp	1,168,023	Grass	Roofs	C	Pond N

LID Facility Sizing Details

Pond Sizing Details

Pond ID	Design Criteria(1)	Facility Soil Type	Max Depth (ft)(2)	Top Area (sq-ft)	Side Slope (1:H)	Facility Vol. (cu-ft)(3)	Water Storage Vol. (cu-ft)(4)	Adequate Size?
Pond A	FCWQT	D1	7.00	41,079.0	3	232,081.5	180,208.7	Yes
Pond B	FCWQT	D1	7.00	72,906.0	3	435,074.5	333,912.3	Yes
Pond D	FCWQT	D1	7.00	14,126.0	3	68,053.8	54,738.5	Yes
Pond E	FCWQT	D1	7.00	13,567.0	3	64,841.1	52,249.0	Yes
Pond G	FCWQT	D1	7.00	85,827.0	3	518,773.5	397,080.2	Yes

Pond I	FCWQT	D1	7.00	62,798.0	3	370,027.0	284,752.5	Yes
Pond J	FCWQT	C3	7.00	14,170.0	3	68,309.6	54,936.2	Yes
Pond K	FCWQT	D1	7.00	40,823.0	3	230,475.0	178,988.0	Yes
Pond L	FCWQT	C3	7.00	43,873.0	3	249,644.4	193,548.6	Yes
Pond F	FCWQT	D1	7.00	39,090.0	3	219,617.9	170,735.6	Yes
Pond H	FCWQT	D1	7.00	17,292.0	3	86,499.0	68,986.8	Yes
Pond C	FCWQT	D1	7.00	26,111.0	3	139,387.7	109,575.1	Yes
Pond M	FCWQT	C3	7.00	16,805.0	3	83,639.6	66,782.0	Yes
Pond N	FCWQT	C3	7.00	31,038.0	3	169,585.4	132,638.3	Yes

1. FCWQT = Flow control and water quality treatment, WQT = Water quality treatment only

2. Depth is measured from the bottom of the facility and includes the three feet of media (drain rock, separation layer and growing media).

3. Maximum volume of the facility. Includes the volume occupied by the media at the bottom of the facility.

4. Maximum water storage volume of the facility. Includes water storage in the three feet of soil media assuming a 40 percent porosity.

Simple Pond Geometry Configuration

Pond ID: Pond A
Design: FlowControlAndTreatment

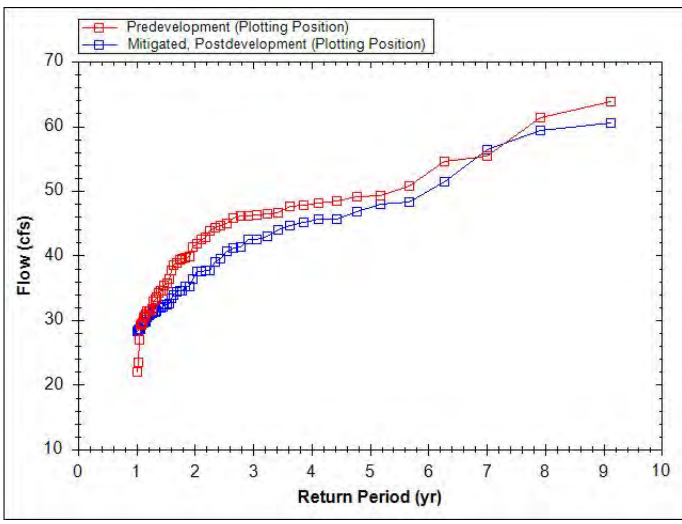
Shape Curve

Depth (ft)	Area (sq ft)
7.0	41,079.0

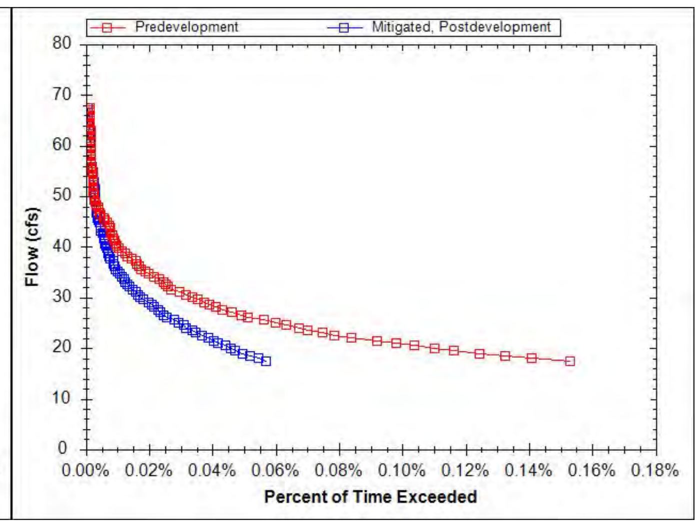
Outlet Structure Details

Lower Orifice Invert (ft)	0.0
Lower Orifice Dia (in)	15.8
Upper Orifice Invert(ft)	4.7
Upper Orifice Dia (in)	35.6
Overflow Weir Invert(ft)	6.0
Overflow Weir Length (ft)	6.3

