Greater Kelsey Creek Watershed Assessment Report

prepared in support of the City of Bellevue Watershed Management Plan

Revision 3 (Final)

November 13, 2021

Bellevue Utilities Department

Prepared by:

Jacobs

Jacobs Engineering Inc.
1100 112th Avenue NE, Suite 500
Bellevue, Washington 98004-5118
United States
T +1.425.453.5000
www.jacobs.com

HERRERA

Herrera Environmental Consultants, Inc.
2200 6th Avenue, Suite 1100
Seattle, WA 98121
United States
T +1.206.441.9080
www.herrerainc.com

Watershed Management Plan
Our streams, our future

Document history and status

Revision	Date	Description	Author	Checked	Reviewed	Approved
0	7/2/21	Preliminary Draft of Sections 1, 2.1, and 2.2				
1	8/27/21	Revised Draft including all Report Sections				
2	11/4/21	Update to Revised Draft				
3	11/13/21	Final				

Distribution of copies

Revision	Issue approved	Date issued	Issued to	Comments

Contents

Tables

Figures

Preface

Urban development in the lowland regions of the Puget Sound over the past 150 years has resulted in the conversion of large tracts of forested area to residential, industrial, and commercial land uses. Changing environmental conditions that resulted from this land conversion have dramatically impacted the health of the region's streams, lakes, and marine water bodies. Common symptoms of water resource degradation from urbanization include poor water quality, loss of riparian and aquatic habitat, and stream channel erosion. In combination, these impacts have resulted in widespread disruption in the ecological function of water bodies causing sensitive aquatic life to decline in abundance or disappear completely. To address this problem, state and local jurisdictions are making a concerted effort to rehabilitate these water bodies through coordinated planning efforts that direct new storm and surface water management practices to existing urban development that was built without stormwater detention or water quality controls that do not meet current requirements and standards.

Commensurate with these regional efforts, the City of Bellevue (City) is committed to improving and protecting the aquatic health of water bodies within its boundaries. To that end, the City is developing a Watershed Management Plan (WMP) that will focus on improving the health and condition of the City's streams using a toolbox of holistic storm and surface water management practices. The WMP will direct investments to high-priority watersheds providing measurable environmental benefits to stream health within a shorter time frame than past or current approaches. The WMP will also help prevent further degradation in non-priority watersheds. The WMP will include an implementation plan with recommended projects, policies, programs, and operational plans to meet performance goals for Bellevue's streams, and to provide multiple benefits that help advance City objectives across departments and programs.

The City is preparing a series of watershed assessment reports and watershed improvement plans that will provide the basis for the recommended actions in the WMP. A Watershed Assessment Report (AR) will be prepared for each of the City's major watersheds: Coal Creek, Greater Kelsey Creek, the Lake Sammamish tributaries within Bellevue (including Lewis Creek), and the small Lake Washington tributaries within Bellevue.

This report is an assessment of the current conditions in the Greater Kelsey Creek Watershed, which includes Kelsey Creek and all the tributaries that drain into it. This information, along with other subsequent reports, will be used to develop the final WMP.

City of Bellevue Watershed Management Plan

Greater Kelsey Creek Watershed Assessment

EXECUTIVE SUMMARY

Purpose of This Assessment

The purpose of this report is to assess the conditions in the Greater Kelsey Creek Watershed that are limiting the health of its streams. This assessment includes the evaluation of potential limiting factors from the Conceptual Model that describes the primary effects of urban runoff on streams (See Figure 2) and their consequences for stream health.

The City is preparing a series of Watershed Assessment Reports (ARs) that will provide the basis for the recommended actions to improve stream health culminating in a city-wide Watershed Management Plan (WMP). One AR will be prepared for each of the City of Bellevue's (City's) major watersheds: Coal Creek, Greater Kelsey Creek, the Lake Sammamish tributaries within Bellevue (including Lewis Creek), and the small Lake Washington tributaries within Bellevue.

In addition to the watershed condition assessment, each AR will include limiting factors, data gaps (if any), and identified opportunities for improving in-stream watershed conditions. The ARs are based on data from three primary sources: 1) the recent Open Streams Condition Assessment (OSCA) performed by the City; 2) existing data collected by the City from past projects and ongoing monitoring efforts; and 3) existing project and environmental monitoring data collected by the City and a variety of public resource agencies.

Watershed Management Plan
Our streams, our future

Description and History of the Greater Kelsey Creek Watershed

The mainstem of Kelsey Creek flows approximately 10.7 miles from its present-day headwaters in the Lake Hills Greenbelt to Mercer Slough and ultimately, Lake Washington. Kelsey Creek receives flow from the smaller tributaries of Richards Creek, Sunset Creek, West Tributary, Goff Creek, Valley Creek, and Sears Creek before joining with Sturtevant Creek at Mercer Slough. In addition to fluvial channels and tributaries, surface water features in the Greater Kelsey Creek Watershed include floodplains, wetlands, and lakes.

The Greater Kelsey Creek Watershed is relatively low gradient at the headwaters, with many streams originating in large wetland complexes. Gradients tend to increase as the channel flows over the edge of the plateau, then decrease again as they approach Mercer Slough and Lake Washington. Streams in the Greater Kelsey Creek Watershed have been highly affected by urbanization, including altered riparian vegetation, high-flow bypasses, dams, detention facilities, ditching and confinement by roadways, and long stretches that are piped underground. While urbanization has affected all of the City's watersheds, this is especially true for the Greater Kelsey Creek Watershed.

The geology of the Greater Kelsey Creek Watershed is primarily characterized by a combination of glacial and post-glacial deposits (glacial till) deposited during the Fraser glaciation, approximately 13,000 to 16,000 years ago. The Greater Kelsey Creek Watershed is unique within the City because of extensive peat deposits along the stream channel in its headwaters and in the Mercer Slough and Sturtevant subbasins. These peat deposits are bordered by glacial outwash and non-glacial deposits. The valley that contains the mainstem of Kelsey Creek was formed by the incision of the erosive glacial meltwaters into the glacial deposits described above. Although ongoing channel incision is a part of a natural geologic and geomorphic process, there are some places within the Watershed where the rates of channel incision have been exacerbated by hydrologic alterations. The soils at the surface tend to be highly erodible and the soils just below the surface tend to have low permeability.

The land cover in the Greater Kelsey Creek Watershed is typical of urban watersheds with a lower percentage of tree canopy and higher percentage of impervious surface. The Greater Kelsey Creek Watershed is comprised of large Parks including Kelsey Creek Park, Lake Hills Greenbelt, and several smaller City parks. Several wetland complexes exist within the Greater Kelsey Creek Watershed, including Mercer Slough, the wetlands at Kelsey Creek Park, and the Lake Hills Greenbelt. Within Bellevue, ownership of the riparian corridor across all of the subbasins within the Greater Kelsey Creek Watershed is approximately 90 percent private property and 10 percent publicly owned (primarily parks).

Human intervention in proximate waterbodies has affected Greater Kelsey Creek Watershed and Kelsey Creek itself. In the late 1800's, the outlet of Phantom Lake was diverted to Lake Sammamish, effectively reducing flow to Kelsey Creek. Also, lowering of the Lake Washington lake level in 1917 impacted Mercer Slough, as have the seasonal raising and lowering of lake levels to reduce winter storm impacts since that time. Human use and activity within the Greater Kelsey Creek Watershed includes unauthorized encampments, recreational use of riparian areas, roadway and vehicle pollutants, and numerous other urban residential pollutants which all have the potential to negatively impact water quality.

Beavers are active throughout much of the Greater Kelsey Creek Watershed. Beaver activity has the potential to cause flooding in confined urban areas if it is not properly managed. While beaver activity in certain areas may have negative effects for people and infrastructure, beavers play a critical role in habitat creation and enhancement with significant benefits to fish and wildlife habitat. Beaver activity can reduce water velocities, increase sediment and stormwater retention, increase habitat complexity, and increase water depths (for example, behind beaver dams) that results in cooler stream temperatures and water storage to help with climate change resiliency.

The Greater Kelsey Creek Watershed has a number of regional stormwater facilities and high-flow bypasses. Instream regional stormwater facilities were designed to address flooding issues caused by development that occurred prior to the requirement for stormwater control. More than 37 percent of the Greater Kelsey Creek Watershed was developed before 1974 with more than half (57.6 percent) developed before the mid-1980s, at which point multiple regional flow control facilities were built.

The Greater Kelsey Creek Watershed is important for salmon, as it has historically provided extensive spawning and rearing habitat for a larger number of anadromous and migratory salmonids and other fish species. Salmonid species such as Chinook (Oncorhynchus tshawytscha), Sockeye (Oncorhynchus nerka), Coho (Oncorhynchus kisutch), Cutthroat Trout (Oncorhynchus clarkii), and Steelhead (Oncorhynchus mykiss). Also, Peamouth Minnows (Mylocheilus caurinus) return to Kelsey Creek from Lake Washington to spawn, via the Mercer Slough, in the spring. Several of these species can still be observed throughout the Watershed today, though spawning and rearing habitat extents have decreased with urbanization.

Factors that Limit the Health of the Greater Kelsey Creek Watershed

The following were identified as limiting factors for the Greater Kelsey Creek Watershed per the Conceptual Model, in general order of importance across all nine subbasins within the Watershed:

1. **Pollutant Loading:** Stormwater runoff from impervious surfaces (Limiting Factor #1) causes erosion from higher flows, and transports pollutants (metals, nutrients, fecal coliform, and others) associated with urban development that are detrimental to the health of aquatic organisms and people. Road runoff, illicit discharges, and possibly septic systems are the likely sources of these pollutants. Also, water quality treatment facilities were not required for approximately 94 percent of the current developed area in the Bellevue portion of the Greater Kelsey Creek Watershed.

2. **Stormwater Runoff from Effective Impervious Surfaces:** Increased stormwater runoff flow rates and volumes during storm events from impervious surfaces in the Watershed, in combination with historic channel alterations for flood risk reduction purposes or land development, are contributing to negative effects on water quality, instream habitat quality, including fish and wildlife habitat.

   Although the City required stormwater flow control for new development beginning the mid-1970s, these facilities designed and built through the mid-1990s, has been shown to be not very effective at protecting streams from erosion and other negative effects of runoff. These facilities and parts of the City that were developed prior to any stormwater control requirement make up approximately 86 percent of the current developed area in the Bellevue portion of the Watershed.

3. **Road Culverts and Other Physical Barriers:** A number of physical barriers to fish passage have been identified in all the streams of the Greater Kelsey Creek Watershed. In addition, there are undocumented barriers on private properties throughout the Watershed. These barriers prevent fish from accessing areas for spawning and/or rearing, effectively reducing their activities to areas of the stream downstream of these barriers.

4. **Loss of Floodplain and Riparian Function:** Urban development has confined many of the stream reaches in the Watershed. This effectively reduces the amount of floodplain storage and reduces wood from entering the stream, leading to high velocities and flowrates with limited channel complexity. There are tracts of wetlands and floodplains where the creek channel can migrate naturally which is why other Limiting Factors are of greater importance in the Greater Kelsey Creek Watershed. The tree canopy in the Greater Kelsey Creek Watershed is largely concentrated in the park areas around the creek channels. There are several stream reaches with very limited tree canopy and vegetation and these should be addressed. Because the Greater Kelsey Creek Watershed does have a relatively large percentage of tree canopy overall, this limiting factor is of lower importance than the others at the watershed scale.

   The Greater Kelsey Creek Watershed has wetlands and connected floodplain that essentially provide storage for the high flows and stormwater volumes witnessed in the Watershed. The existing storage and relatively low gradient of the Greater Kelsey streams means that the high velocities and volumes haven't caused erosion to the same extent as seen in other high-gradient systems in the City with limited or no wetlands or connected floodplain.

Past and Present Investments

The City has invested tens of millions of dollars in the Greater Kelsey Creek Watershed over the past 15 years on in-stream projects that include repairing stormwater outfalls, stabilizing stream slopes, removing fish passage barriers, catching and removing fine sediment, and improving conveyance.

Future Opportunities

Potential future investments in the Greater Kelsey Creek Watershed will address the limiting factors identified here and include both in-stream investments and investments in the contributing areas so as to address the pollutant loading and stormwater runoff challenges in the Watershed.

Prepared by Jacobs HERRERA

1. Introduction

This section discusses the watershed management planning process, introduces the Greater Kelsey Creek Watershed, and describes the document organization.

1.1 The Watershed Management Planning Process

For all documents prepared as part of the City's Watershed Management Plan, the word 'watershed' will be used to describe the boundaries of the large areas that drain to creeks and waterbodies. The word 'subbasin' will be used to describe the smaller drainages within the watersheds. For this planning effort, the City has defined the following four (4) watersheds: Kelsey Creek, Coal Creek, Lake Washington Tributaries, and Lake Sammamish Tributaries. These four (4) watersheds are made up of a total of twenty-six (26) subbasins, as shown in Figure 3.

The City of Bellevue (City) is developing the Watershed Management Plan (WMP) using a stepwise process that builds on information obtained from each proceeding step to ensure the final plan is comprehensive, makes the best use of new and existing data and information, and reflects the community's values and goals. As shown in Figure 1, this stepwise process leading up to WMP development includes the following major components:

- **Foundational Element Memoranda** will be prepared at the onset of WMP development to define critical inputs to the process including the overarching framework for the plan (Foundational Element #1), the metrics that will be used to measure progress towards meeting stream health goals (Foundational Element #2), and the approach that will be used for prioritizing watersheds (Foundational Element #3).
- The **Open Streams Condition Assessment (OSCA)** was initiated by the City in 2018 to survey approximately 80 miles of open stream within the City limits. Completed in the fall of 2020, the data generated from this effort will be used in three aspects of the WMP: 1) provide a current understanding of the physical habitat of Bellevue streams through the development of stream habitat reports; 2) provide baseline data to assess if future improvements to stream health are successful; and 3) provide a comprehensive "boots-on-the ground" assessment of opportunities to improve the physical, chemical, and biological health of the streams.
- **Watershed Assessment Reports (ARs)** will be prepared to characterize existing conditions in the City's watersheds: Greater Kelsey Creek, Coal Creek, Small Lake Washington Tributaries, and Lake Sammamish Tributaries (including Lewis Creek). Each Watershed AR will identify limiting factors, data gaps (if any), and opportunities for improving watershed health. These ARs will be developed based on data from three primary sources: 1) the OSCA described above; 2) existing data collected by the City from past projects and ongoing monitoring efforts; and 3) existing project and environmental monitoring data collected by a variety of public resource agencies.
- **A Watershed Management Toolbox** will be prepared to identify and document the different tools (or strategies) that could be used to meet the WMP goals. These tools could include stormwater Best Management Practices (BMPs), policy/regulatory changes, operational strategies, engineered solutions, management strategies, etc. The toolbox will also indicate which stressors on stream health are addressed by each individual tool or management strategy.
- **Initial and Revised Watershed Prioritizations** will be performed to identify which subbasins within the City's watersheds would have the quickest positive response to rehabilitation efforts, with the goal of maximizing return on the City's investments in stream health. The initial prioritization (performed

before and during AR development) will also provide the technical basis for meeting regulatory requirements for watershed planning that stem from the City's Phase II Municipal Stormwater Permit (Phase II Permit). The revised prioritization (performed after the ARs are complete) will include input from Community Metrics (see below) and other stakeholders and will guide all subsequent phases of WMP development.

- **Community Metrics** will be identified based on community values and goals for quantifying ancillary benefits that may be realized from the WMP in addition to those directly related to improved stream health. These metrics will be formed during a robust public engagement process. For example, these metrics might quantify benefits from the plan related to increased access to open space, educational opportunities, enhanced aesthetics, and/or environmental and social justice issues.

- **Watershed Improvement Plans (WIPs)** will be prepared for each watershed that list and describe each of the solutions and/or opportunities recommended for watershed improvement with associated costs and a schedule for implementation. These plans will provide details on the tools and opportunities considered for watershed improvement, provide information on how the opportunities were evaluated, and the results of those evaluations. The WIPs will focus on investments to improve stream health rather than broader community goals, which will be addressed in the WMP itself.

All the work performed to develop these components of the WMP will be informed by a conceptual model (Figure 2) that was created by the City to describe the primary effects of urbanization on stream health. This model shows the linkages between specific sources of stress on stream health (e.g., stormwater runoff) and the consequences, impacts, and outcomes that collectively contribute to degraded stream health. This model will be particularly important for identifying the specific limiting factors that are responsible for impaired stream health during preparation of the ARs and the appropriate solutions for improving conditions during preparation of the WIPs.

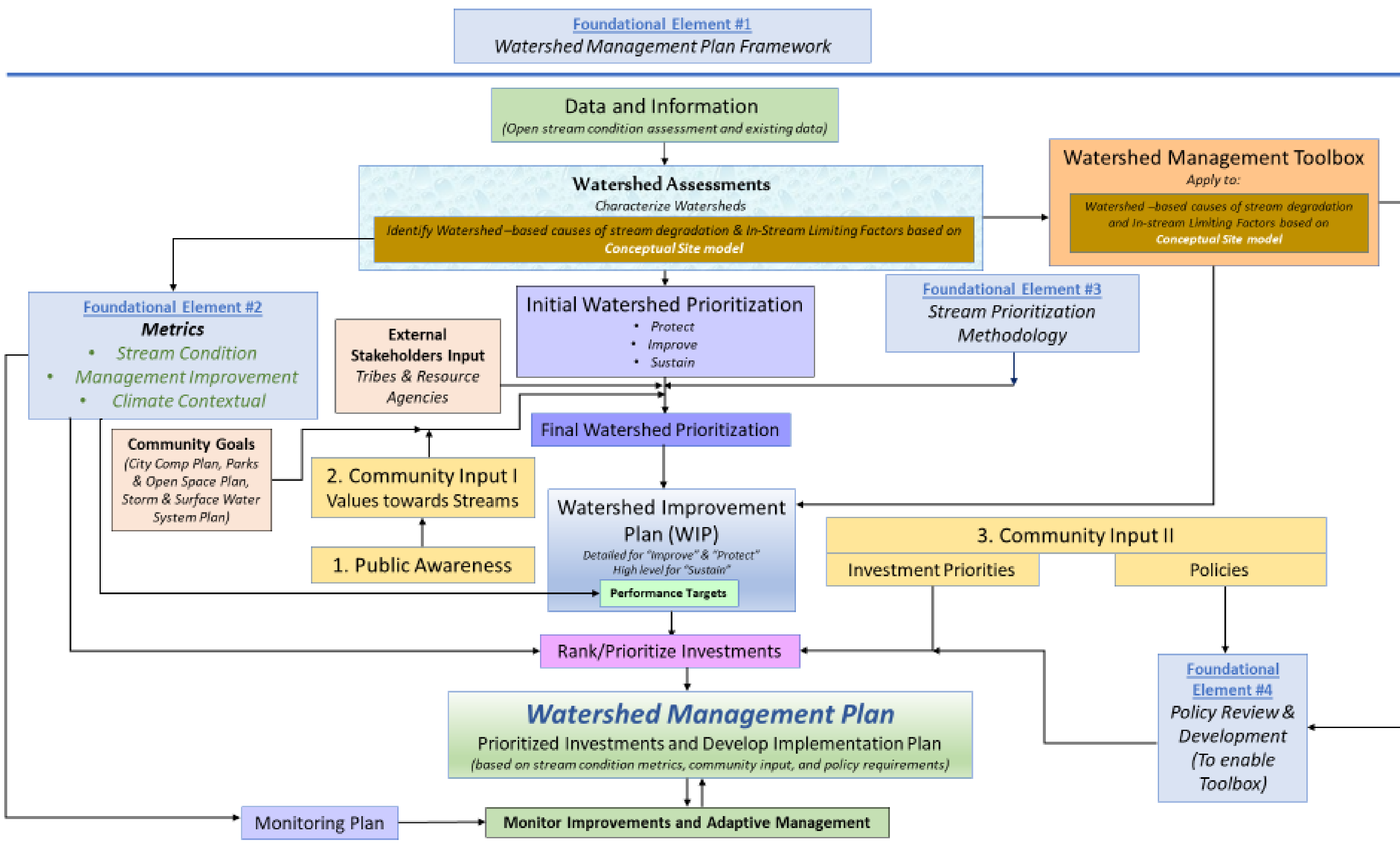


Figure 1. Watershed Management Plan Development Process.

1.2 The Greater Kelsey Creek Watershed

The Greater Kelsey Creek Watershed encompasses a total area of approximately 10,950 acres with 95 percent of this area located within the City's boundary (Figure 3). The remaining 5 percent of the watershed is within the City of Kirkland or the City of Redmond. The Greater Kelsey Creek Watershed is comprised of 9 subbasins that are briefly characterized below, with more detail provided within this report:

- Mercer Slough is the most downstream subbasin in the Greater Kelsey Creek Watershed and receives flow from the other eight subbasins before flowing into Lake Washington. The Mercer Slough Subbasin land use includes large tracts of park land as well as commercial/office and single family residential.
- Kelsey Creek Subbasin is the largest subbasin within the Greater Kelsey Creek Watershed. The Kelsey Creek Subbasin is located in the center of the City and connects the six upstream subbasins in the Watershed to Mercer Slough. The Kelsey Creek Subbasin is predominantly single family residential with large areas of parks, multi-family, and commercial/office.
- Sturtevant Creek flows from Lake Bellevue to Mercer Slough and is the only subbasin within the Greater Kelsey Creek Watershed that does not discharge to Kelsey Creek. The headwaters of Sturtevant Creek are north of Lake Bellevue, with Sturtevant Creek draining half of the Central Business District and the Wilburton neighborhood east of Interstate 405 (I-405). The Sturtevant Subbasin is mainly commercia/office and mixed-use.
- Richards Creek receives flow from East Creek (a part of the Richards Creek Subbasin), then receives flow from Sunset Creek before converging with Kelsey Creek. This Subbasin is characterized by relatively diverse land use including commercial/office, multi-family, mixed-use, and parks and includes the Factoria Mall area.
- Sunset Creek is the southern-most subbasin and is characterized by mostly residential land use. Sunset Creek runs through a residential area and underneath Interstate 90 (I-90) before its confluence with Richards Creek.
- West Tributary Subbasin is located in the northwestern section of the Greater Kelsey Creek Watershed. The upper reaches of West Tributary run through a mixed-use, commercial/office, and industrial/medical area of the City, before flowing through a mainly residential area.
- Goff Creek Subbasin's upstream portions are mainly residential land use. After Goff Creek flows past State Route 520 (SR-520), the land use is mixed-use and commercial/office with a small amount of residential land use before Goff Creek converges with the West Tributary at the Goff Creek Regional Pond.
- Valley Creek Subbasin's most upstream portions are within the Cities of Kirkland and Redmond. Valley Creek flows from its headwaters upstream of Bellevue Golf Course, through mainly residential areas, underneath SR-520, then picks up the flow of Sears Creek in a mixed-use area before its confluence with Kelsey Creek at Bel-Red Road.
- Sears Creek Subbasin is mainly in the City of Redmond. The portion within the City of Redmond is mainly mixed-use, with residential and commercial/office and some mixed-use land use covering the portion in the City.

This Watershed AR was prepared to meet the following objectives:

- Characterize the current Greater Kelsey Creek Watershed and instream conditions and identify any trends compared to previously collected data
- Identify limiting factors to stream health, data gaps (if any), and opportunities for improvement

- When combined with the other three ARs, provide input into prioritizing subbasins for the improvement of stream health

1.3 Organization

This Watershed AR is organized to include the following information for the Greater Kelsey Creek Watershed under separate sections:

Existing conditions - a summary of existing conditions for the following attributes: watershed characteristics, built infrastructure, and natural systems.

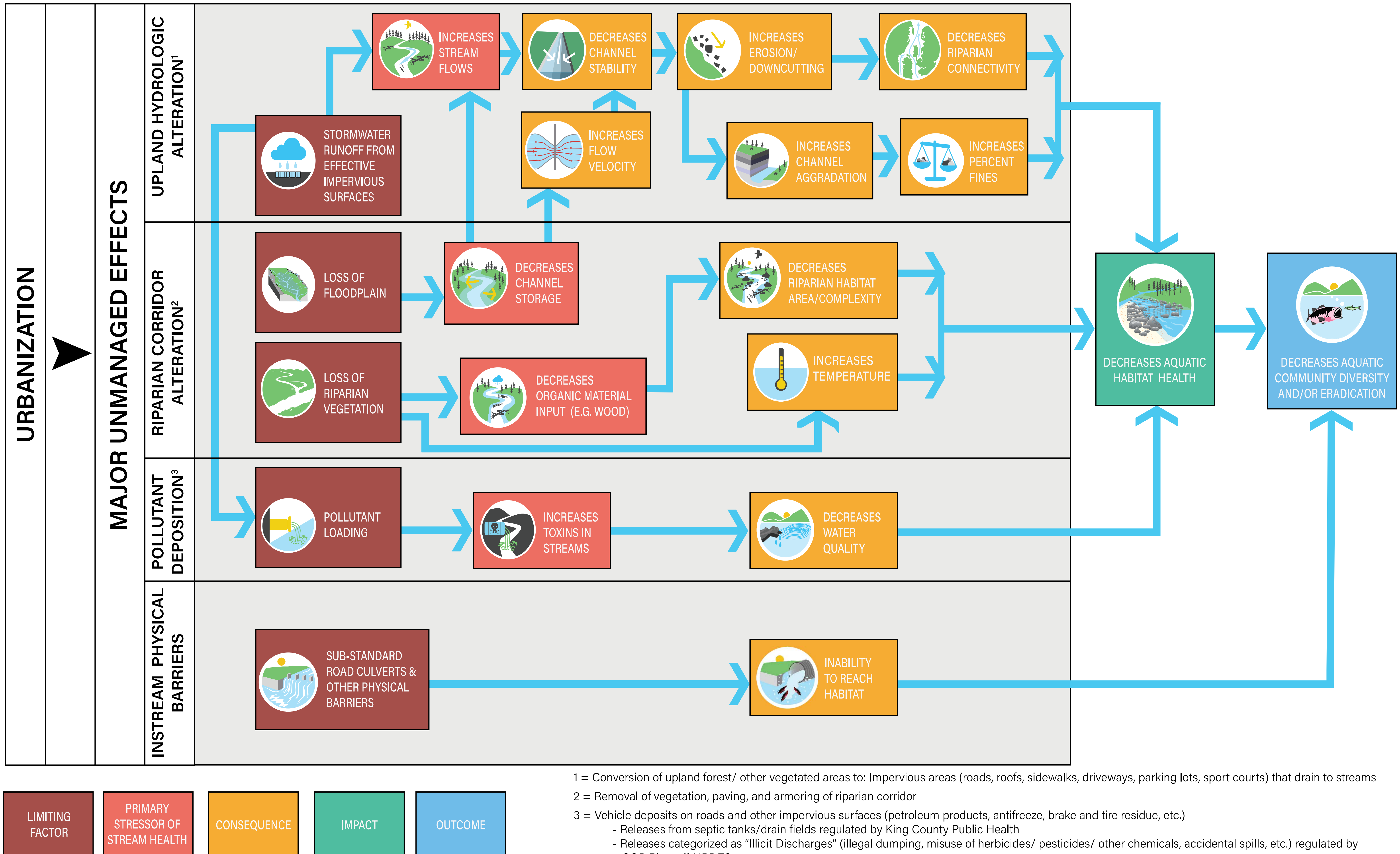
Limiting factors – based on an analysis of existing conditions, a summary of the primary factors from the conceptual model in Figure 2 that are limiting aquatic health in the Watershed.

Past and present investment – a summary of investments that have already been made to improve stream health in the Watershed.

Future opportunities – a summary of future opportunities that could be implemented to improve stream health in the Watershed based on the current understanding of existing conditions and limiting factors.

Data gaps – missing or incomplete information that were not available to inform this Watershed AR or future phases of WMP development.

CONCEPTUAL MODEL OF THE IMPACTS OF URBANIZATION ON STREAM HEALTH



1 = Conversion of upland forest/ other vegetated areas to: Impervious areas (roads, roofs, sidewalks, driveways, parking lots, sport courts) that drain to streams

2 = Removal of vegetation, paving, and armoring of riparian corridor

3 = Vehicle deposits on roads and other impervious surfaces (petroleum products, antifreeze, brake and tire residue, etc.)
- Releases from septic tanks/drain fields regulated by King County Public Health
- Releases categorized as "Illicit Discharges" (illegal dumping, misuse of herbicides/ pesticides/ other chemicals, accidental spills, etc.) regulated by COB Phase II NPDES program

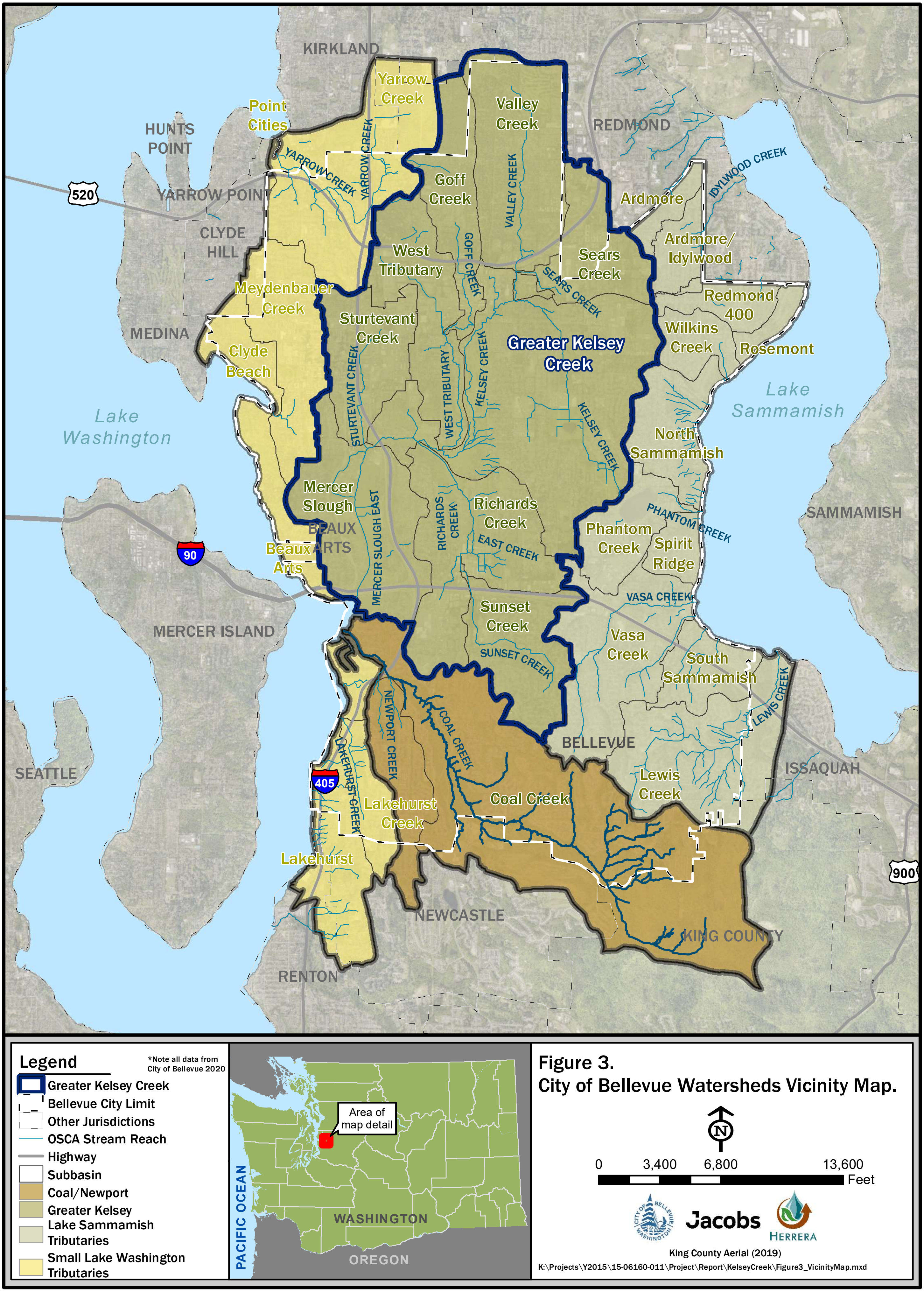


Figure 3.
City of Bellevue Watersheds Vicinity Map.

2. Existing Conditions

This section documents existing conditions in the Greater Kelsey Creek Watershed under separate subsections for the following attributes: watershed characteristics; built infrastructure; and natural systems. Data sources and methods used to summarize geospatial attributes in this section are presented in Appendix A.

2.1 Watershed Characteristics

Existing conditions in the Greater Kelsey Creek Watershed are summarized herein for the following attributes: climate, geology and soils, topography and geomorphology, surface water features, groundwater, and human and wildlife interaction. Figures 4-8 show surface water features for the Mercer Slough and Sturtevant Creek subbasins, the Kelsey Creek Subbasin, the Richards Creek and Sunset Creek subbasins, the West Tributary and Goff Creek subbasins, and the Valley Creek and Sears Creek subbasins, respectively.

2.1.1 Climate

As shown in the conceptual model (Figure 2), precipitation falling on impervious surfaces causes stormwater runoff. This alteration of the natural hydrology is associated with erosive peak flows and pollutant transport. These stressors degrade both aquatic habitat and water quality.

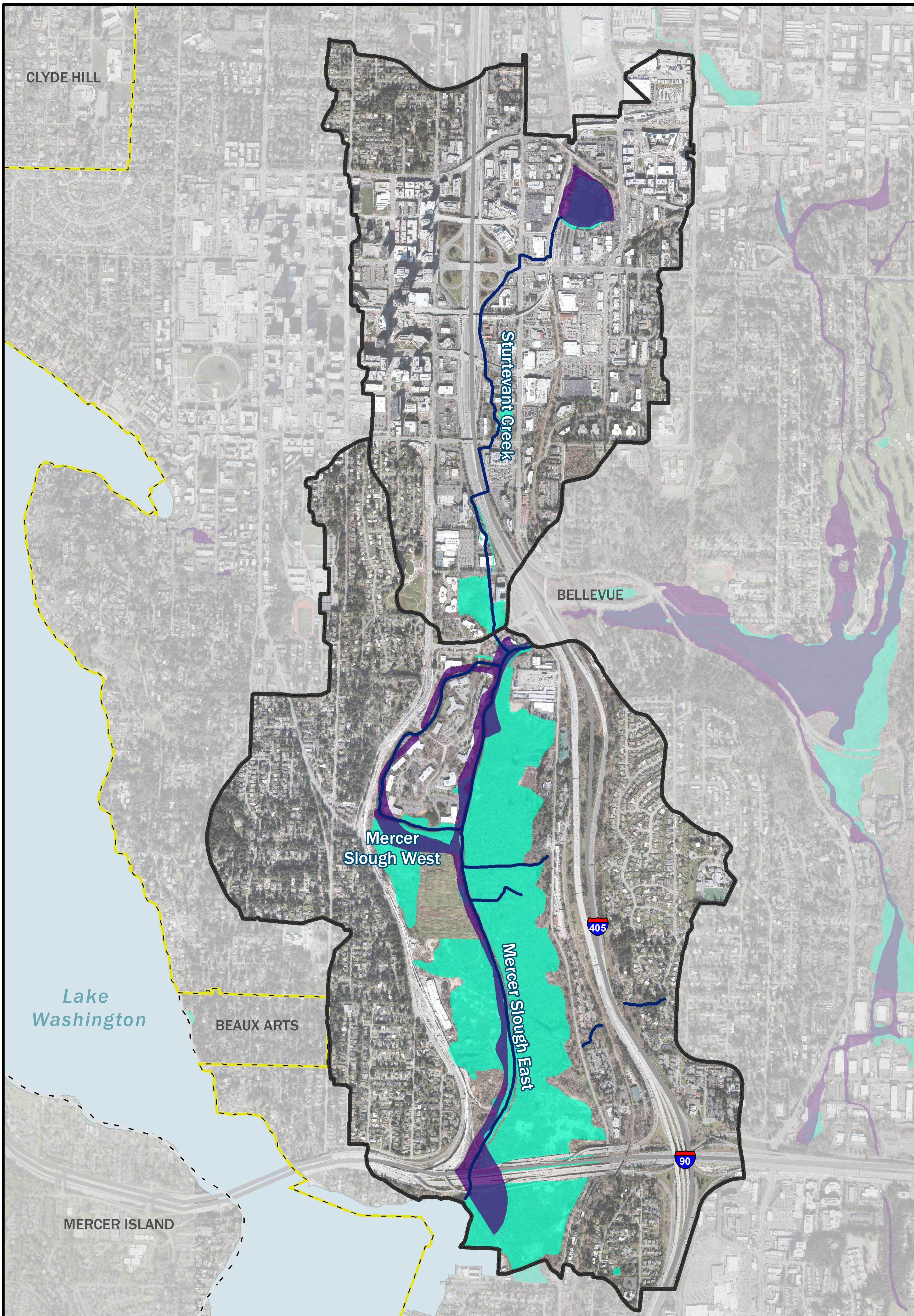
Existing climatic conditions in the Greater Kelsey Creek Watershed, similar to the other watersheds in the City, are characterized by cool, dry summers and mild, wet winters that are typical of maritime regions (Tetra Tech *et al*. 2006). Seasonal and spatial precipitation patterns within the Watershed were analyzed based on data collected from two rain gauges in the Watershed that are maintained by King County, with data accessed via the King County Hydrologic Information Center (HIC):

- XRDS - Bellevue Crossroads I&I Rain Gauge – 16100 NE 8th Street – Approximate elevation 430 ft NAVD88
- FACT - Factoria I&I Rain Gauge Transfer station at 13351 SE 32nd Street – Approximate elevation 105 NAVD88

The XRDS rain gauge is located approximately 3 miles northeast of FACT at Bellevue Fire Station No 3, near the intersection of 8th Street and 164th Avenue NE. XRDS has an approximate elevation of 430 feet and is located in the northeastern corner of the Greater Kelsey Creek Watershed as shown in Figure 5. (Figure 5 also shows the COB_RG08, which was not included in this analysis.) As shown in Figure 6, the FACT rain gauge is located near the East Creek Tributary of Richards Creek in the Richards Creek Subbasin, at the Puget Sound Energy (PSE) Factoria Service Center that is near the intersection of Richards Road and I-90. The FACT rain gauge has an approximate elevation of 105 feet. (Figure 6 also shows the COB_RG10, which was not included in this analysis.)

Rain gauge data for both FACT and XRDS were analyzed for the period spanning from January 1, 2015 to December 31, 2019. For these time periods, the average annual precipitation for FACT and XRDS were 44.0 and 44.4 inches, respectively. On average, the Watershed received the most precipitation during the months of November and December. As shown in Figure 9, FACT and XRDS measured similar amounts of precipitation over that period. These data suggest that the entire Greater Kelsey Creek Watershed receives spatially consistent rainfall over the month period.

While it is difficult to infer any long-term trends from the limited data that are available from the gauges identified above, regional studies on climate change are predicting a modest increase (15 percent) in the average of the annual daily maximum rainfall total over the period from 2020 to 2050, with larger storms (storms with over 3 inches of rain per 24-hour period) generally predicted to be larger and smaller storms generally predicted to be smaller (King County 2014). Based on this shift in precipitation patterns, the impacts from urbanization noted above are anticipated to become more severe as impervious surfaces intercept additional rainfall that would normally have infiltrated to groundwater under natural, forested conditions.