Flow Frequency Chart



Flow Duration Chart



Simple Pond Geometry Configuration

Pond ID: Pond B

Design: FlowControlAndTreatment

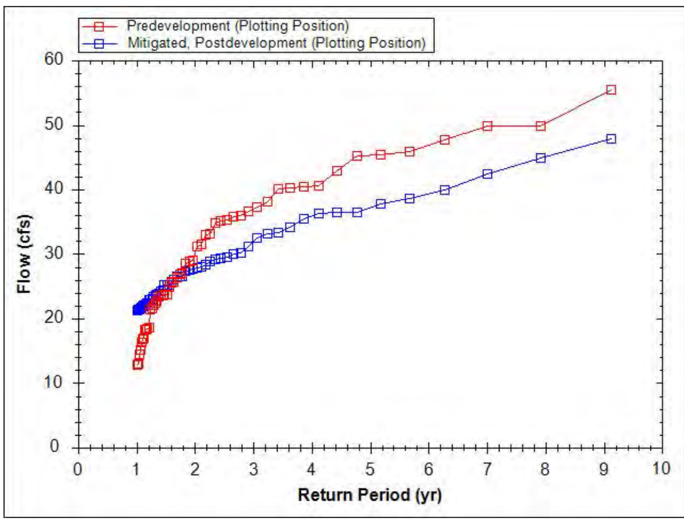
Shape Curve

Depth (ft)	Area (sq ft)
7.0	72,906.0

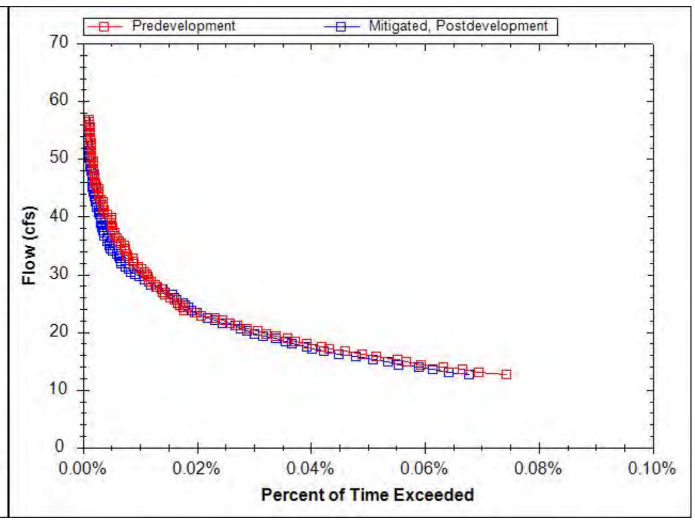
Outlet Structure Details

Lower Orifice Invert (ft)	0.0
Lower Orifice Dia (in)	13.5
Upper Orifice Invert(ft)	4.7
Upper Orifice Dia (in)	33.4
Overflow Weir Invert(ft)	6.0
Overflow Weir Length (ft)	6.3

Flow Frequency Chart



Flow Duration Chart



Simple Pond Geometry Configuration

Pond ID: Pond D

Design: FlowControlAndTreatment

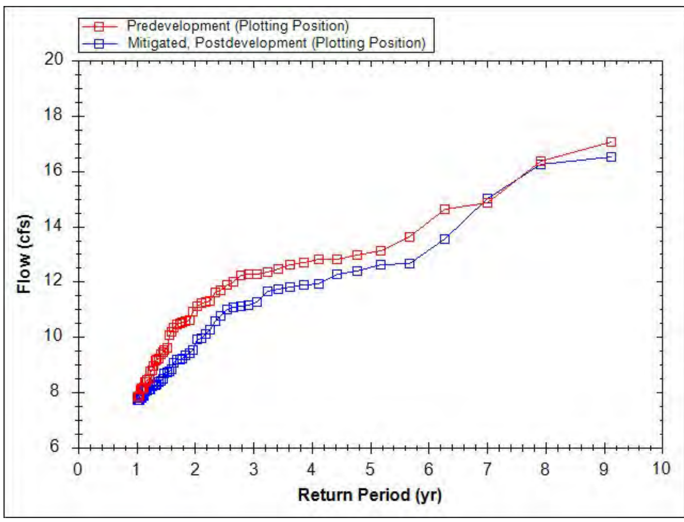
Shape Curve

Depth (ft)	Area (sq ft)
7.0	14,126.0

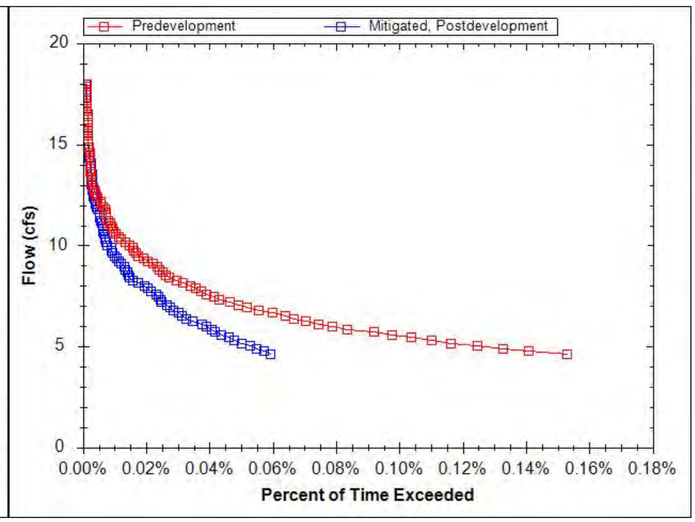
Outlet Structure Details

Lower Orifice Invert (ft)	0.0
Lower Orifice Dia (in)	8.2
Upper Orifice Invert(ft)	4.7
Upper Orifice Dia (in)	18.4
Overflow Weir Invert(ft)	6.0
Overflow Weir Length (ft)	6.3