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- FEMA 100 year floodplain
- King County Sensitive Area Ordinance Wetlands (2020)
- NWI Wetlands (2020)
- Stream (City of Bellevue 2020)
- Highway (City of Bellevue 2020)

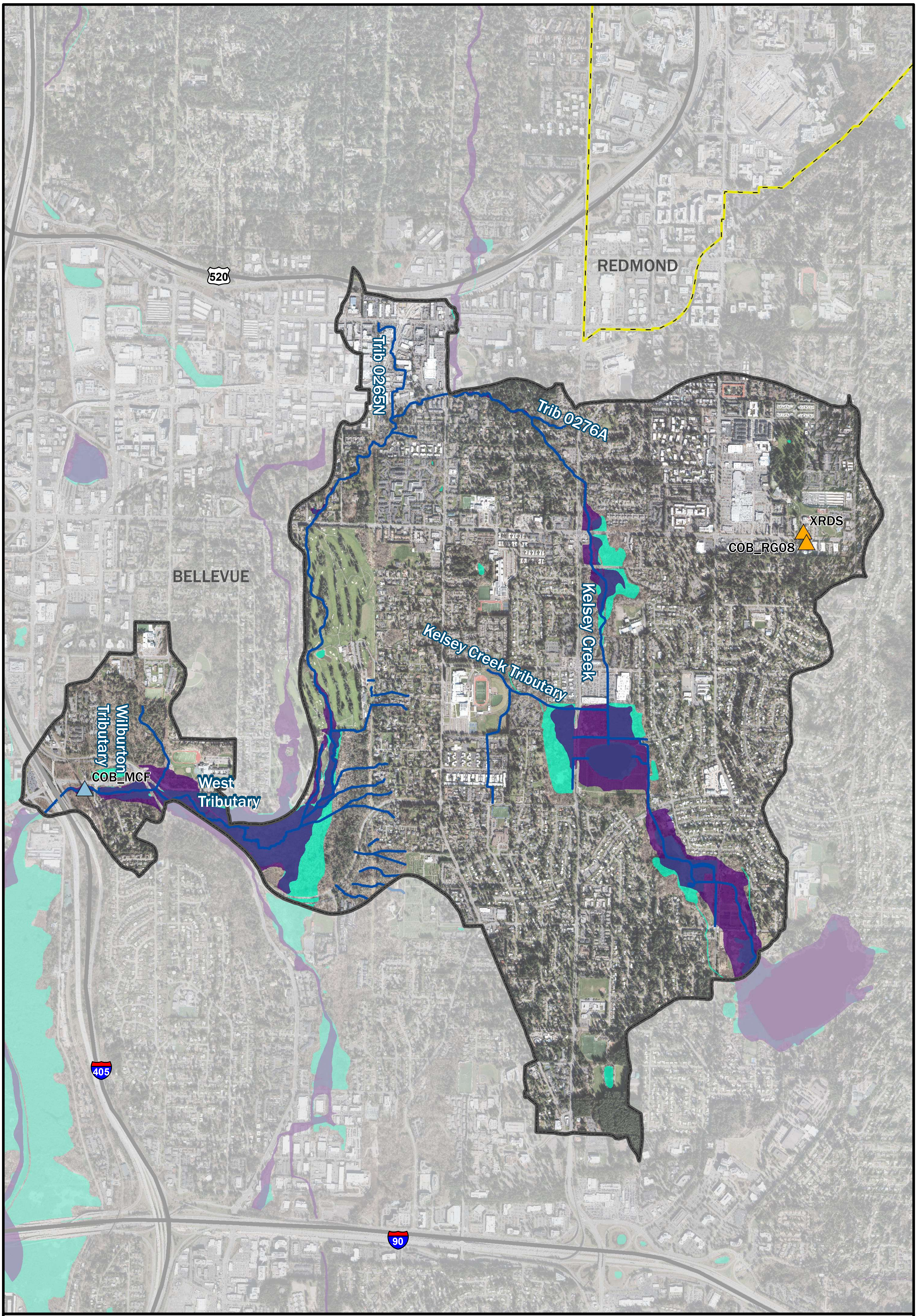
Note: Federal Emergency Management Area (FEMA), National Wetland Inventory (NWI), Open Stream Conditions Assessment Database (OSCA).

Figure 4.
Mercer Slough and Sturtevant Creek Subbasins Surface Water Features and Monitoring Sites.

0 700 1,400 2,800 Feet

Jacobs HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_SurfaceWater_SturMercer_.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- FEMA 100 Year Floodplain (King County 2020)
- NWI Wetlands (2020)
- Stream (City of Bellevue 2020)
- Highway (City of Bellevue 2020)

King County Monitoring

- Precipitation Gauge, Active
- Stream Gauge, Active

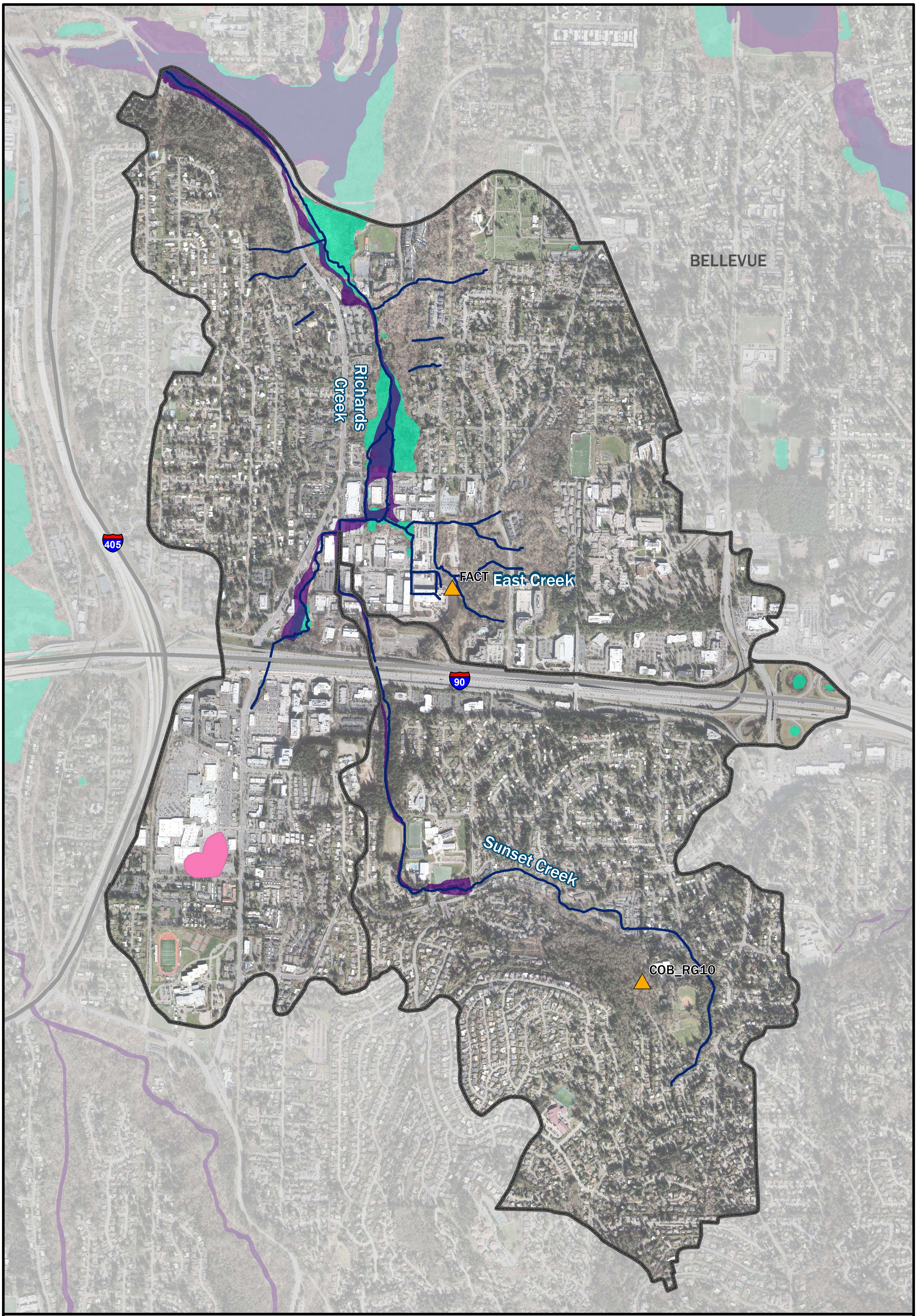
Note: Federal Emergency Management Area (FEMA), National Wetland Inventory (NWI), Open Stream Conditions Assessment Database (OSCA).

Figure 5.
Kelsey Creek Subbasin Surface Water Features and Monitoring Sites.

0 875 1,750 3,500 Feet

Jacobs HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_SurfaceWater_Kelsey_.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- FEMA 100 year floodplain
- King County Sensitive Area Ordinance Wetlands (2020)
- NWI Wetlands (2020)
- Highway (City of Bellevue 2020)
- Stream (City of Bellevue 2020)

King County Monitoring (King County 2020)

- Precipitation Gauge, Active

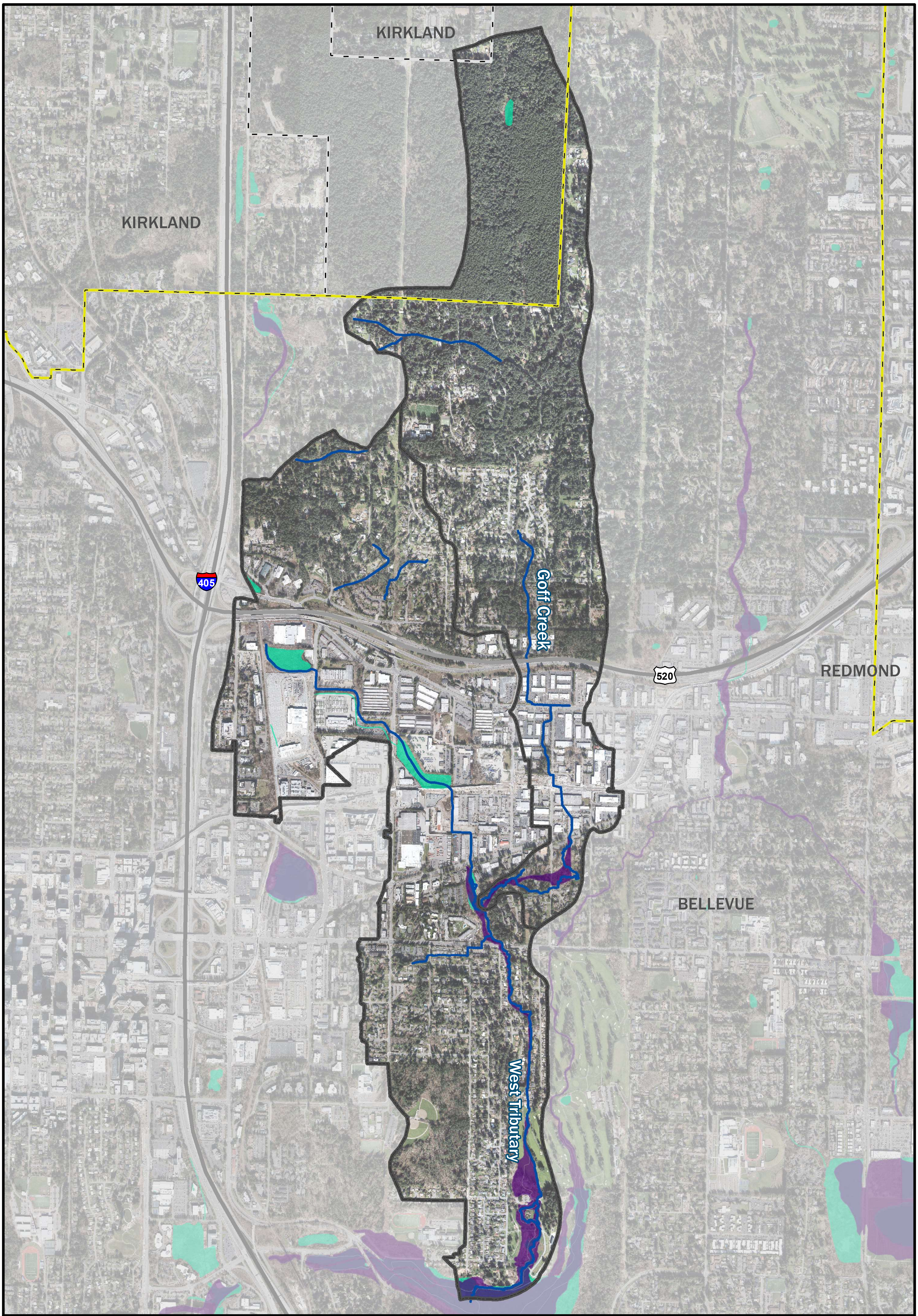
Note: Federal Emergency Management Area (FEMA), National Wetland Inventory (NWI), Open Stream Conditions Assessment Database (OSCA).

Figure 6.
Richards Creek and Sunset Creek Subbasin Surface Water Features and Monitoring Sites.

0 625 1,250 2,500 Feet

Jacobs HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_SurfaceWater_Sun_Valley_.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- FEMA 100 year floodplain
- NWI Wetlands (2020)
- Highway (City of Bellevue 2020)
- Stream (City of Bellevue 2020)

Note: Federal Emergency Management Area (FEMA), National Wetland Inventory (NWI), Open Stream Conditions Assessment Database (OSCA).

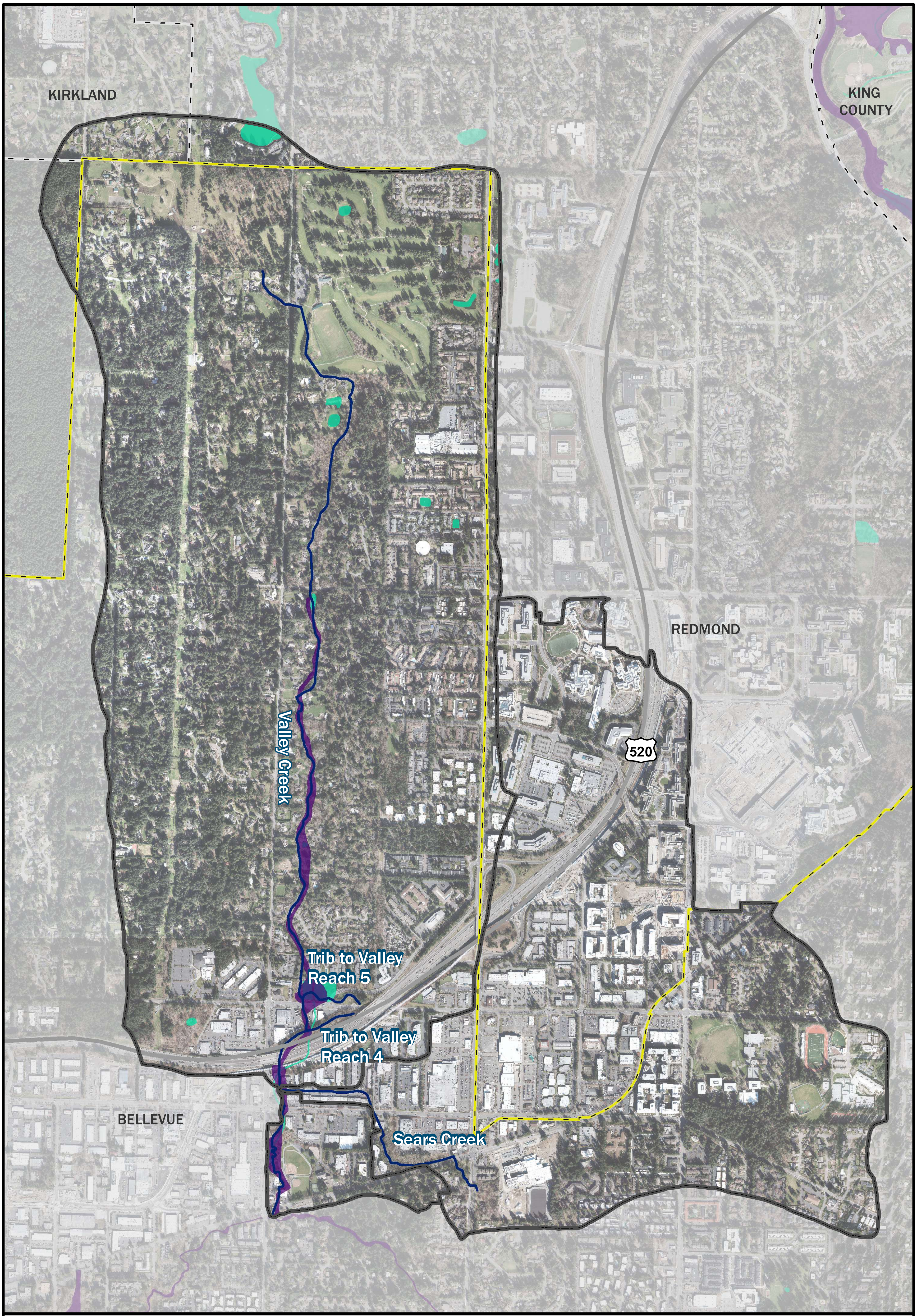
Figure 7.
West Tributary and Goff Creek Subbasins Surface Water Features and Monitoring Sites.

N

0 750 1,500 3,000 Feet

Jacobs
HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_SurfaceWater_GoffWest.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- FEMA 100 year floodplain
- NWI Wetlands (2020)
- Highway (City of Bellevue 2020)
- Stream (City of Bellevue 2020)

Note: Federal Emergency Management Area (FEMA), National Wetland Inventory (NWI), Open Stream Conditions Assessment Database (OSCA).

Figure 8.
Valley Creek and Sears Creek Subbasin Surface Water Features and Monitoring Sites.

N

0 550 1,100 2,200 Feet

Jacobs HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_SurfaceWater_Sun_Valley_.mxd

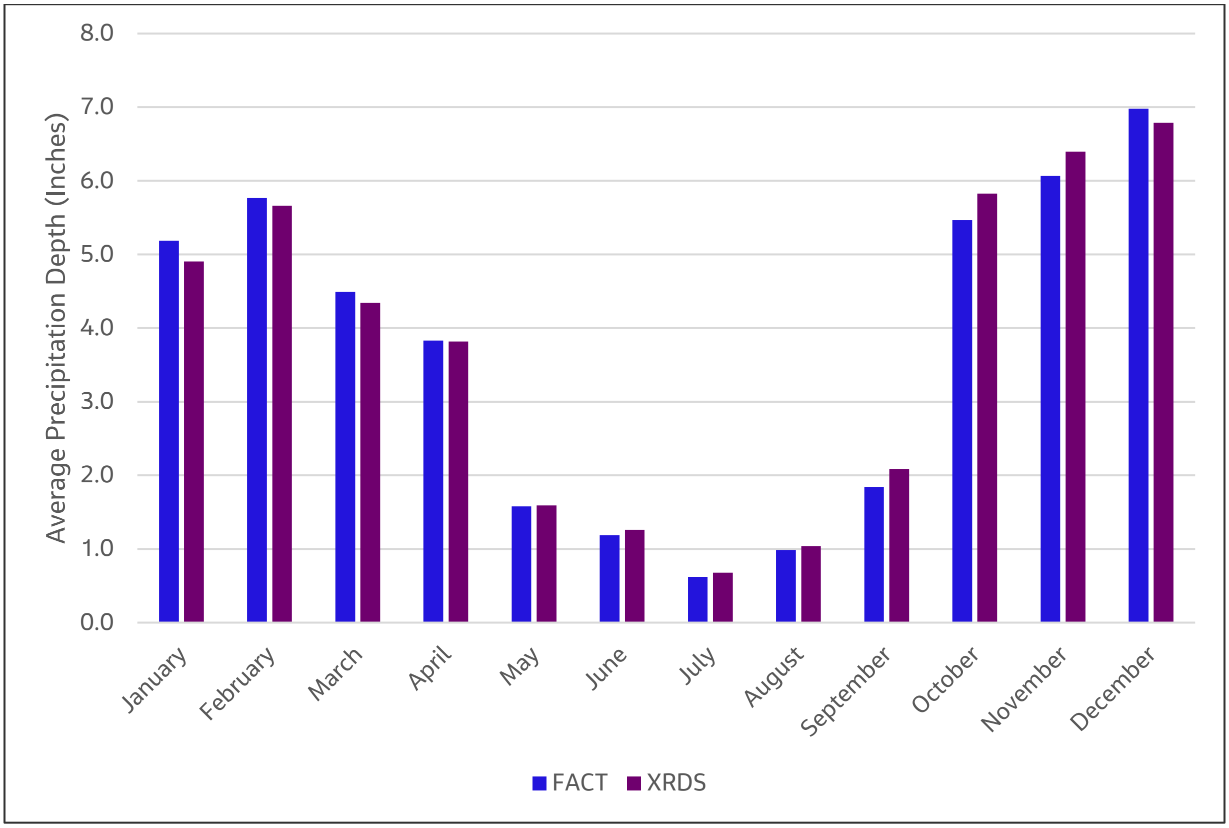


Figure 9. Precipitation Depth by Month in the Greater Kelsey Creek Watershed

2.1.2 Geology and Soils

The regional and local geologic setting has a considerable influence on the physical characteristics of a watershed, such as the watershed area, the geometry of the channel, floodplain, and valley, and how water and sediment move through the watershed and its channels. These physical characteristics in turn influence the responsiveness of a river or stream to changes (whether anthropogenic impacts or attempted restoration efforts) and therefore drive the levels of biological activity that are even possible in a watershed. As illustrated by the conceptual model presented in Figure 2, understanding the relationships between these physical characteristics and the biological functioning in watersheds is important for both the identification of limiting factors as well as the development of opportunities for improvement.

2.1.2.1 Geology

As a part of the Puget Lowland, the Greater Kelsey Creek Watershed has been formed by a long history of tectonic and depositional processes; yet the geologic episode with the most influence on the current landscape was the last glaciation that culminated approximately 16,000 years ago. As a result, the surface geology of the Greater Kelsey Creek Watershed is primarily characterized by a combination of glacial and post-glacial deposits (glacial till) deposited during the Fraser glaciation, approximately 13,000 to 16,000 years ago. The Greater Kelsey Creek Watershed is unique within the City because of the large tract of peat deposits along the stream channel in the Mercer Slough Subbasin with peat deposits also located in the Sturtevant Subbasin. These peat deposits are bordered by glacial outwash and non-glacial deposits. Figures 10-14 show the geology of the Mercer Slough and Sturtevant Creek subbasins, the Kelsey Creek Subbasin, the Richards Creek and Sunset Creek subbasins, the West Tributary and Goff Creek subbasins, and the Valley Creek and Sears Creek subbasins, respectively. Table 1 provides a summary of the percentages of the mapped surface geologic types by subbasin as well as for the entire Greater Kelsey Creek Watershed (USGS 2016).

The soils of the Mercer Slough and Sturtevant Creek Subbasins (Figure 10) are glacial and post-glacial deposits with a large tract of peat proximate to Mercer Slough. The Kelsey Creek Subbasin (Figure 11), the Richards and Sunset Creek subbasins (Figure 12), and the West Tributary and Goff Creek subbasins (Figure 13) are also made up of glacial and post-glacial deposits (glacial till), with large tracts of post-glacial (outwash) deposits observed in only small extents in the Valley Creek, Sears Creek, Mercer Slough, and Sturtevant Creek subbasins. The predominant surface geologic type in the Valley and Sears Creek subbasins (Figure 14) are glacial and post-glacial deposits with a small area of alluvium in the southwest part of the Sears Creek Subbasin.

The valley that contains Kelsey Creek was formed by the incision of the erosive glacial meltwaters into the glacial deposits described above. Although ongoing channel incision is a part of a natural geologic and geomorphic process, there are some places within the Watershed where the rates of channel incision have been exacerbated by hydrologic alterations, described later in this report.

2.1.2.2 Soils

The soil types that have been deposited above the glacial geologic layers influence the feasibility of using infiltration-focused stormwater management BMPs. As described below, the soils at the surface tend to be highly erodible and the soils just below the surface tend to have a low permeability. Table 2 provides a summary of the percentages of different soil types within individual subbasins as well as the entire Greater Kelsey Creek Watershed. Figures 15-19 show the soils of the Mercer Slough and Sturtevant Creek subbasins, the Kelsey Creek Subbasin, the Richards Creek and Sunset Creek subbasins, the West Tributary and Goff Creek subbasins, and the Valley Creek and Sears Creek subbasins, respectively.

Alderwood soils are the predominant soil type found in the Greater Kelsey Creek Watershed, covering 50 percent of the Watershed. Arent soils (Alderwood material) cover an additional 26 percent and Arent soils (Everett material) cover an additional 12 percent. Of the remaining Greater Kelsey Creek Watershed area, 4 percent of the area is covered by Beausite soils, with 1 percent covered in Peat soils and the remaining soil types not identified (Bellevue 2020; Snyder *et al*. 1973). Arent soils (Alderwood material or Everett material) consist of soils that have been disturbed through urbanization that they are no longer classified as Alderwood or Everett (Snyder *et al*. 1973). The extents of Arent (Alderwood material) soil have likely expanded with the area's extensive development since the King County Soil Survey took place in 1973.

Alderwood soils belong to hydrologic soil group B and consist of moderately deep, moderately well-drained gravelly sandy loams that sit on top of a very slowly permeable layer of consolidated glacial till. The Arent (Alderwood material) soils belong to hydrologic soil group B/D that range from moderately well drained (with moderate infiltration potential) to very

Hydrologic soil group is a way of characterizing the relative infiltration potential, which is the ability of that soil to accept rainfall instead of that rainfall becoming runoff. Soils are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D), with Group A having the greatest infiltration potential (low runoff potential) and Group D having the lowest potential for infiltration (highest runoff potential). If a dual hydrologic group is assigned, the first letter is for drained areas and the second is for undrained areas. Only the soils that are in their natural condition in group D are assigned to dual classes. (United States Department of Agriculture, Natural Resources Conservation Service website, accessed 7/2/21) slow drained. The Arent (Everett material) soils are gravelly sandy loam underlain by very gravelly sand and belong to hydrologic soil group A with high infiltration potential. Beausite soils (gravelly sandy loam) belong to hydrologic soil group C and consist of well-drained gravelly sandy loams that sit on top of sandstone.

Both Alderwood and Beausite soils are found in glaciated foothills of Western Washington with rolling to very steep slopes (Snyder *et al.* 1973). Alderwood and Beausite soils have severe erosion potential for slopes greater than 15 percent. The steep narrow ravines in the Greater Kelsey Creek Watershed (for example those in the Goff and Sunset Creek Subbasins) have a naturally severe potential for erosion.

The heavily compacted glacial till geology underlying the majority of the Greater Kelsey Creek Watershed is a deposit that is generally more resistant to change and thus affords the Watershed some resiliency from the full force of the hydrologic changes that would otherwise result from upland urbanization and unmanaged stormwater runoff. At the same time, however, the Alderwood and Beausite soils that have deposited above the till have severe erosion potential that is easily exacerbated by increased delivery of concentrated flows and stormwater runoff leading to increased rates of upper slope instability, mass-wasting (as observed in Sunset Creek and Goff Creek), channel incision, and the delivery of fine sediment to streams and subsequent transport to downstream depositional reaches in the Watershed.

The very low permeability of the glacial till geology often limits the effectiveness of infiltration-focused stormwater management techniques in the Watershed. However, this is not uniformly the case in the Greater Kelsey Creek Watershed as there are large areas in the Bel-Red neighborhood that have good capacity for infiltration (2016 Louis Berger).

Table 1. Surface Geology in the Greater Kelsey Creek Watershed.

Subbasin	Geologic Map Unit	Geologic Unit Age	Geologic Type	Geologic Description	Area (Acres)	Subbasin Area (Acres)	Percent of Subbasin (%)	Percent of the Greater Kelsey Creek Watershed (%)
Mercer Slough	Qf	Holocene	Artificial fill and modified land	Holocene artificial fill and modified land	0	1330	0%	0%
Mercer Slough	Qga	Pleistocene	Advance continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	146	1330	11%	1%
Mercer Slough	Qgo	Pleistocene	Continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	27	1330	2%	0%
Mercer Slough	Qgpc	Pleistocene	Continental glacial drift, pre-Fraser, and nonglacial deposits	Pleistocene glacial and nonglacial deposits	96	1330	7%	1%
Mercer Slough	Qgt	Pleistocene	Continental glacial till, Fraser-age	Pleistocene continental glacial till	663	1330	50%	6%
Mercer Slough	Qp	Holocene	Peat deposits	Quaternary bog, marsh, swamp, or lake deposits	397	1330	30%	4%
Mercer Slough	wtr	Holocene	Water	Water	1	1330	0%	0%
Kelsey Creek	Qa	Holocene	Alluvium	Quaternary alluvium	8	2899	0%	0%
Kelsey Creek	Qga	Pleistocene	Advance continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	195	2899	7%	2%
Kelsey Creek	Qgo	Pleistocene	Continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	983	2899	34%	9%
Kelsey Creek	Qgpc	Pleistocene	Continental glacial drift, pre-Fraser, and nonglacial deposits	Pleistocene glacial and nonglacial deposits	34	2899	1%	0%
Kelsey Creek	Qgt	Pleistocene	Continental glacial till, Fraser-age	Pleistocene continental glacial till	1679	2899	58%	16%
Sturtevant Creek	Qga	Pleistocene	Advance continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	4	773	1%	0%
Sturtevant Creek	Qgo	Pleistocene	Continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	43	773	6%	0%
Sturtevant Creek	Qgt	Pleistocene	Continental glacial till, Fraser-age	Pleistocene continental glacial till	720	773	93%	7%
Sturtevant Creek	Qp	Holocene	Peat deposits	Quaternary bog, marsh, swamp, or lake deposits	6	773	1%	0%
Richards Creek	Oen	Oligocene-Eocene	Nearshore sedimentary rocks	Tertiary sedimentary rocks and deposits	6	1380	1%	0%
Richards Creek	Qga	Pleistocene	Advance continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	105	1380	8%	1%
Richards Creek	Qgo	Pleistocene	Continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	519	1380	38%	5%
Richards Creek	Qgpc	Pleistocene	Continental glacial drift, pre-Fraser, and nonglacial deposits	Pleistocene glacial and nonglacial deposits	14	1380	1%	0%
Richards Creek	Qgt	Pleistocene	Continental glacial till, Fraser-age	Pleistocene continental glacial till	736	1380	53%	7%
Sunset Creek	OEn	Oligocene-Eocene	Nearshore sedimentary rocks	Tertiary sedimentary rocks and deposits	21	854	3%	0%
Sunset Creek	Qgo	Pleistocene	Continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	407	854	48%	4%
Sunset Creek	Qgt	Pleistocene	Continental glacial till, Fraser-age	Pleistocene continental glacial till	425	854	50%	4%
West Tributary	Qga	Pleistocene	Advance continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	92	958	10%	1%
West Tributary	Qgo	Pleistocene	Continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	349	958	36%	3%

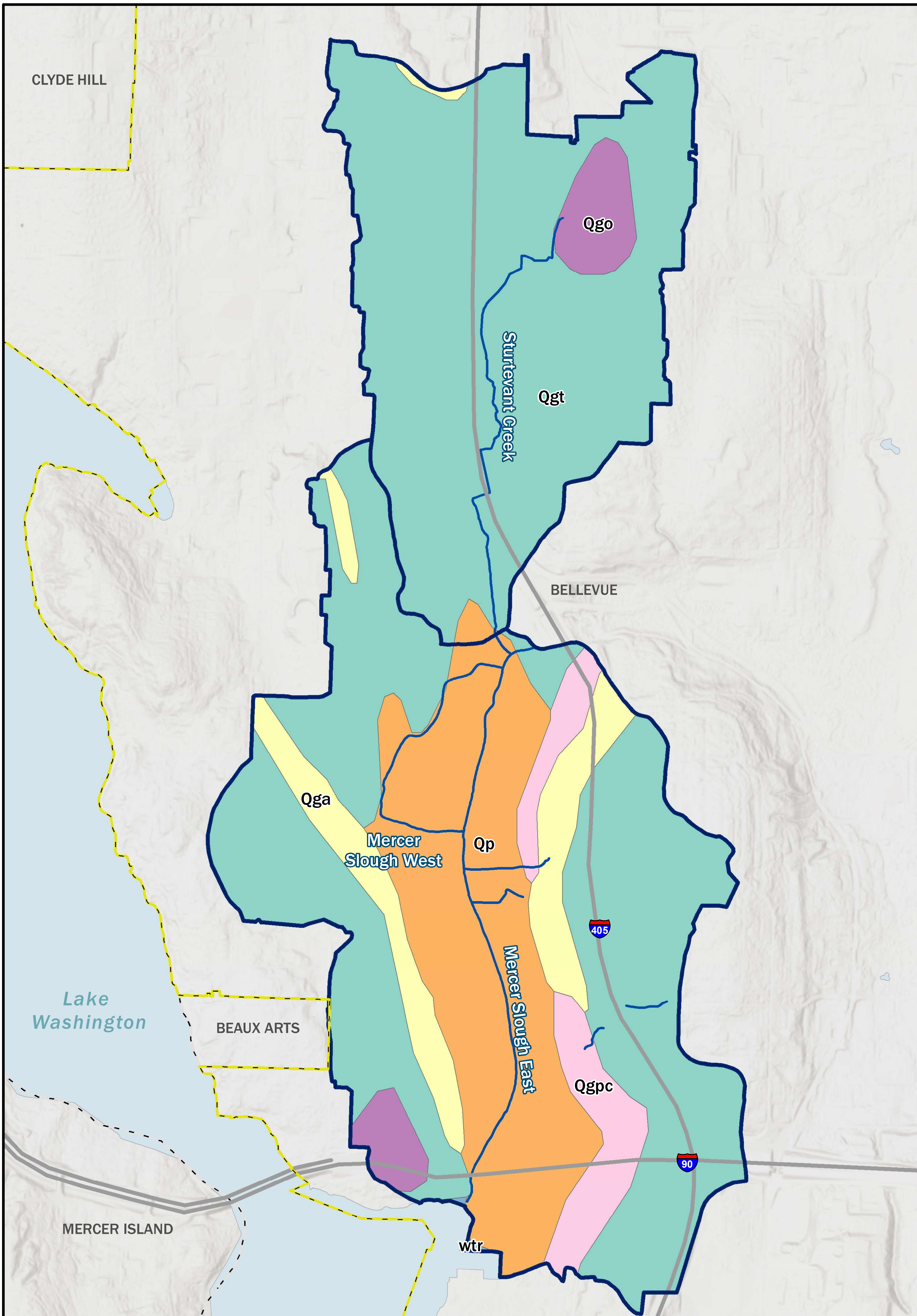
Subbasin	Geologic Map Unit	Geologic Unit Age	Geologic Type	Geologic Description	Area (Acres)	Subbasin Area (Acres)	Percent of Subbasin (%)	Percent of the Greater Kelsey Creek Watershed (%)
West Tributary	Qgt	Pleistocene	Continental glacial till, Fraser-age	Pleistocene continental glacial till	516	958	54%	5%
Goff Creek	Qga	Pleistocene	Advance continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	124	700	18%	1%
Goff Creek	Qgo	Pleistocene	Continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	61	700	9%	1%
Goff Creek	Qgt	Pleistocene	Continental glacial till, Fraser-age	Pleistocene continental glacial till	347	700	50%	3%
Valley Creek	Qa	Holocene	Alluvium	Quaternary alluvium	3	1383	0%	0%
Valley Creek	Qga	Pleistocene	Advance continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	642	1383	46%	6%
Valley Creek	Qga(t)	Pleistocene	Pleistocene continental glacial drift	Advance continental glacial outwash, Fraser-age	52	1383	4%	1%
Valley Creek	Qgo	Pleistocene	Continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	25	1383	2%	0%
Valley Creek	Qgt	Pleistocene	Continental glacial till, Fraser-age	Pleistocene continental glacial till	577	1383	42%	6%
Sears Creek	Qga	Pleistocene	Advance continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	7	678	1%	0%
Sears Creek	Qga(t)	Pleistocene	Pleistocene continental glacial drift	Advance continental glacial outwash, Fraser-age	8	678	1%	0%
Sears Creek	Qgo	Pleistocene	Vashon Stade in western WA; unnamed in eastern WA	Pleistocene continental glacial drift	0	678	0%	0%
Sears Creek	Qgt	Pleistocene	Continental glacial till, Fraser-age	Pleistocene continental glacial till	330	678	49%	3%

SOURCE 100k USGS: Washington Division of Geology and Earth Resources, 2016, Surface geology, 1:100,000--GIS data, November 2016: Washington Division of Geology and Earth Resources Digital Data Series DS-18, version 3.1, previously released June 2010

Table 2. Soils in the Greater Kelsey Creek Watershed

Hydrologic Soil Group	Soil Classification	Relative Infiltration Potential	Soil Notation	Mercer Slough	Kelsey Creek Subbasin	Sturtevant Creek	Richards Creek	Sunset Creek	West Tributary	Goff Creek	Valley Creek	Sears Creek	Greater Kelsey Creek Watershed
A	Arents, Everett material Everett gravelly sandy loam, 0 to 5 percent slopes Everett gravelly sandy loam, 15 to 30 percent slopes Everett gravelly sandy loam, 5 to 15 percent slopes Indianola loamy fine sand, 4 to 15 percent slopes Ragnar-Indianola association, moderately steep Ragnar-Indianola association, sloping	High	An EvB EvC EvD InC RdC RdE	0%	4%	0%	21%	23%	24%	19%	28%	0%	13%
A/D	Norma sandy loam Orcas peat	High (drained condition); Very low (undrained/high water table condition)	No Or	0%	1%	3%	0%	2%	2%	0%	0%	0%	1%
B	Alderwood and Kitsap soils, very steep Alderwood gravelly sandy loam, 0 to 8 percent slopes Alderwood gravelly sandy loam, 15 to 30 percent slopes Alderwood gravelly sandy loam, 8 to 15 percent slopes Everett-Alderwood gravelly sandy loams, 6 to 15 percent slopes	Moderate	AgB AgC AgD AkF EwC	36%	50%	34%	41%	7%	56%	81%	66%	87%	48%
B/D	Arents, Alderwood material, 0 to 6 percent slopes Arents, Alderwood material, 6 to 15 percent slopes Seattle muck Shalcar muck Tukwila muck	Moderate (drained condition); Very slow (undrained/high water table condition)	AmB AmC Sk Sm Tu	51%	40%	39%	18%	36%	5%	0%	0%	9%	27%
C	Beausite gravelly sandy loam, 15 to 30 percent slopes Beausite gravelly sandy loam, 6 to 15 percent slopes Kitsap silt loam, 15 to 30 percent slopes Kitsap silt loam, 2 to 8 percent slopes	Slow	BeC BeD KpB KpD	5%	0%	0%	4%	27%	4%	0%	0%	0%	4%
C/D	Bellingham silt loam Snohomish silt loam		Bh So	3%	3%	1%	5%	0%	3%	0%	5%	2%	3%
Hydrologic Not identified	Pits Urban land Water	NA	Pits Ur W	5%	1%	23%	10%	6%	6%	0%	0%	2%	5%
Areas (acres)	N/A	N/A	N/A	1328	2899	773	1380	854	958	531	1299	345	10365

SOURCE: Bellevue Soils, retrieved City of Bellevue GIS portal 2020



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Waterbody
- Highway (City of Bellevue 2020)
- Stream (City of Bellevue 2020)

USGS Geology 100k (2020)