Flow Frequency Chart



Flow Duration Chart



Simple Pond Geometry Configuration

Pond ID: Pond E
Design: FlowControlAndTreatment

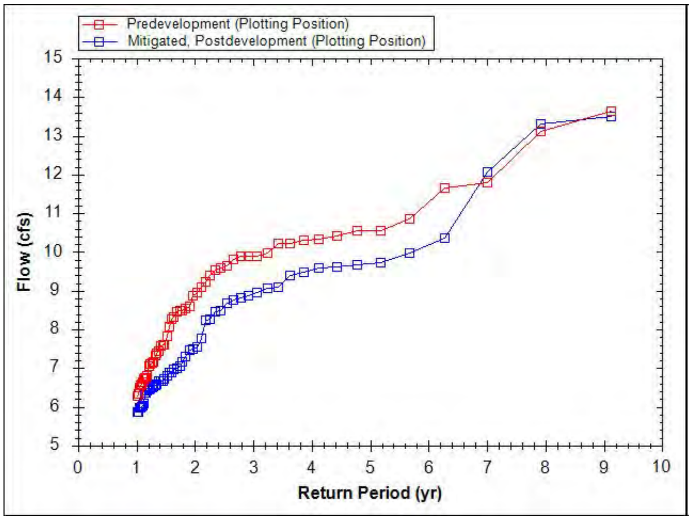
Shape Curve

Depth (ft)	Area (sq ft)
7.0	13,567.0

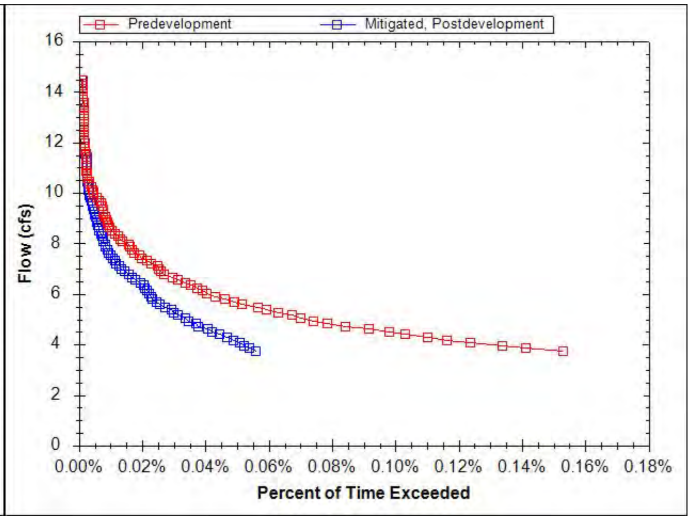
Outlet Structure Details

Lower Orifice Invert (ft)	0.0
Lower Orifice Dia (in)	7.3
Upper Orifice Invert(ft)	4.7
Upper Orifice Dia (in)	16.5
Overflow Weir Invert(ft)	6.0
Overflow Weir Length (ft)	6.3

Flow Frequency Chart



Flow Duration Chart



Simple Pond Geometry Configuration

Pond ID: Pond G

Design: FlowControlAndTreatment

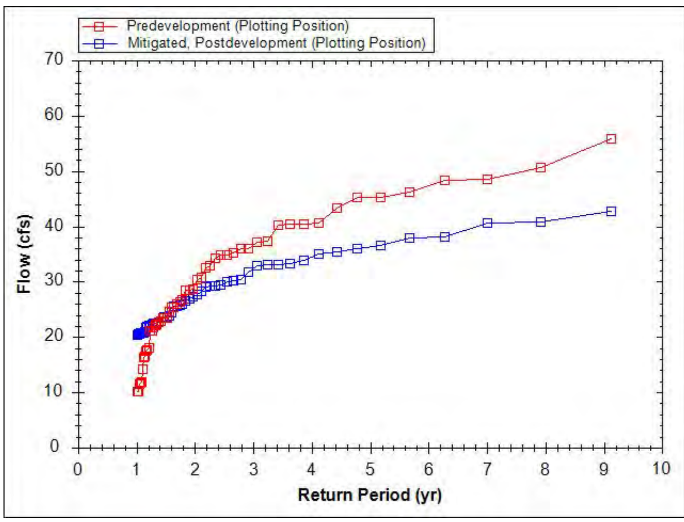
Shape Curve

Depth (ft)	Area (sq ft)
7.0	85,827.0

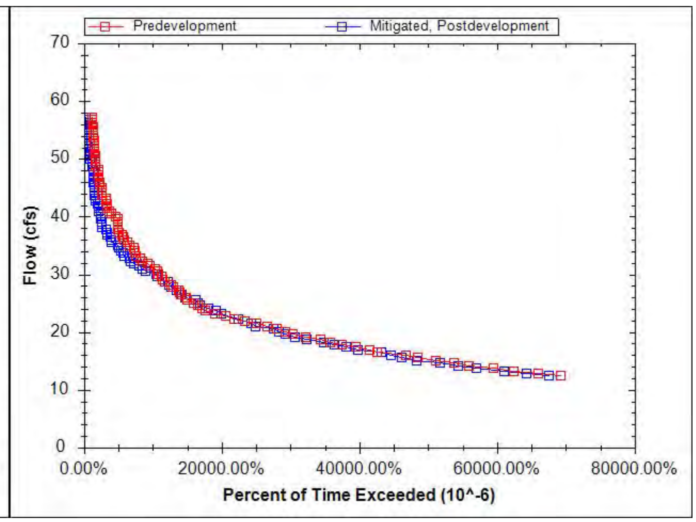
Outlet Structure Details

Lower Orifice Invert (ft)	0.0
Lower Orifice Dia (in)	13.3
Upper Orifice Invert(ft)	4.7
Upper Orifice Dia (in)	33.7
Overflow Weir Invert(ft)	6.0
Overflow Weir Length (ft)	6.3

Flow Frequency Chart



Flow Duration Chart



Simple Pond Geometry Configuration

Pond ID: Pond I
Design: FlowControlAndTreatment

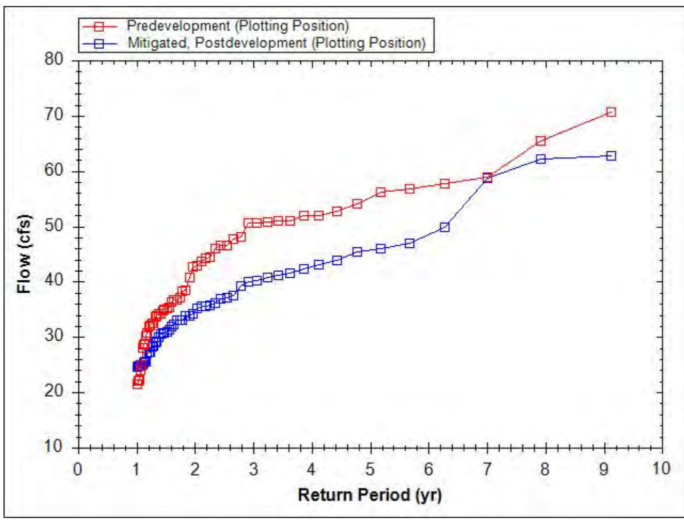
Shape Curve

Depth (ft)	Area (sq ft)
7.0	62,798.0

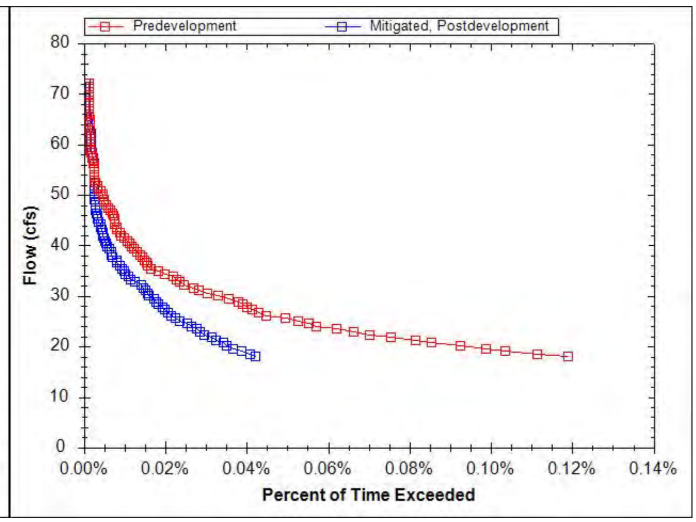
Outlet Structure Details

Lower Orifice Invert (ft)	0.0
Lower Orifice Dia (in)	16.1
Upper Orifice Invert(ft)	4.7
Upper Orifice Dia (in)	37.0
Overflow Weir Invert(ft)	6.0
Overflow Weir Length (ft)	6.3