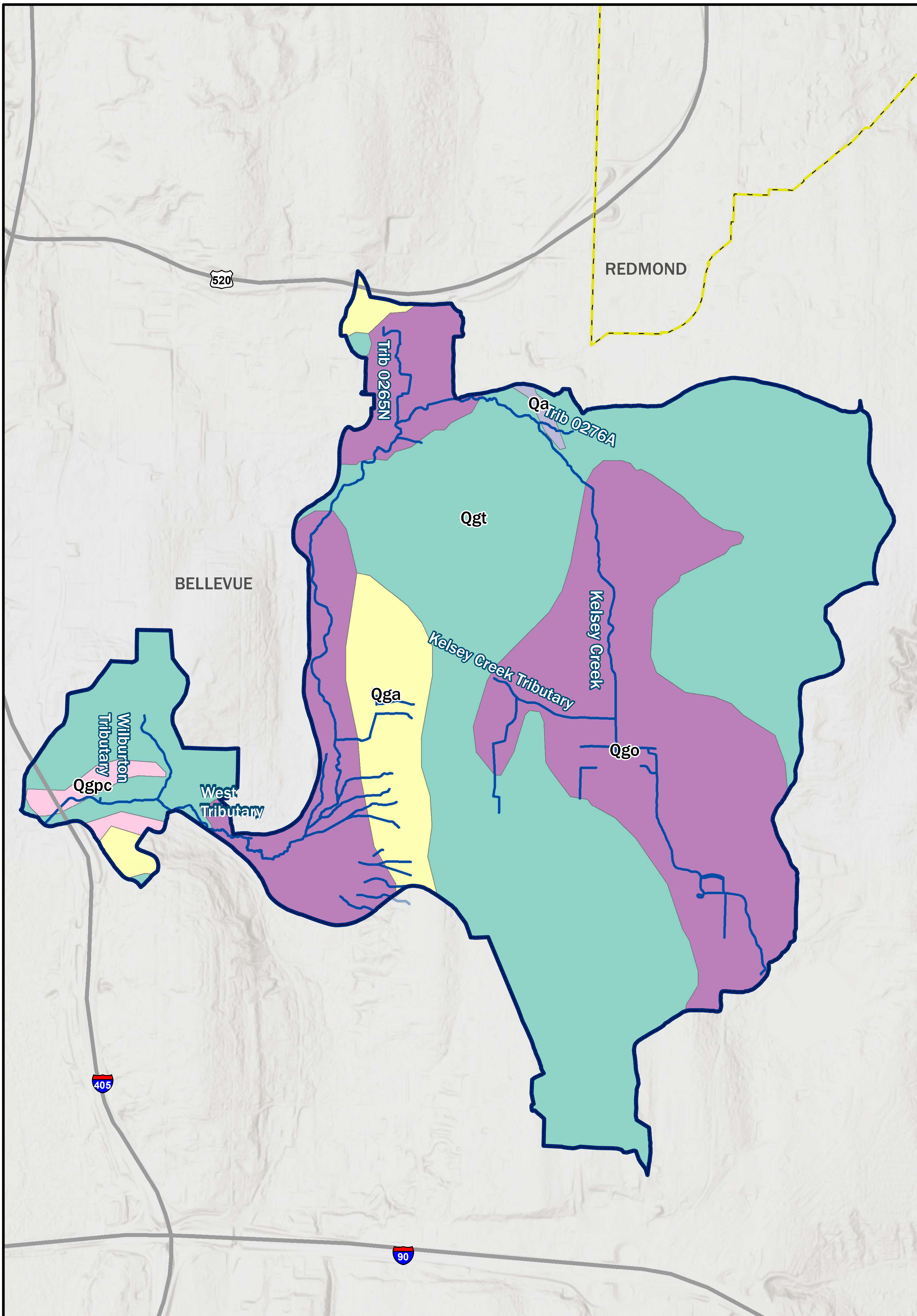
- Qga, Pleistocene, Advance continental glacial outwash Fraser-age
- Qgpc, Pleistocene Continental glacial drift pre-Fraser, and nonglacial deposits,
- Qgt, Pleistocene, Continental glacial till Fraser-age
- Qp, Quaternary, Peat deposits
- Wtr, Present, Water,
- Qgo, Pleistocene, Continental glacial outwash, Fraser-age

Note: United States Geological Survey (USGS), Open Stream Conditions Assessment Database (OSCA).

Figure 10.
Mercer Slough and Sturtevant Creek Subbasins Geology.

0 700 1,400 2,800 Feet

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_Geology_SturMercer.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Stream (City of Bellevue 2020)
- Highway (City of Bellevue 2020)

Note: United States Geological Survey (USGS), Open Stream Conditions Assessment Database (OSCA).

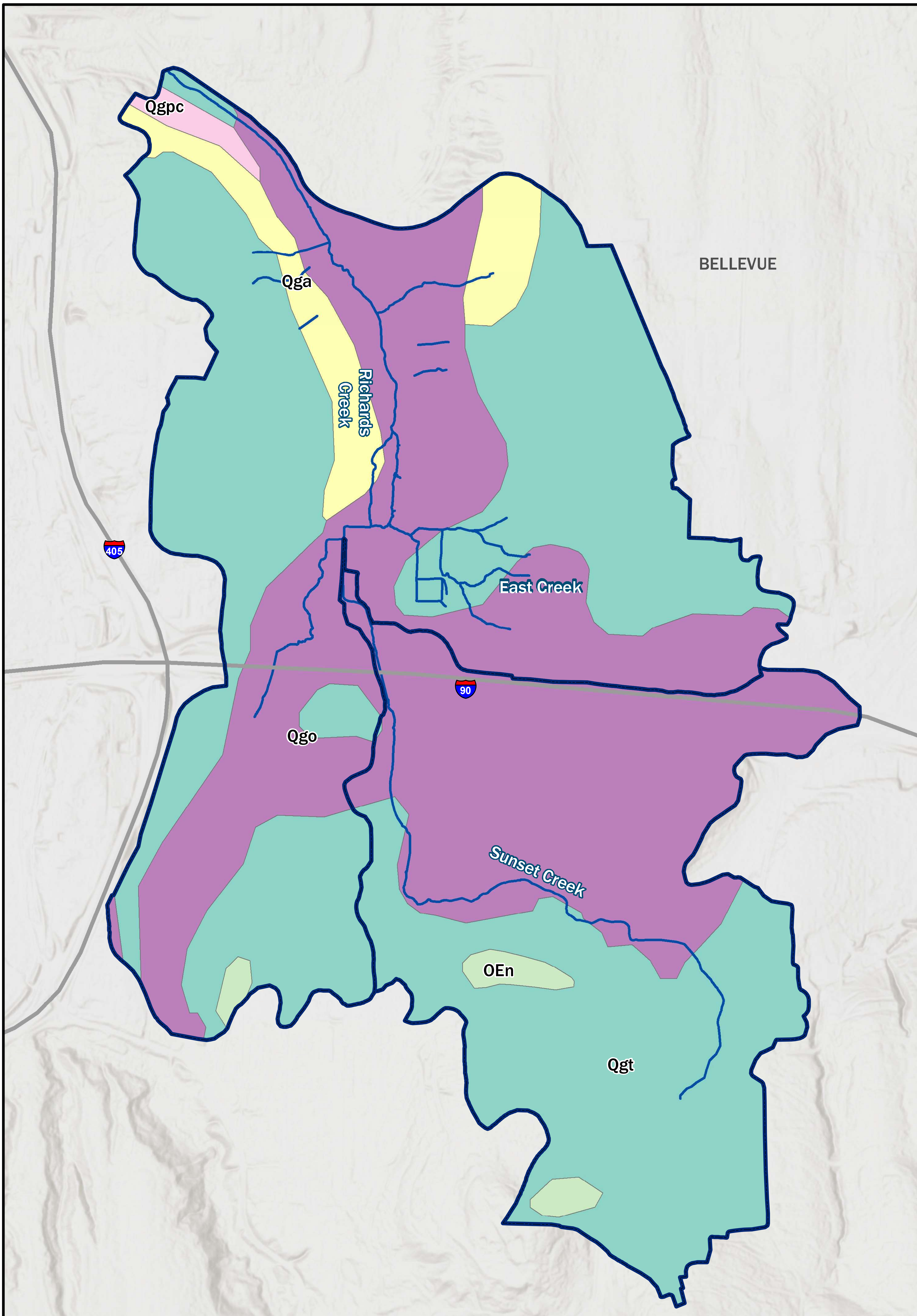
USGS Geology 100k (2020)

- Qa, Quaternary, Alluvium
- Qga, Pleistocene, Advance continental glacial outwash
- Qgpc, Pleistocene, Continental glacial drift pre-Fraser, and nonglacial deposits,
- Qgt, Pleistocene, Continental glacial till Fraser-age
- Qgo, Pleistocene, Continental glacial outwash, Fraser-age

Figure 11.
Kelsey Creek Subbasin Geology.

0 875 1,750 3,500 Feet

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_Geology_Kelsey.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Highway (City of Bellevue 2020)
- Stream (City of Bellevue 2020)

USGS Geology 100k (2020)

- OEn, Oligocene-Eocene, Nearshore sedimentary rocks
- Qga, Pleistocene, Advance continental glacial outwash, Fraser-age
- Qgo, Pleistocene, Continental glacial outwash, Fraser-age
- Qgpc, Pleistocene Continental glacial drift pre-Fraser, and nonglacial deposits
- Qgt, Pleistocene, Continental glacial, till Fraser-age

Note: United States Geological Survey (USGS), Open Stream Conditions Assessment Database (OSCA).

Figure 12.
Richards Creek and Sunset Creek Subbasin Geology.

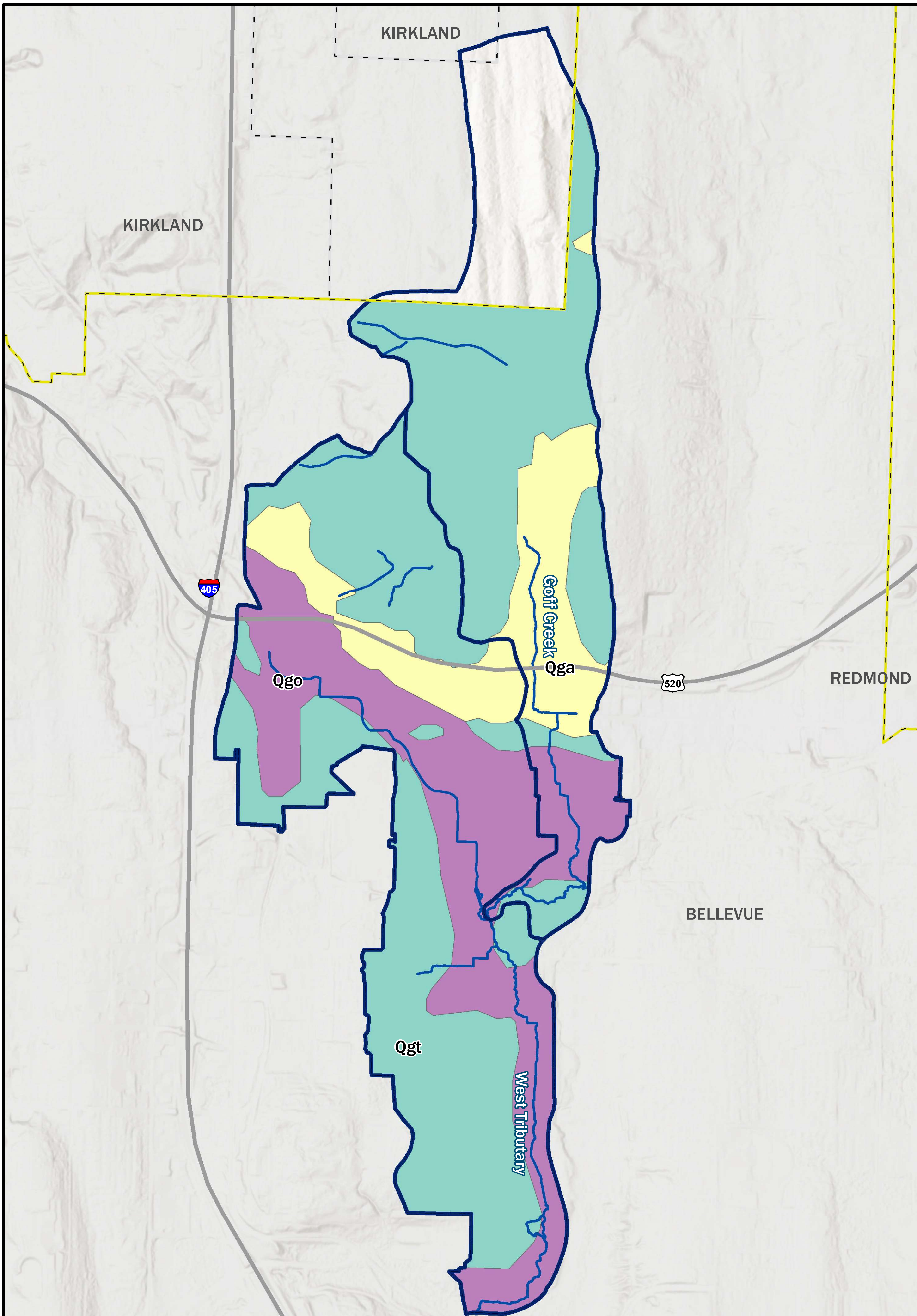
N

0 625 1,250 2,500 Feet

Jacobs

HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_Geology_Sunset_Valley.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Highway (City of Bellevue 2020)
- Stream (City of Bellevue 2020)

USGS Geology 100k (2020)

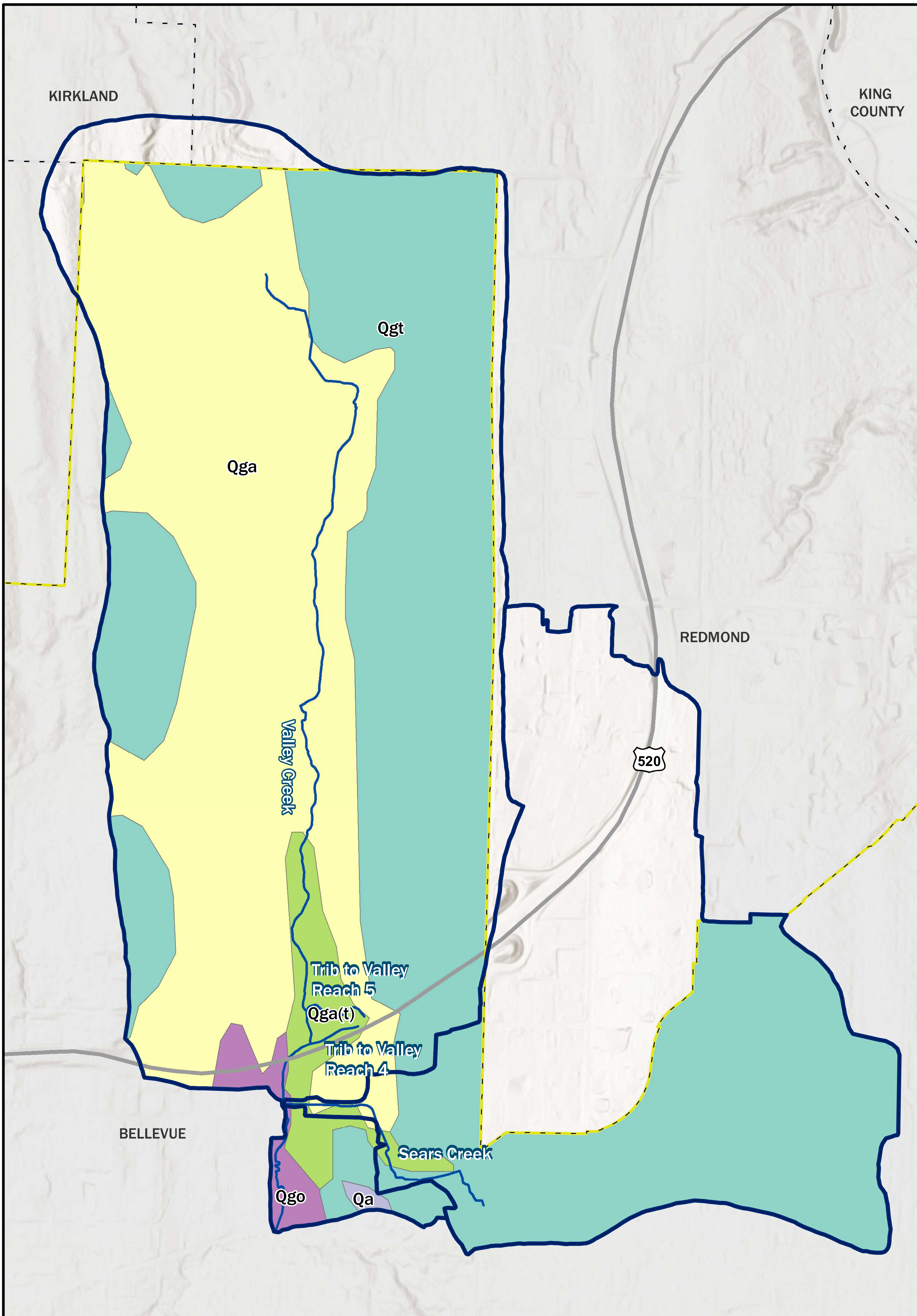
- Qga, Pleistocene, Advance continental glacial outwash, Fraser-age
- Qgo, Pleistocene, Continental glacial outwash, Fraser-age
- Qgt, Pleistocene, Continental glacial till Fraser-age

Note: United States Geological Survey (USGS), Open Stream Conditions Assessment Database (OSCA).

Figure 13.
West Tributary and Goff Creek Subbasins Geology.

0 750 1,500 3,000 Feet

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_Geology_GoffWest.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Highway (City of Bellevue 2020)
- Stream (City of Bellevue 2020)

USGS Geology 100k (2020)

- Qa, Quaternary, Alluvium
- Qga(t), Pleistocene, Advance continental glacial outwash, Fraser-age
- Qga, Pleistocene, Advance continental glacial outwash, Fraser-age
- Qgo, Pleistocene, Continental glacial outwash, Fraser-age
- Qgt, Pleistocene, Continental glacial, till Fraser-age

Note: United States Geological Survey (USGS), Open Stream Conditions Assessment Database (OSCA).

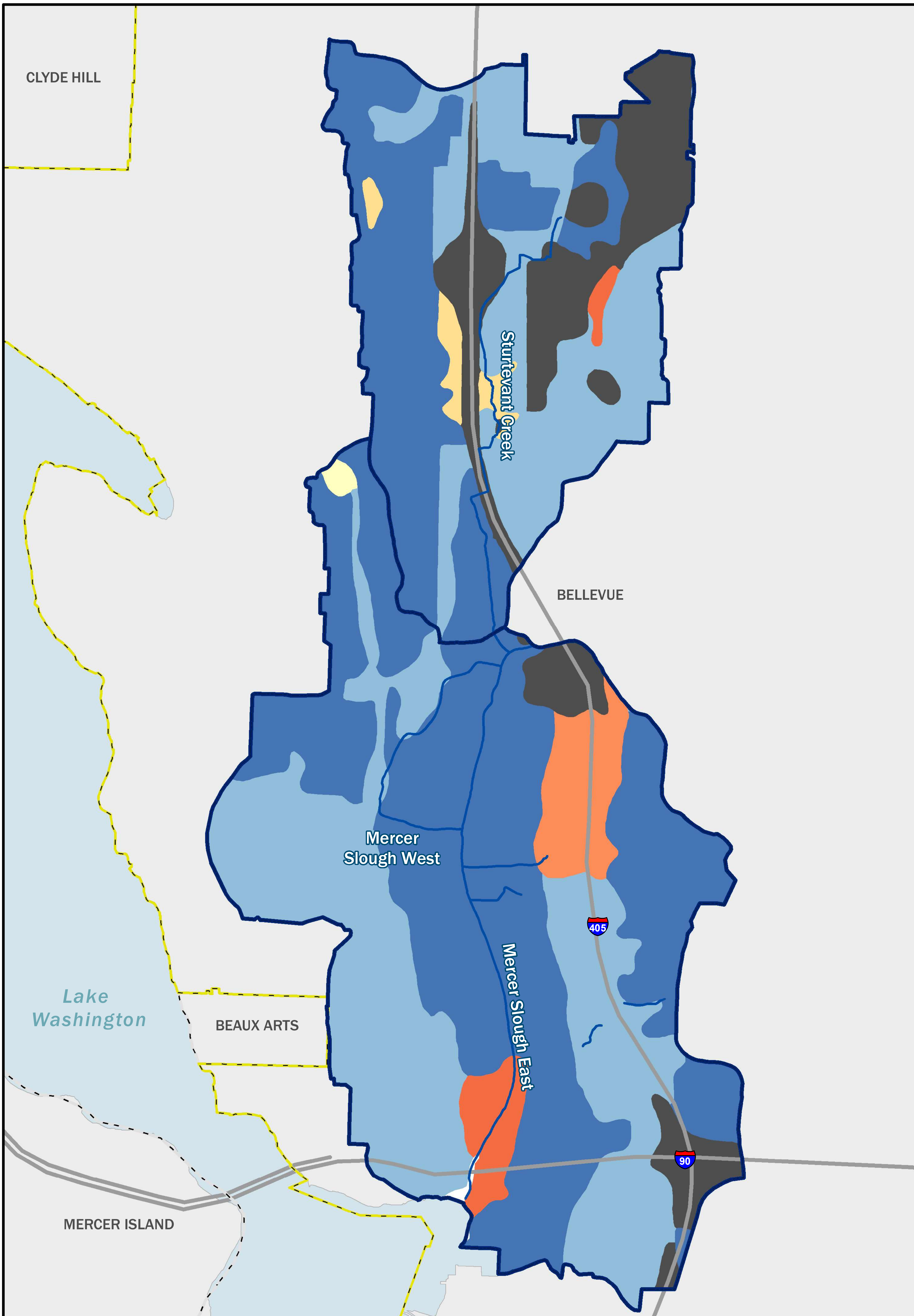
Figure 14.
Valley Creek and Sears Creek Subbasin Geology.

N

0 550 1,100 2,200 Feet

City of Bellevue Washington Jacobs Herrera

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_Geology_Sunset_Valley.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Stream (City of Bellevue 2020)
- Highway (City of Bellevue 2020)

Note: Open Stream Conditions Assessment Database (OSCA).

Hydrologic Group (City of Bellevue 2020)

- Not identified (high impervious)
- A
- A/D
- B
- B/D
- C
- C/D

Soil Description:
A - Sand, loamy sand or sandy loam types of soils.
B - Silt loam or loam.
C - Sandy clay loam.
D- Clay loam, silty clay loam, sandy clay, silty clay or clay.

Figure 15.
Mercer Slough and Sturtevant Creek Subbasins Soils.

0 700 1,400 2,800 Feet

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_Soil_SturMercer_.mxd

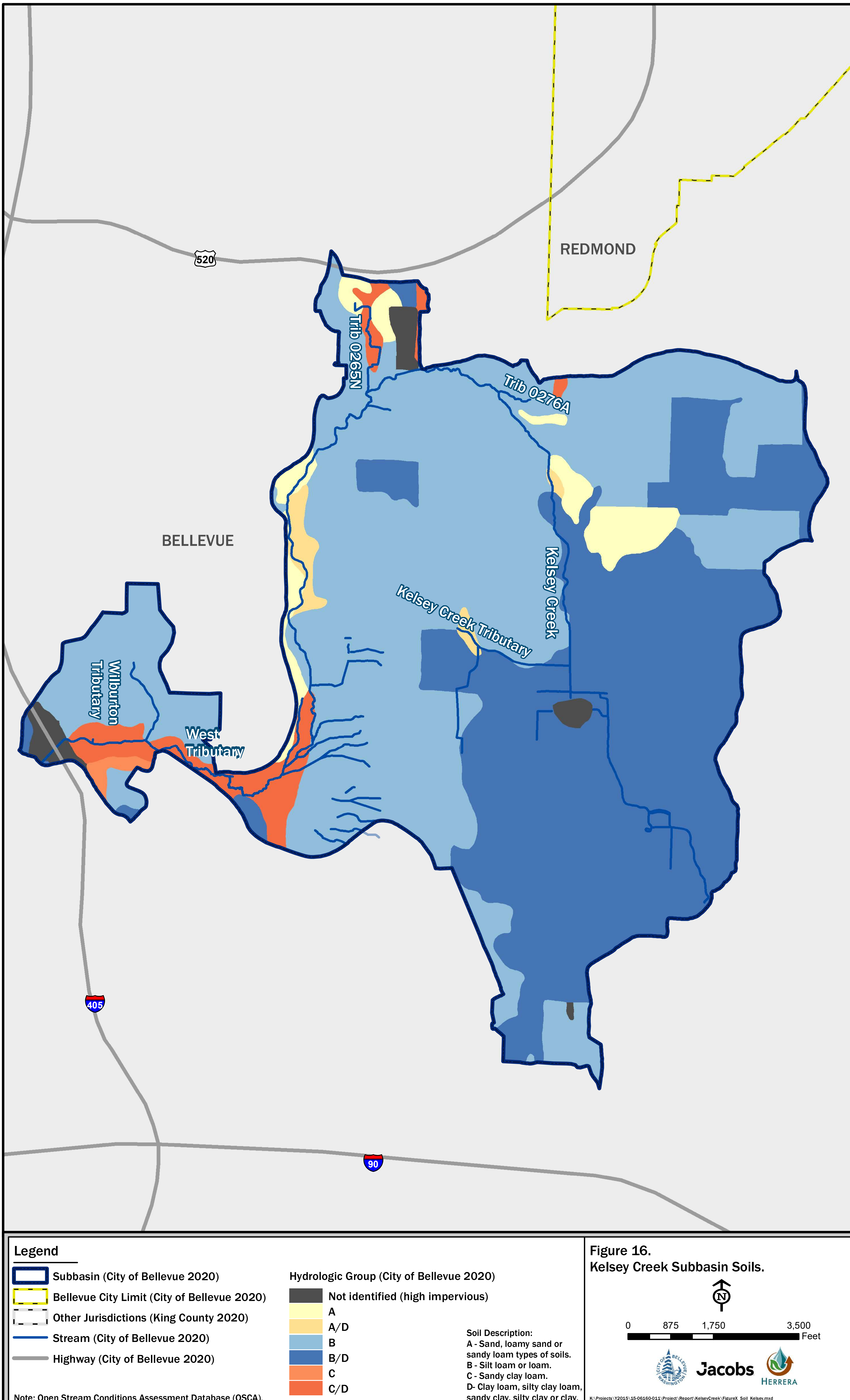
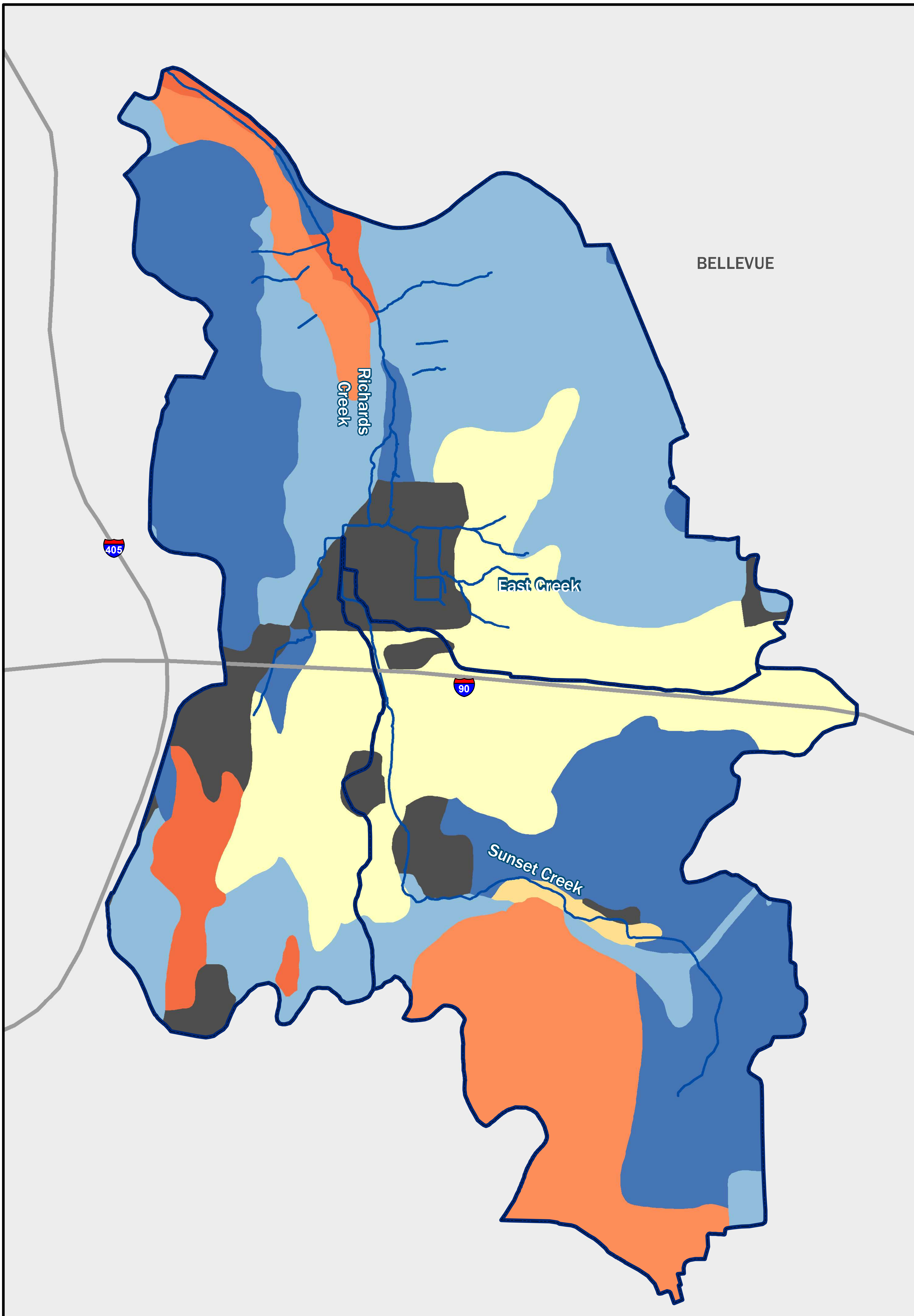


Figure 16.
Kelsey Creek Subbasin Soils.



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Highway (City of Bellevue 2020)
- Stream (City of Bellevue 2020)

Hydrologic Group

- Not identified (high impervious)
- A
- A/D
- B
- B/D
- C
- C/D

Soil Description:
A - Sand, loamy sand or sandy loam types of soils.
B - Silt loam or loam.
C - Sandy clay loam.
D- Clay loam, silty clay loam, sandy clay, silty clay or clay.

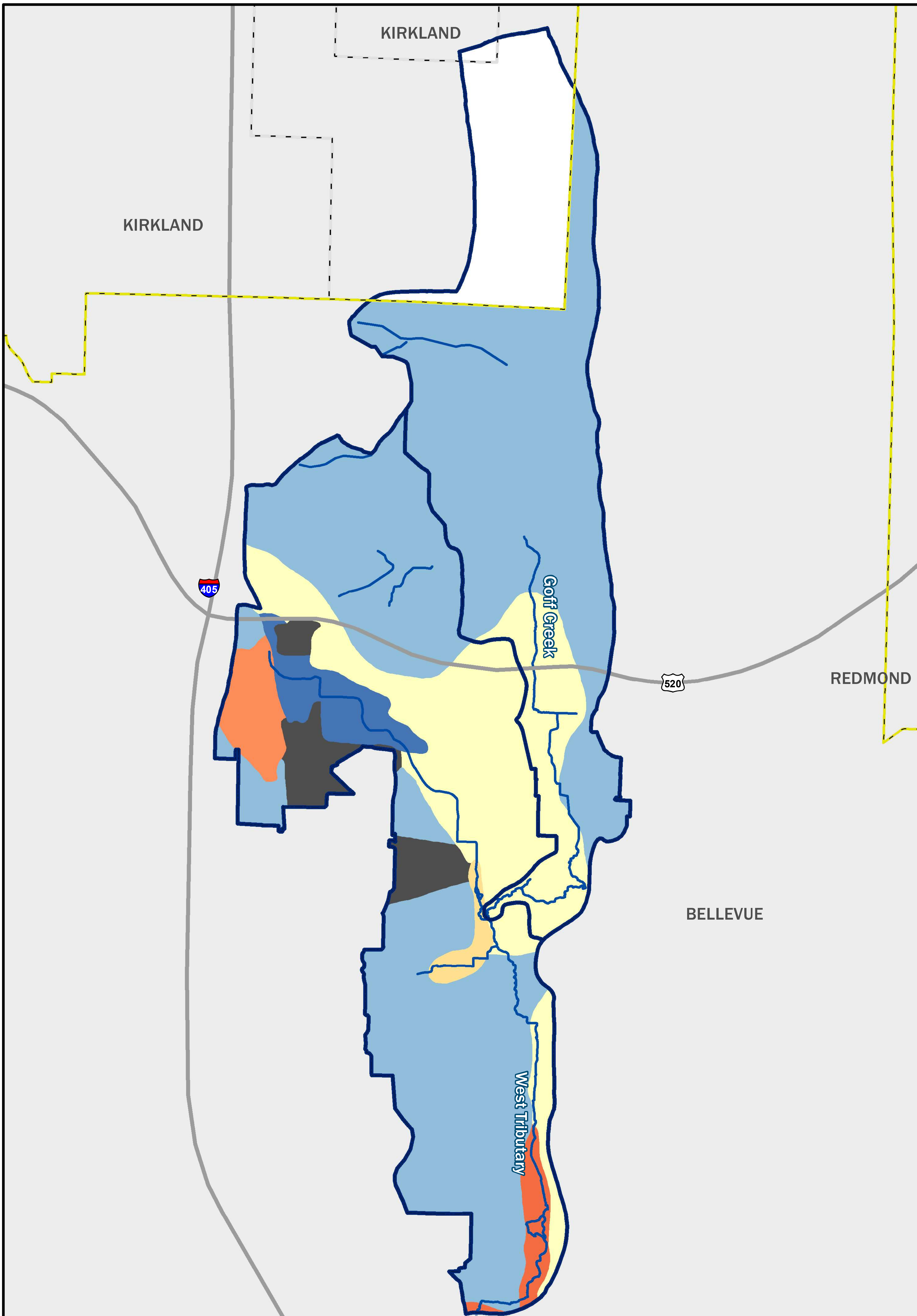
Note: Open Stream Conditions Assessment Database (OSCA).

**Figure 17.
Richards Creek and Sunset Creek Subbasins Soils.**

N

0 625 1,250 2,500 Feet

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_Soil_Sunset_Valley_.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Stream (City of Bellevue 2020)
- Highway (City of Bellevue 2020)

Note: Open Stream Conditions Assessment Database (OSCA).

Hydrologic Group (City of Bellevue 2020)

- Not identified (high impervious)
- A
- A/D
- B
- B/D
- C
- C/D

Soil Description:
A - Sand, loamy sand or sandy loam types of soils.
B - Silt loam or loam.
C - Sandy clay loam.
D- Clay loam, silty clay loam, sandy clay, silty clay or clay.

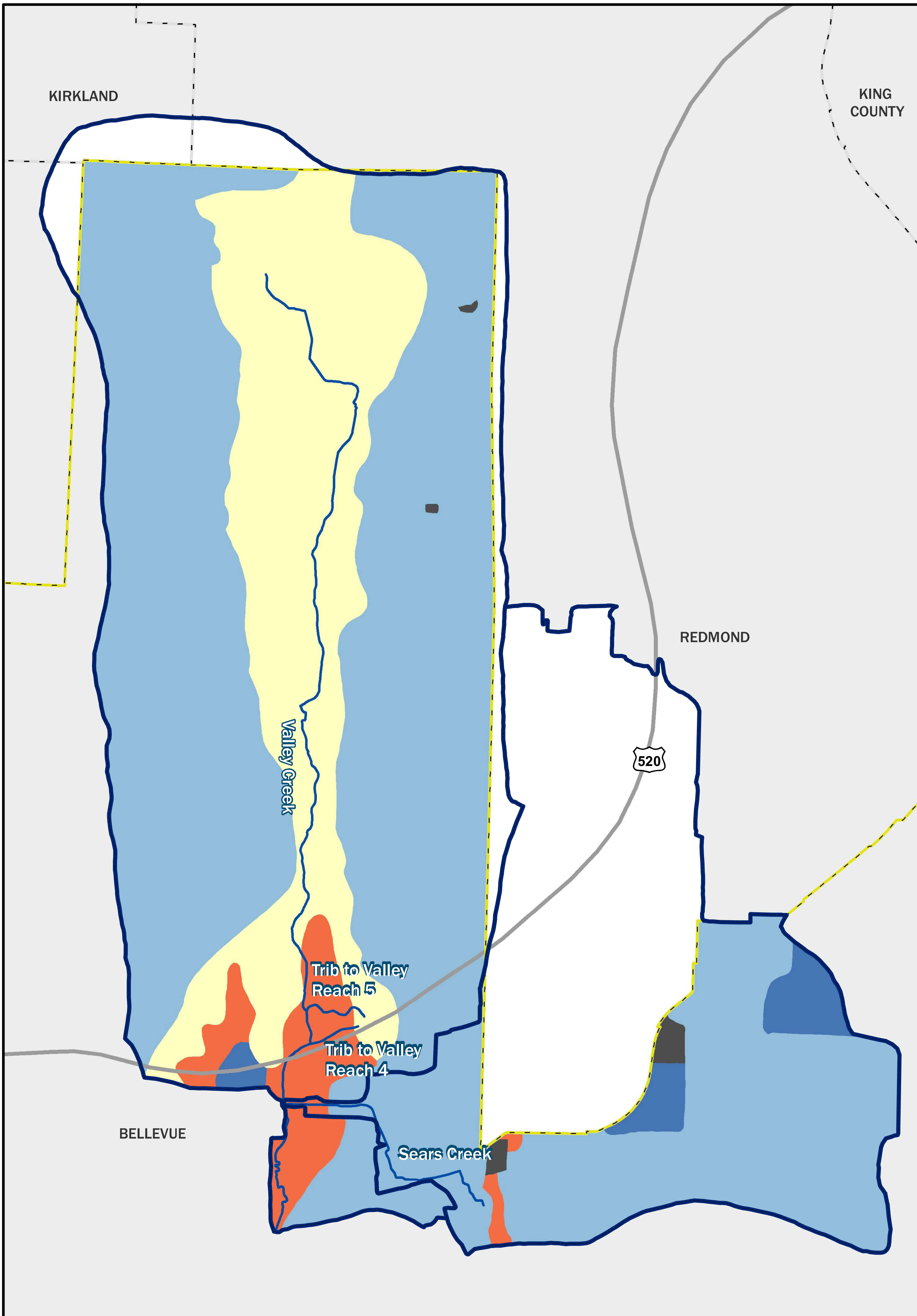
Figure 18.
West Tributary and Goff Creek Subbasins Soils.

N

0 750 1,500 3,000 Feet

Jacobs HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_Soil_GoffWest.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Highway (City of Bellevue 2020)
- Stream (City of Bellevue 2020)

Hydrologic Group

- Not identified (high impervious)
- A
- B
- B/D
- C/D

Soil Description:
A - Sand, loamy sand or sandy loam types of soils.
B - Silt loam or loam.
C - Sandy clay loam.
D- Clay loam, silty clay loam, sandy clay, silty clay or clay.

Note: Open Stream Conditions Assessment Database (OSCA).

Figure 19.
Valley Creek and Sears Creek Subbasins Soils.