Flow Frequency Chart



Flow Duration Chart



Simple Pond Geometry Configuration

Pond ID: Pond J

Design: FlowControlAndTreatment

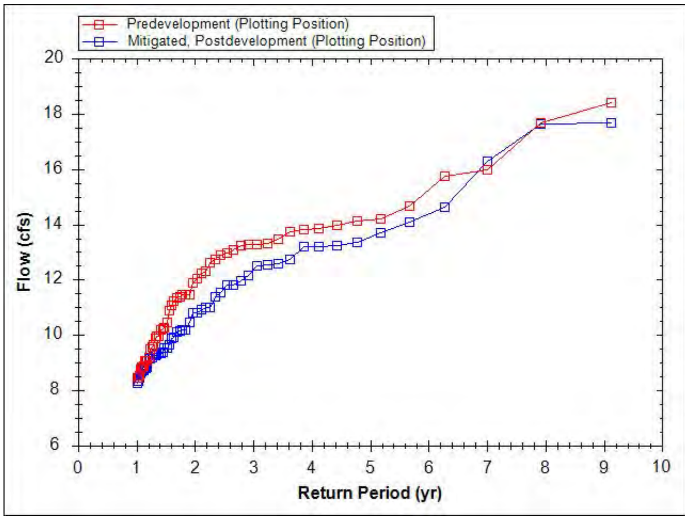
Shape Curve

Depth (ft)	Area (sq ft)
7.0	14,170.0

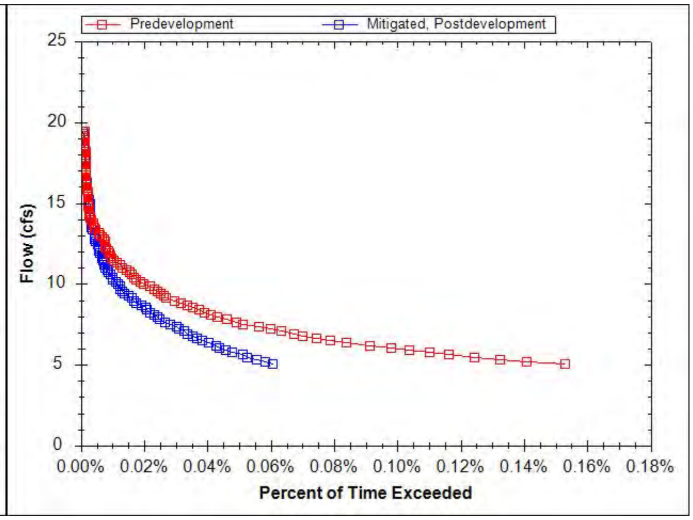
Outlet Structure Details

Lower Orifice Invert (ft)	0.0
Lower Orifice Dia (in)	8.5
Upper Orifice Invert(ft)	4.7
Upper Orifice Dia (in)	19.1
Overflow Weir Invert(ft)	6.0
Overflow Weir Length (ft)	6.3

Flow Frequency Chart



Flow Duration Chart



Simple Pond Geometry Configuration

Pond ID: Pond K

Design: FlowControlAndTreatment

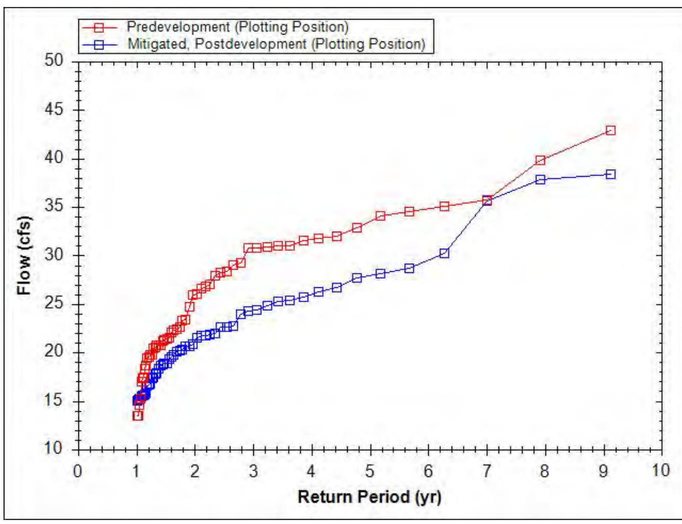
Shape Curve

Depth (ft)	Area (sq ft)
7.0	40,823.0

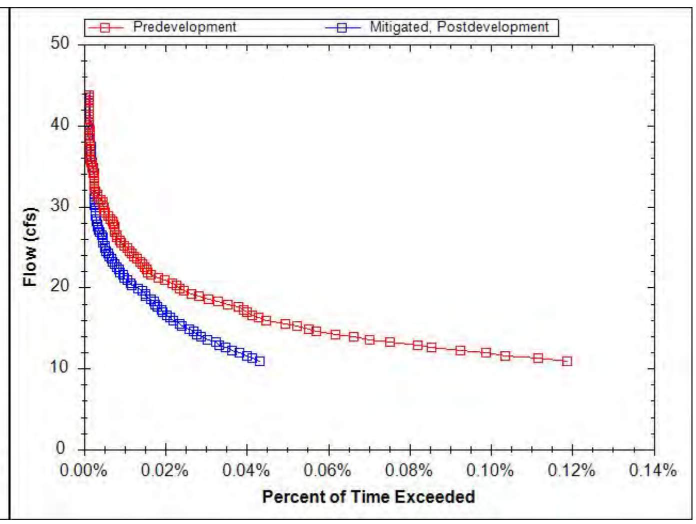
Outlet Structure Details

Lower Orifice Invert (ft)	0.0
Lower Orifice Dia (in)	12.5
Upper Orifice Invert(ft)	4.7
Upper Orifice Dia (in)	28.8
Overflow Weir Invert(ft)	6.0
Overflow Weir Length (ft)	6.3