N

0 550 1,100 2,200 Feet

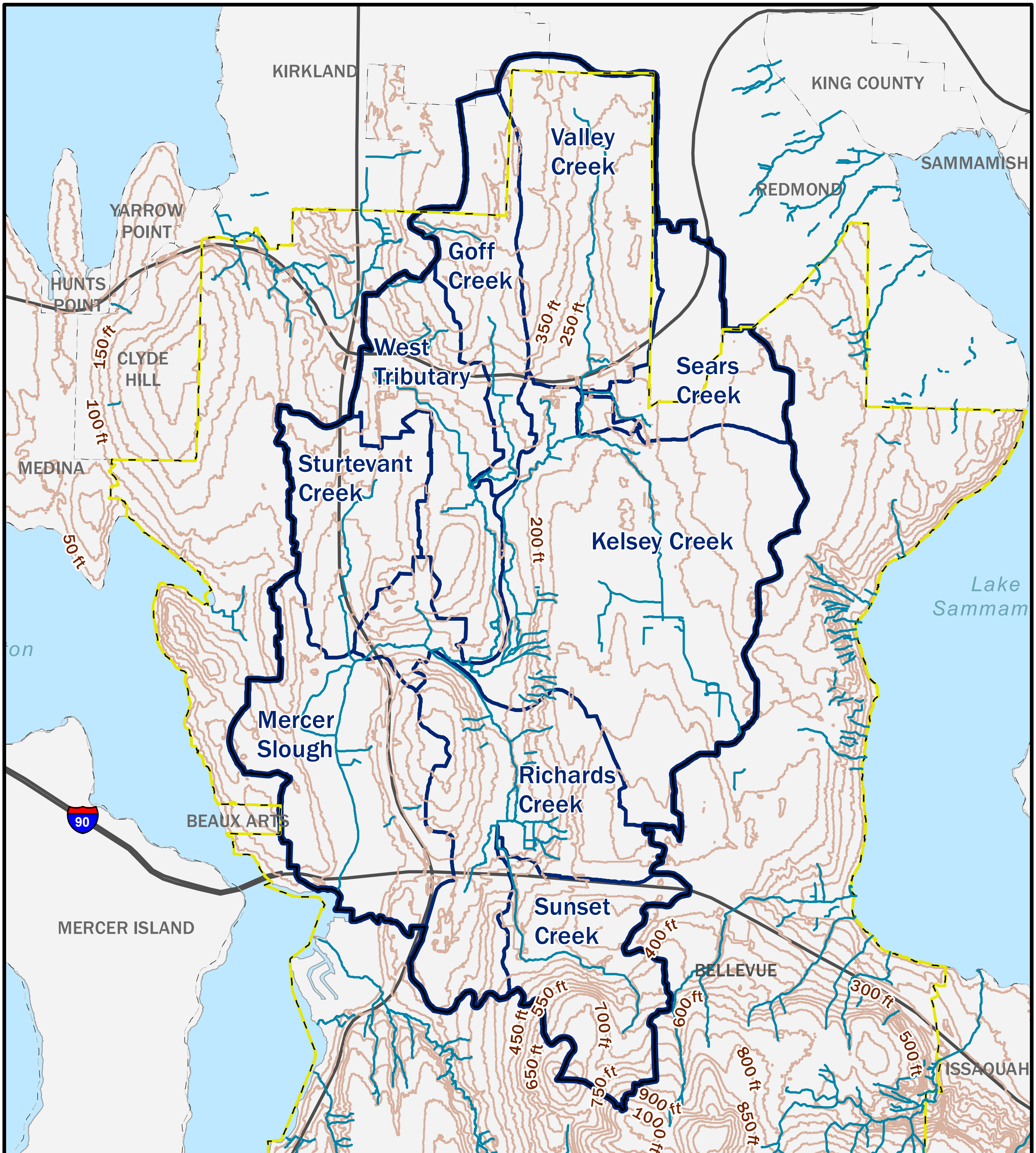
K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_Soil_Sunset_Valley_.mxd

2.1.3 Topography and Geomorphology

The topography of the Greater Kelsey Creek Watershed is shown in Figure 20. The Greater Kelsey Creek Watershed is less steep as compared to the other watersheds of the City. Kelsey Creek drops gradually over its length. This is especially true with the mainstem of Kelsey Creek. This gradual change in elevation means that the Greater Kelsey Creek Watershed has multiple wetlands complexes and wide floodplains. While several of those wetland complexes and wide floodplains still exist, many do not where the creek channel has been confined or manipulated.

The headwaters of the Greater Kelsey Creek Watershed are on a plateau that separates Lake Washington from Lake Sammamish. The Greater Kelsey Creek Watershed is relatively low gradient at the headwaters, with many streams originating in large wetland areas. Gradients tend to increase as the channel flows over the edge of the plateau, then decrease again as they approach Mercer Slough and Lake Washington. Streams in the Greater Kelsey Creek Watershed have been highly affected by urbanization, including altered riparian vegetation, high-flow bypasses, dams, detention facilities, ditching and confinement by roadways, and long stretches that are piped underground.

The natural hydrology of the streams in the Greater Kelsey Creek Watershed have been highly affected by urbanization, including altered riparian vegetation, high-flow bypasses, dams, detention facilities, ditching and confinement by roadways, and long stretches that are piped underground. Because of altered hydrology, several of the stream reaches within the Greater Kelsey Creek Watershed are disconnected from the floodplain. Several are sediment starved. Where creeks are piped, sediment transport is efficient, with high velocities conveying sediment faster than what would occur under natural hydrologic conditions. Areas of channel incision and streambank erosion are a source of sediment. Sediment accumulation as a result of this increased sediment production and transport is an issue in many of the subbasins throughout the City, especially Mercer Slough, and portions of Sturtevant, Kelsey, Richards, and Valley Creeks.



Legend

- Watershed (City of Bellevue 2020)
- Bellevue City Limit
- Other Jurisdictions
- Stream (City of Bellevue 2020)
- Highway (City of Bellevue 2020)
- Contour 50ft (City of Bellevue)

Figure 20. Greater Kelsey Creek Watershed Topography and Geomorphology.

N

0 2,500 5,000 10,000 Feet

Jacobs

HERRERA

King County Aerial (2019)

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_ContourMap8x11_nolabels.mxd

2.1.4 Surface Water Features

The presence, type, and distribution of surface water features are important factors that can influence the severity of impacts from urbanization described in the conceptual model (Figure 2). For example, wetlands can play an important role in storing stormwater from impervious surfaces that might otherwise flow directly to streams. Natural processes in wetlands are effective at storing sediments, nutrients, and many common pollutants that are present in stormwater runoff.

As shown in Figure 5, Kelsey Creek is the predominant drainage feature of the Greater Kelsey Creek Watershed. The mainstem of Kelsey Creek flows approximately 6.3 miles from its present-day headwaters in the Lake Hills Greenbelt to Mercer Slough. Kelsey Creek receives flow from the smaller tributaries of Richards Creek, Sunset Creek, West Tributary, Goff Creek, Valley Creek, and Sears Creek before joining with Sturtevant Creek at Mercer Slough. In addition to fluvial channels and tributaries, surface water features in the Greater Kelsey Creek Watershed include floodplains, wetlands, and lakes. However, much of the Greater Kelsey Creek Watershed is characterized by highly urbanized areas that do not support broad floodplains, impact existing wetlands, and often limit the size and health of wetlands within the Watershed.

As described previously, channel incision exacerbated by upland hydrologic changes coupled with streambank armoring and development that confine alluvial processes have separated the channel from its floodplain and reduced the effectiveness of the floodplain's ability to attenuate peak flows, store nutrients, attenuate pollutants, and support the channel complexity needed for aquatic species to thrive.

Figures 4-8 depict the mapped floodplains and wetlands present in the Greater Kelsey Creek Watershed. The active floodplain of Kelsey Creek is relatively wide when compared to other watersheds within the City, yet the geology depicted in Figures 10-14 (predominately till and outwash) and the topography shown in Figure 20 suggest that the floodplain widths along the creek are severely limited when compared to natural, pre-development conditions.

Figures 4-8 show the wetlands that have been both delineated and mapped by the National Wetland Inventory (NWI, USFWS 2021) as well as King County (King County 2021). In the Greater Kelsey Creek Watershed, there are 602 acres of wetlands, equating to 5.5 percent of the total Watershed area (Table 3). Mercer Slough, the wetlands at Kelsey Creek Park, and the Lake Hills Greenbelt are the three largest wetland areas in the Greater Kelsey Creek Watershed, making up most of the Watershed's wetlands (USFWS 2021). These are described here:

- The most downstream wetland surrounds Mercer Slough (Figure 4) and receives flow from the entire Watershed before crossing under I-90 and flowing to Lake Washington. As the most downstream wetland in the Watershed, Mercer Slough receives nutrients and sediments from all of the upstream basins. Algae blooms and debris have been seen at Mercer Slough when looking at the wetland from the I-90 overpass.
- The Kelsey Creek Park wetland area (Figure 5) is comprised of several wetlands and tributary areas merging together before crossing under I-405. In addition to the Kelsey Creek mainstem, the Kelsey Creek Park wetland area includes wetlands associated with the downstream portions of Richards Creek and West Tributary. The wetlands are largely located in the City-owned park area. The majority of the wetlands in Kelsey Creek Park are classified as seasonally or temporarily flooded by the National Wetlands Inventory.
- The most upstream wetland area is the Lake Hills Greenbelt, which is the present-day headwaters for the Kelsey Creek Subbasin. As the most upstream wetland, the Lake Hills Greenbelt area has the potential to be the least disturbed wetland in the Watershed; however, the wetland is disrupted by

agricultural use at the Larsen Lake Blueberry Farm and adjoining parcels. In addition, the wetlands are bisected by 148th Avenue.

Table 3. Wetlands in the Greater Kelsey Creek Watershed by Subbasin

Subbasin	Wetland Area (acres)	NWI Wetlands AND Sensitive Area Ordinance King County Wetlands 2016 - percent
Mercer Slough	288	21.7%
Kelsey Creek	179	6.2%
Sturtevant Creek	26	3.3%
Richards Creek	46	3.3%
Sunset Creek	9	1.0%
West Tributary	30	3.2%
Goff Creek	5	1.1%
Valley Creek	20	1.7%
Sears Creek	0	0.0%
Greater Kelsey Creek Watershed	602	5.5%

While the Greater Kelsey Creek Watershed does have several large wetland complexes, it is assumed that much larger tracts of wetlands existed before the area was developed. Human activity in proximate waterbodies has also affected Greater Kelsey Creek Watershed and Kelsey Creek itself. In the late 1800s, the outlet of Phantom Lake was diverted to Lake Sammamish, effectively reducing flow to Kelsey Creek. Also, lowering of the Lake Washington lake level in 1917 impacted Mercer Slough, as have the seasonal raising and lowering of lake levels since that time.

2.1.5 Groundwater

In areas that have not been disturbed by urbanization, very little precipitation contributes to direct surface flow. Throughout the Greater Kelsey Creek Watershed precipitation typically infiltrates into the surface soils until meeting the low permeability Vashon till layer below. Groundwater accumulates above this impermeable layer and flows laterally, either emerging as seeps or springs or interacting with the hyporheic flow associated with stream channels and eventually discharging at surface openings into the stream channel. Rainfall that does not flow laterally through the soils slowly penetrates to the deeper confined aquifer (Golder Associates 2019). Streamflows in late summer and early fall are sustained by the seeps and groundwater discharge that flows off of the Vashon till layer, with the seeps documented during the City's OSCA surveys. These seeps were prevalent in the middle Kelsey mainstem area (Bellevue 2021a). These seeps are a source of water for the streams that is a cool temperature and that has not picked up pollutants from impervious surfaces (and is therefore relatively clean as compared to stormwater runoff). These seeps are the source of the summer baseflow in these streams.

Across 14th Street in the West Tributary Subbasin field explorations and groundwater monitoring revealed that groundwater levels generally declined from northwest to southeast (GeoEngineers 2017). Within this section of the West Tributary Subbasin, there are two distinct aquifers. The upper, unconfined, aquifer is typically recharged from precipitation infiltrating into surface soils; the lower, confined, aquifer is separated from the upper aquifer by a low permeability layer of silt. The lower aquifer exhibits artesian conditions, where the aquifer is under pressure causing the static water level to be above the ground surface. Artesian wells and ground seeps allow groundwater from the lower aquifer to rise to the surface, providing cold clean water for instream habitat. Artesian wells and other historic seeps can be found in the West Tributary Subbasin, at the headwaters of Sturtevant Creek, in the Richards Creek Subbasin and near the middle reaches of the Kelsey Creek Mainstem (Bellevue 2021a).

2.1.6 Wildlife and Human Interaction within the Greater Kelsey Creek Watershed

2.1.6.1 Beaver Activity

Many of the streams in the Greater Kelsey Creek Watershed feature wetlands and riparian areas mixed with culverts and detention facilities. These conditions are attractive to wildlife, including beavers. Beaver activity has the potential to cause destructive flooding if it is not properly managed. While beaver activity in certain areas may have negative effects for people, beavers can restore and enhance habitat with significant benefits for fish and wildlife. Beaver activity can reduce water velocities, increase sediment and stormwater retention, increase habitat complexity, and increase water depths (for example, behind beaver dams) that results in cooler stream temperatures.

Because of all the potential benefits and negative impacts of beaver activity depending on location of the beaver activity, the City plans to develop a Beaver Management Plan. This Beaver Management Plan will identify locations to attract beaver activity to maximize habitat benefits that are the result of beaver activity and will identify locations to discourage beaver activity. Table 4 indicates which subbasins might present opportunities to promote beaver activity. The Beaver Management Plan will work in concert with the City’s Beaver Maintenance Manual (currently being revised).

Information on beaver activity from City staff observations during OSCA surveys (2019 -2020) is presented in Table 4. It should be noted that the OSCA surveys only took place in primary stream channels. Wetland reaches, which are prime beaver habitat, were not surveyed and are thus not included in the data below. Overall, there is a large amount of Beaver Activity across the Watershed. Of the primary stream channels surveyed during the OSCA effort, Richards Creek had the most beaver activity within the Greater Kelsey Creek Watershed. Note that Table 4 summarizes beaver activity at the time of the OSCA surveys and very likely has changed since the dates of those surveys.

Table 4. Beaver Activity in the Greater Kelsey Creek Watershed

Subbasin	Beaver Dam	Beaver Lodge	Other Beaver Activity	Beaver Maintenance Site
Mercer Slough	Not surveyed	Not surveyed	Not surveyed	1
Kelsey Creek	5	2	4	1
Sturtevant Creek	0	0	3	1
Richards Creek	18	0	15	2
Sunset Creek	0	0	0	0
West Tributary	Not surveyed	Not surveyed	Not surveyed	3
Goff Creek	3	0	3	0
Valley Creek	3	0	1	2
Sears Creek	0	0	0	0

In Table 4, *Beaver Dams* refer to an active or abandoned stick pile that was encountered in the stream channel during the OSCA effort. A *Beaver Lodge* marks a true beaver home but may not necessarily be associated with a stream channel. The term *Beaver Activity* represents a number of potential conditions such as beaver exclusion devices, chewed vegetation, and other general signs of beavers. *Beaver Maintenance Areas* where there is chronic beaver activity are locations that have usually been identified as having a high potential for causing damage and are being maintained and monitored over time. Many Beaver Maintenance Areas are located near regional detention ponds and other critical infrastructure, such as roads and stream crossings. It should be noted that many locations where "Beaver Dams" were recorded also indicated "Beaver Activity," and may represent an overlap in the data points.

2.1.6.2 Human Interaction within the Greater Kelsey Creek Watershed

Like many communities in King County, the City is experiencing a large growth in population and thus additional environmental stressors. As the City becomes more urban it is important to recognize the impact of human activity on the Greater Kelsey Creek Watershed. Unauthorized encampments, recreational use of riparian areas, and unremoved pet waste are a few examples of environmental stressors that have the potential to negatively impact water quality. For example, caffeine, which enters waterways via human waste and wastewater, has been found to be harmful to fish embryos (Institute of Life Sciences 2010) yet is so ubiquitous in our Puget Sound waterways that caffeine was found in 100 percent of the samples (N=15) taken by King County from Lake Union and the Ship Canal (King County 2019). The more use of streams and riparian areas by people, the more of a chance caffeine and other contaminants will enter the stream.

Pet waste, discarded needles, litter, illegal dumping, and other pollutants decrease the quality and safety of the water in the Greater Kelsey Creek Watershed. Despite current enforcement approaches, threats to public health and safety were observed in the Sturtevant Creek, lower Sunset Creek, lower Valley Creek, Goff Creek, and Sears Creek subbasins. Appendix B documents stream impacts from human activity observed during the City's OSCA surveys.

2.2 Built Infrastructure

Existing conditions are summarized below for the following built infrastructure attributes: land cover and land use, and stormwater and non-stormwater infrastructure.

2.2.1 Land Cover and Land Use

The land cover in the Greater Kelsey Creek Watershed is typical of urban watersheds with a lower percentage of tree canopy and higher percentage of impervious surface. Existing land cover in the Greater Kelsey Creek Watershed is predominantly (41 percent) impervious surfaces, with 34 percent urban tree canopy, and 16 percent non-canopy vegetation (Bellevue 2013, 2017) (Table 5). Bare soil, scrub/shrub, and water surface together comprise less than 8 percent of total land cover. Urban tree canopy is relatively dispersed throughout the Watershed with a relatively high concentration in the Goff Creek Subbasin. Although the entire Watershed is largely urbanized, Sears Creek and Sturtevant Creek have noticeably higher percentages of impervious area at 64 percent and 70 percent, respectively.

Figures 21-25 show the land cover and tree canopy of the Mercer Slough and Sturtevant Creek Subbasins, the Kelsey Creek Subbasin, the Richards Creek and Sunset Creek subbasins, the West Tributary and Goff Creek subbasins, and the Valley Creek and Sears Creek subbasins, respectively.

Table 5. Land Cover in the Greater Kelsey Creek Watershed

Subbasin	Bare Soil and Dry Vegetation (%)	Impervious (%)	Non-Canopy Vegetation (%)	Scrub/Shrub (%)	Urban Tree Canopy (%)	Water (%)
Mercer Slough	4%	32%	19%	9%	34%	2%
Kelsey Creek	6%	42%	17%	4%	31%	0%
Sturtevant Creek	2%	70%	8%	2%	16%	1%
Richards Creek	4%	46%	14%	2%	34%	0%
Sunset Creek	7%	42%	15%	0%	35%	0%
West Tributary	5%	44%	16%	1%	34%	0%
Goff Creek	3%	30%	17%	0%	50%	0%
Valley Creek	5%	27%	24%	0%	44%	0%
Sears Creek	6%	57%	12%	0%	26%	0%
Greater Kelsey Creek Watershed	5%	41%	16%	3%	34%	0%

As shown in Figures 26-30, the land use of the subbasins of the Greater Kelsey Creek Watershed reflects land cover. The predominant land use types include single family residential (51.8 percent), commercial/office (11.8 percent), parks (11.3 percent), multi-family (11.0 percent), mixed-use (8.4 percent), industrial/medical (1.7 percent), and highway (2.9 percent) (Table 6). The areas with developed land use types (e.g., commercial, industrial, mixed use, and single- or multi-family residential) within the Watershed include approximately 241.5 miles of streets (mostly local access streets). The pollutant loading from highways, industrial, and mixed use/commercial land uses is higher than for the other land uses (residential, parks). Therefore, areas with a higher portion of these land uses will have higher pollutant loading to receiving water bodies.

As the third most predominant land use type in the Watershed and in the Kelsey Creek Subbasin, park space correlates with the most concentrated urban tree canopy land cover present within the riparian corridor of Kelsey Creek. These park areas include Kelsey Creek Park, Lake Hills Greenbelt, and several smaller City parks as well as Mercer Slough. The park area also includes Glendale Country Club, which includes a private golf course and does not provide the same benefits as tree-canopy, or scrub/shrub. Publicly-owned land (including parks, and land owned by The City's Utilities Department) represent opportunities to site investments in stream health. When individual investments are developed in future phases of the WMP, sites on publicly-owned land will be evaluated first as a way to provide benefits for the least cost.