Flow Frequency Chart



Flow Duration Chart



Simple Pond Geometry Configuration

Pond ID: Pond L
Design: FlowControlAndTreatment

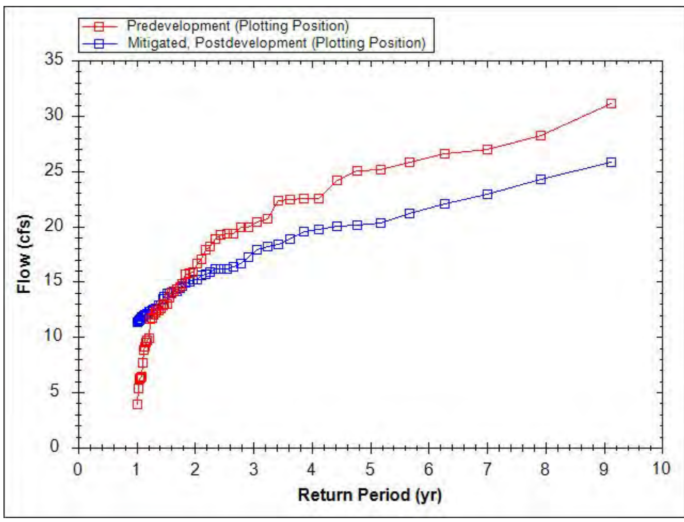
Shape Curve

Depth (ft)	Area (sq ft)
7.0	43,873.0

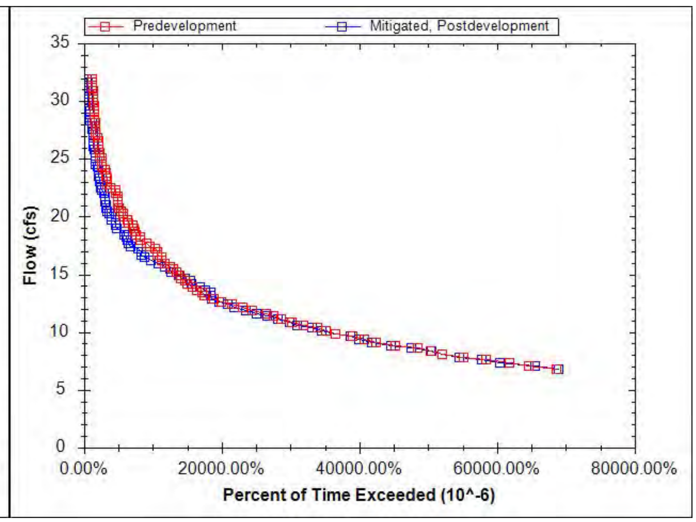
Outlet Structure Details

Lower Orifice Invert (ft)	0.0
Lower Orifice Dia (in)	9.9
Upper Orifice Invert(ft)	4.7
Upper Orifice Dia (in)	25.2
Overflow Weir Invert(ft)	6.0
Overflow Weir Length (ft)	6.3

Flow Frequency Chart



Flow Duration Chart



Simple Pond Geometry Configuration

Pond ID: Pond F
Design: FlowControlAndTreatment

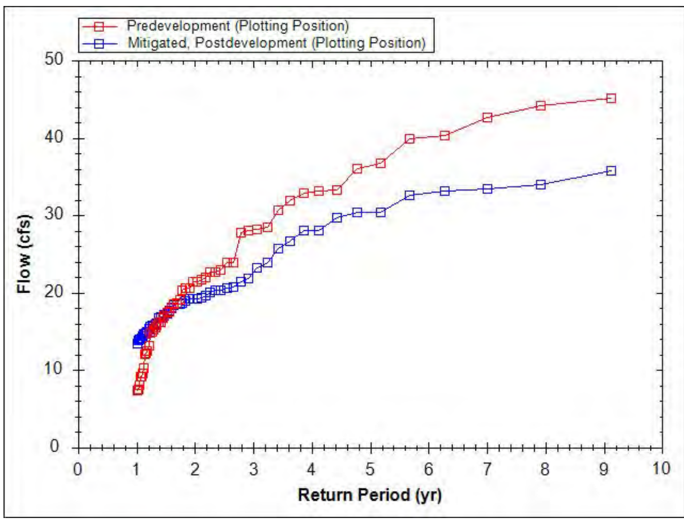
Shape Curve

Depth (ft)	Area (sq ft)
7.0	39,090.0

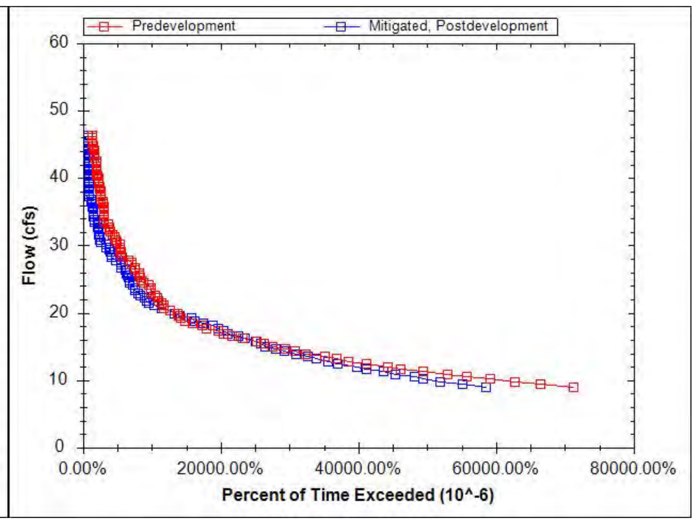
Outlet Structure Details

Lower Orifice Invert (ft)	0.0
Lower Orifice Dia (in)	11.4
Upper Orifice Invert(ft)	4.7
Upper Orifice Dia (in)	30.7
Overflow Weir Invert(ft)	6.0
Overflow Weir Length (ft)	6.3

Flow Frequency Chart



Flow Duration Chart



Simple Pond Geometry Configuration

Pond ID: Pond H
Design: FlowControlAndTreatment

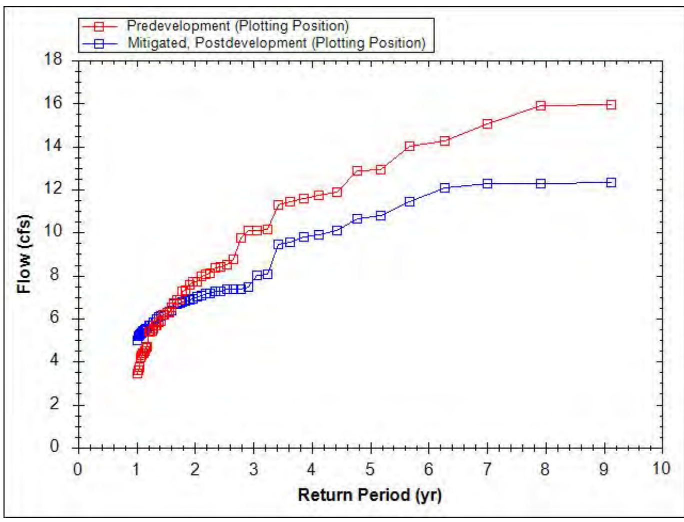
Shape Curve

Depth (ft)	Area (sq ft)
7.0	17,292.0

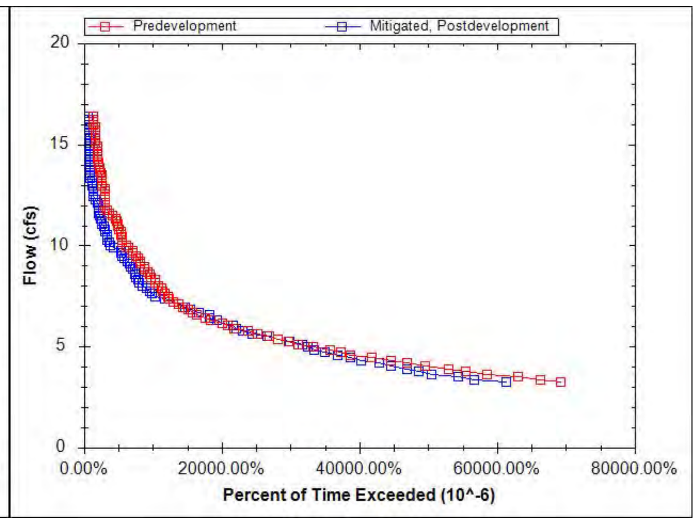
Outlet Structure Details

Lower Orifice Invert (ft)	0.0
Lower Orifice Dia (in)	6.8
Upper Orifice Invert(ft)	4.7
Upper Orifice Dia (in)	18.2
Overflow Weir Invert(ft)	6.0
Overflow Weir Length (ft)	6.3

Flow Frequency Chart



Flow Duration Chart



Simple Pond Geometry Configuration

Pond ID: Pond C
Design: FlowControlAndTreatment

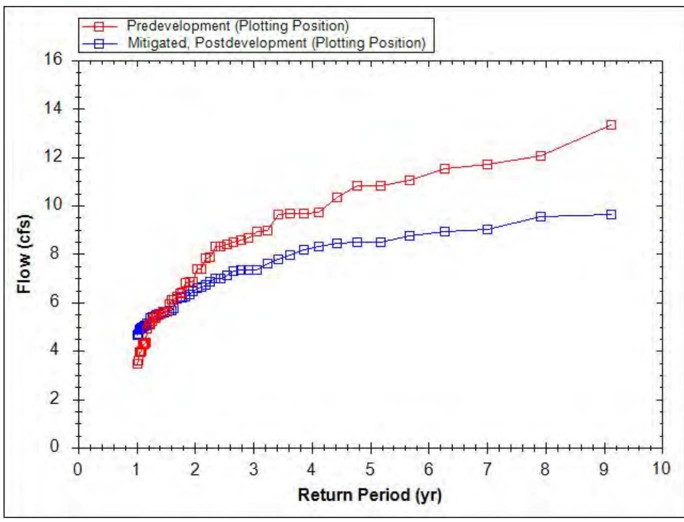
Shape Curve

Depth (ft)	Area (sq ft)
7.0	26,111.0

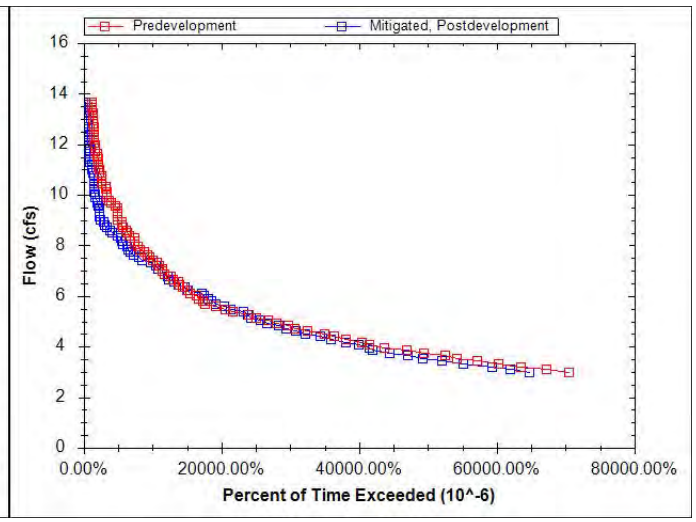
Outlet Structure Details

Lower Orifice Invert (ft)	0.0
Lower Orifice Dia (in)	6.6
Upper Orifice Invert(ft)	4.7
Upper Orifice Dia (in)	16.4
Overflow Weir Invert(ft)	6.0
Overflow Weir Length (ft)	6.3

Flow Frequency Chart



Flow Duration Chart



Simple Pond Geometry Configuration

Pond ID: Pond M
Design: FlowControlAndTreatment

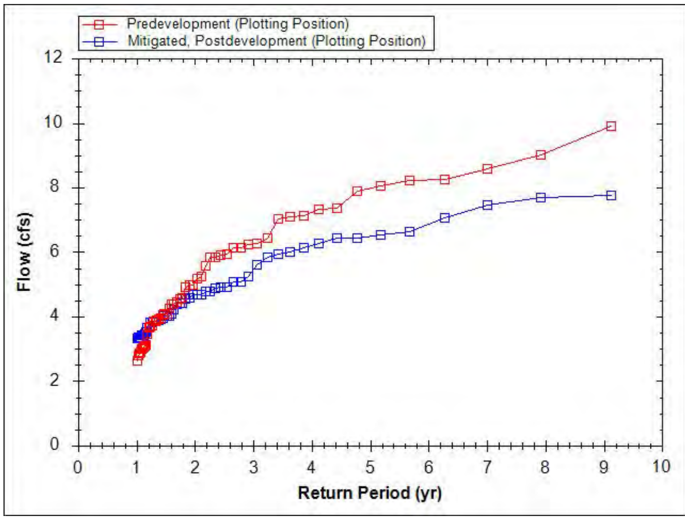
Shape Curve

Depth (ft)	Area (sq ft)
7.0	16,805.0

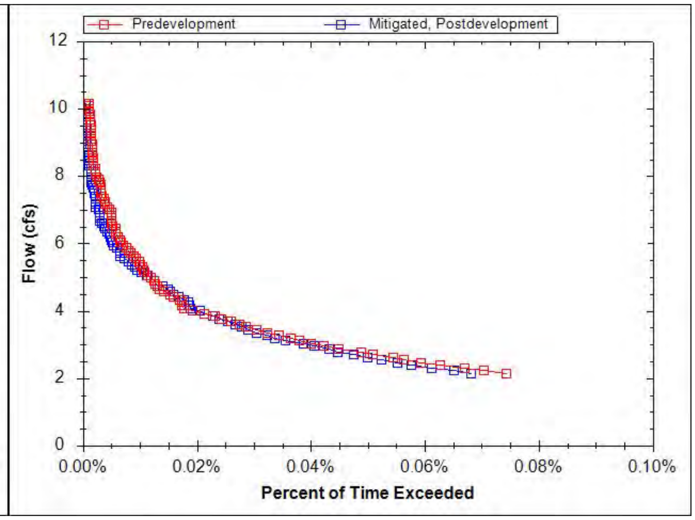
Outlet Structure Details

Lower Orifice Invert (ft)	0.0
Lower Orifice Dia (in)	5.5
Upper Orifice Invert(ft)	4.7
Upper Orifice Dia (in)	14.3
Overflow Weir Invert(ft)	6.0
Overflow Weir Length (ft)	6.3

Flow Frequency Chart



Flow Duration Chart



Simple Pond Geometry Configuration

Pond ID: Pond N

Design: FlowControlAndTreatment

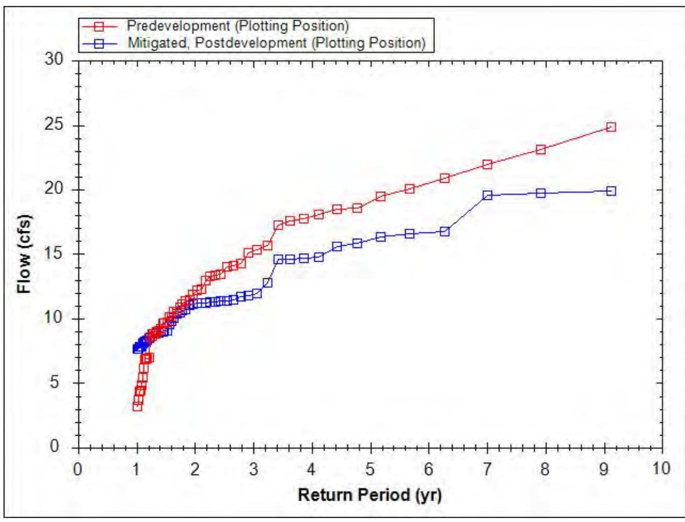
Shape Curve

Depth (ft)	Area (sq ft)
7.0	31,038.0

Outlet Structure Details

Lower Orifice Invert (ft)	0.0
Lower Orifice Dia (in)	8.5
Upper Orifice Invert(ft)	4.7
Upper Orifice Dia (in)	22.3
Overflow Weir Invert(ft)	6.0
Overflow Weir Length (ft)	6.3

Flow Frequency Chart



Flow Duration Chart