Table 6. Land Use in the Greater Kelsey Creek Watershed

Subbasin	Commercial/ Office (%)	Highway (%)	Industrial (%)	Mixed-use (%)	Multi-Family (%)	Park (%)	Single-family (%)	Total (ac)
Mercer Slough	9.7%	7.1%	3.8%	0.2%	8.5%	24.4%	46.3%	1328
Kelsey Creek	9.7%	0.4%	0.2%	2.2%	16.4%	14.5%	56.6%	2899
Sturtevant Creek	31.9%	7.3%	0.0%	35.8%	3.6%	1.9%	11.9%	773

Subbasin	Commercial/ Office (%)	Highway (%)	Industrial (%)	Mixed-use (%)	Multi-Family (%)	Park (%)	Single-family (%)	Total (ac)
Richards Creek	13.3%	1.9%	8.1%	4.8%	17.0%	10.2%	44.8%	1380
Sunset Creek	5.6%	6.3%	1.0%	2.4%	1.6%	4.0%	79.2%	854
West Tributary	8.4%	2.4%	0.0%	26.2%	4.4%	9.2%	44.2%	958
Goff Creek	8.4%	0.8%	0.0%	10.3%	0.0%	4.4%	76.2%	529
Valley Creek	7.2%	2.0%	0.0%	5.0%	15.0%	10.0%	60.8%	1300
Sears Creek	32.7%	3.0%	0.0%	21.8%	9.8%	0.0%	32.8%	355
Greater Kelsey Creek Watershed	11.8%	2.9%	1.7%	8.4%	11.0%	11.3%	51.8%	10376

Table 7 compares the change in canopy cover and impervious surfaces between 2006 and 2017 for the nine subbasins and the Greater Kelsey Creek Watershed (HRCD 2021). The Sears Creek Subbasin and the Sturtevant Creek Subbasin experienced the largest tree canopy loss and impervious surface increase of all the subbasins in the Greater Kelsey Creek Watershed.

Table 7. Change in Tree Canopy and Impervious Surfaces from 2006 to 2017 in the Greater Kelsey Creek Watershed

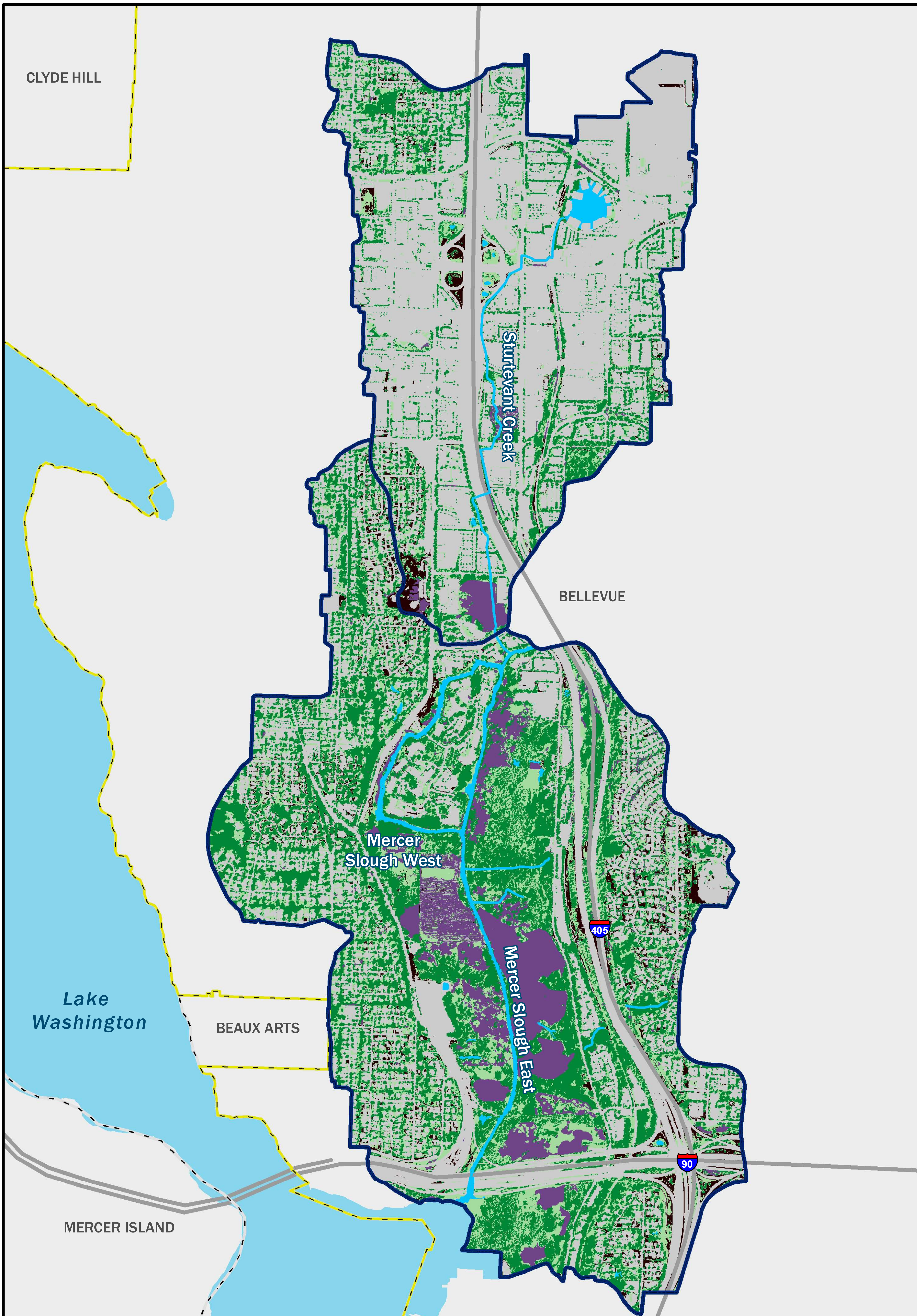
Subbasins	Tree Canopy Loss (2006 – 2017)		Impervious Surfaces Increase (2006 – 2017)		Primary Agent of Change
	Change	Trend	Change	Trend	
Goff Creek	0.4 %		0.5 %		Development
Kelsey Creek	1.0 %		1.0 %		Development
Mercer Slough	1.5 %		1.1 %		Development
Richards Creek	1.5 %		1.1 %		Development
Sears Creek	3.9 %		3.4 %		Development
Sturtevant Creek	2.2 %		3.8 %		Development
Sunset Creek	0.5 %		0.7 %		Development
Valley Creek	0.5 %		0.2 %		Tree removal
West Tributary	1.2 %		0.7 %		Development
Total Greater Kelsey Watershed	1.2 % (133 acres)		1.2 % (125 acres)		Development

data source: https://hrcd-wdfw.hub.arcgis.com/

Based on changes in tree canopy and impervious area data, since 2006 there has been a large amount of development in the majority of the Watershed's subbasins. Table 7 shows the decrease in tree canopy and increase in impervious surfaces associated with rapid development and urbanization—where development indicates the conversion of a vegetated lot or parcel into a built lot or parcel, and redevelopment indicates building on a previously developed lot. With development across so much of the Greater Kelsey Creek

Watershed it is important to consider the impacts of the City's growth on water quality and habitat within the riparian corridor.

Within Bellevue, ownership of the riparian corridor (within 100 linear feet of the stream) across all of the subbasins within the Greater Kelsey Creek Watershed is approximately 90 percent private property and 10 percent publicly owned (primarily parks). The land adjacent to the streams in West Tributary and Goff Creek subbasins are entirely located within private property (100 percent privately owned, except for City-owned right-of-way) severely limiting the number of approaches available to improve these streams. Developing stream improvement plans in collaboration with private property owners is essential for the Greater Kelsey Creek Watershed. The City's current approach limits using public resources that improve stream channel conditions or riparian corridors to City-owned property only. A future tool to improve riparian corridors within the Watershed may be a City program to provide funds and/or information to assist streamside residents in improving steams and riparian corridors or incentive programs promoting green stormwater infrastructure on private properties.



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Stream (City of Bellevue 2020)
- Highway (City of Bellevue 2020)

Note: Open Stream Conditions Assessment Database (OSCA).

Landcover Class (City of Bellevue 2020)

- Bare Soil and Dry Vegetation
- Impervious
- Non-Canopy Vegetation
- Tree Canopy
- Scrub/Shrub
- Water

Figure 21.
Mercer Slough and Sturtevant Creek Subbasins Land Cover/Tree Canopy.

N

0 700 1,400 2,800 Feet

Jacobs HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_LandCover_SturMercer.mxd

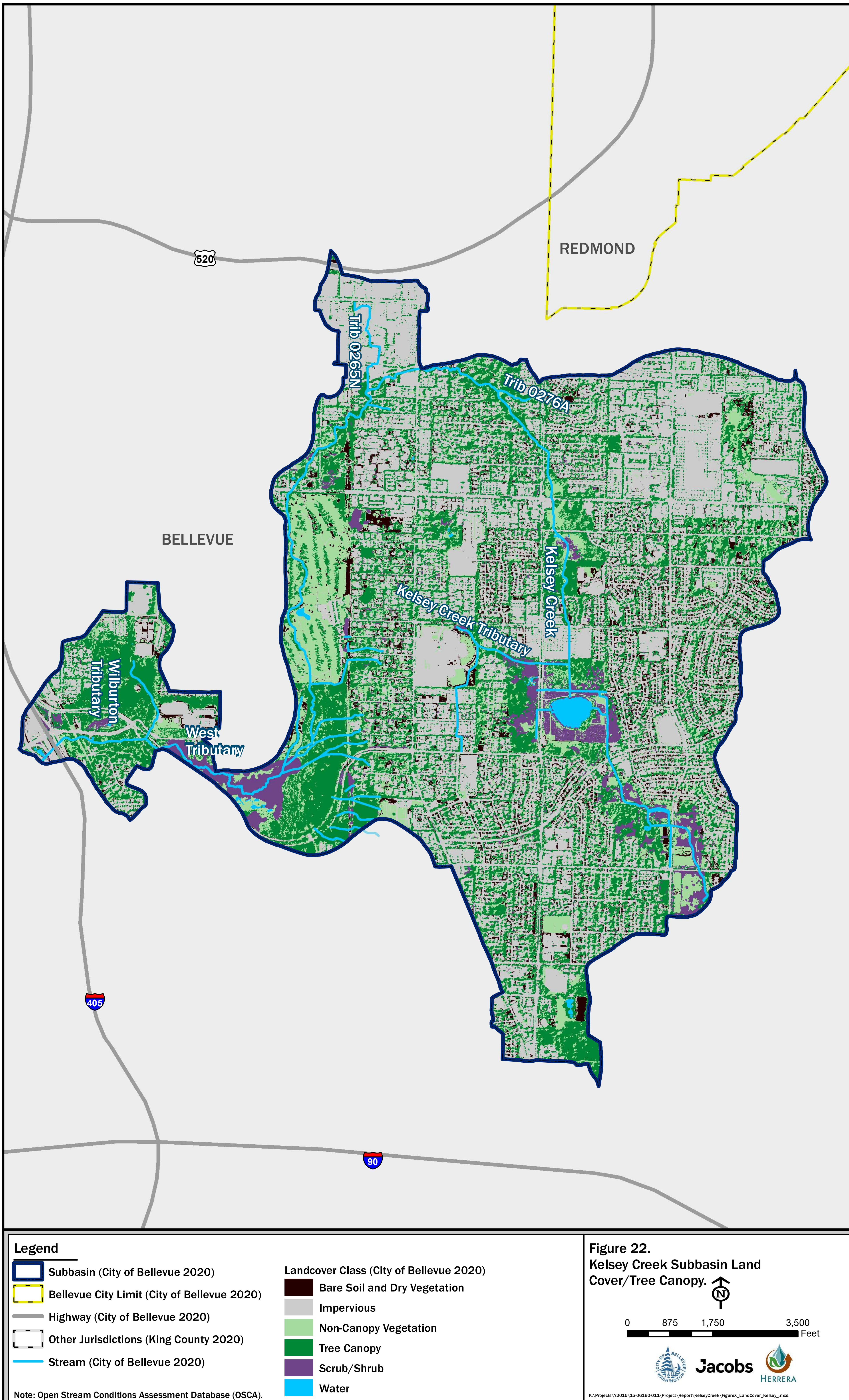
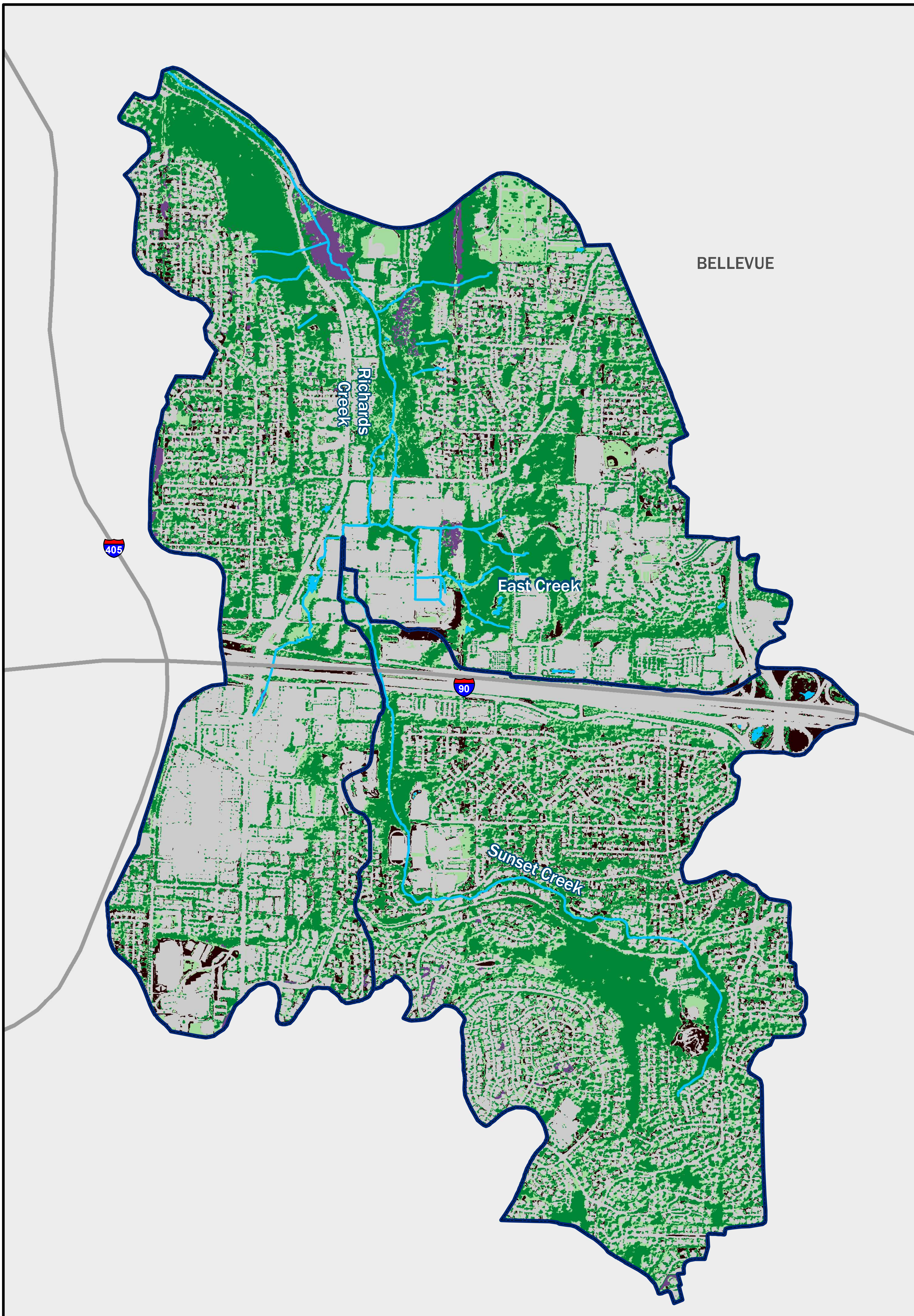


Figure 22.
Kelsey Creek Subbasin Land Cover/Tree Canopy.



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Highway (City of Bellevue 2020)
- Stream (City of Bellevue 2020)

Note: Open Stream Conditions Assessment Database (OSCA).

Landcover Class

- Bare Soil and Dry Vegetation
- Impervious
- Non-Canopy Vegetation
- Tree Canopy
- Scrub/Shrub
- Water

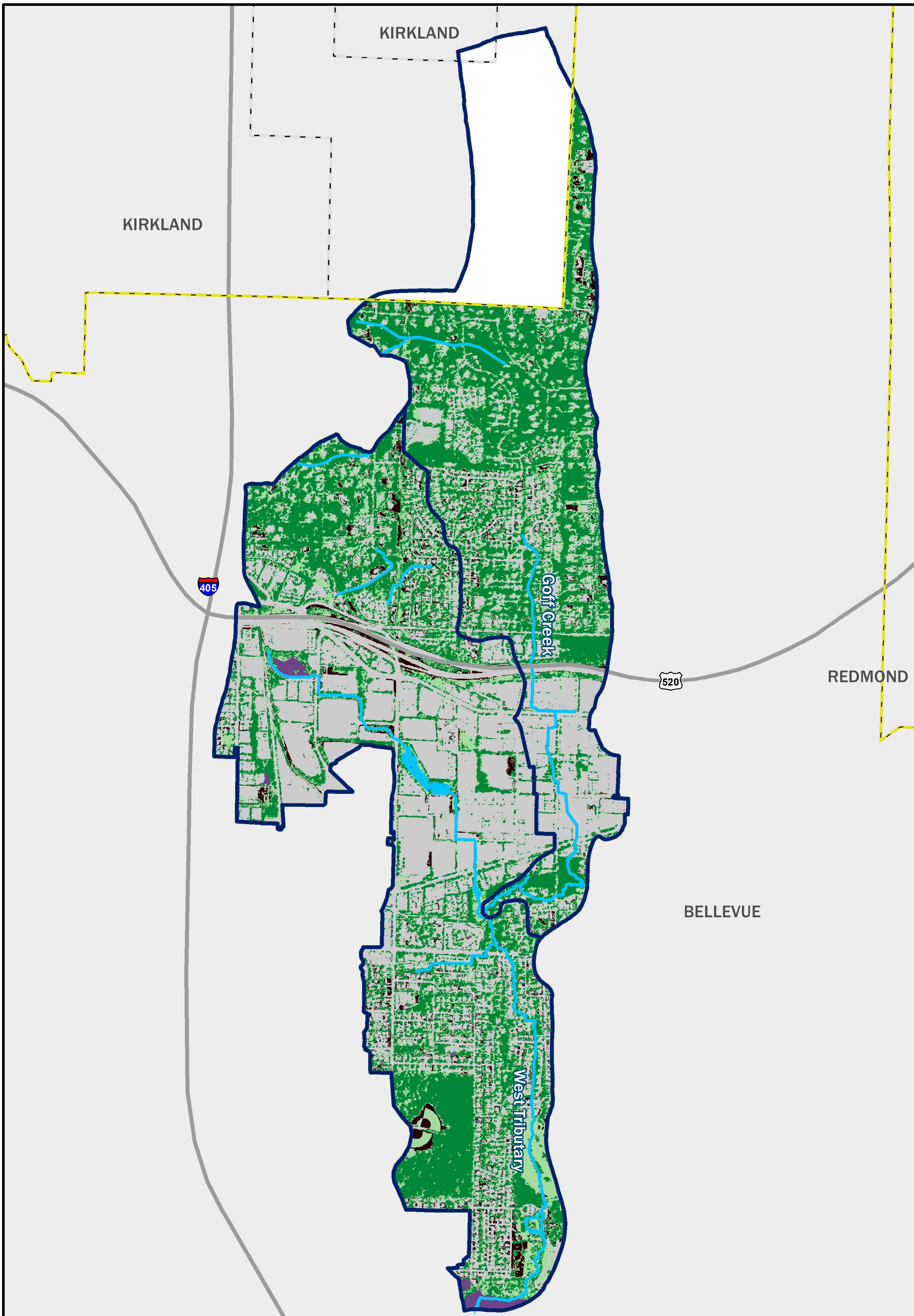
Figure 23.
Richards Creek and Sunset Creek Subbasins Land Cover/Tree Canopy.

N

0 625 1,250 2,500 Feet

CITY OF BELLEVUE WASHINGTON Jacobs HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_LandCover_Richard_Sunset.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Highway (City of Bellevue 2020)
- Stream (City of Bellevue 2020)

Note: Open Stream Conditions Assessment Database (OSCA).

Landcover Class

- Bare Soil and Dry Vegetation
- Impervious
- Non-Canopy Vegetation
- Tree Canopy
- Scrub/Shrub
- Water

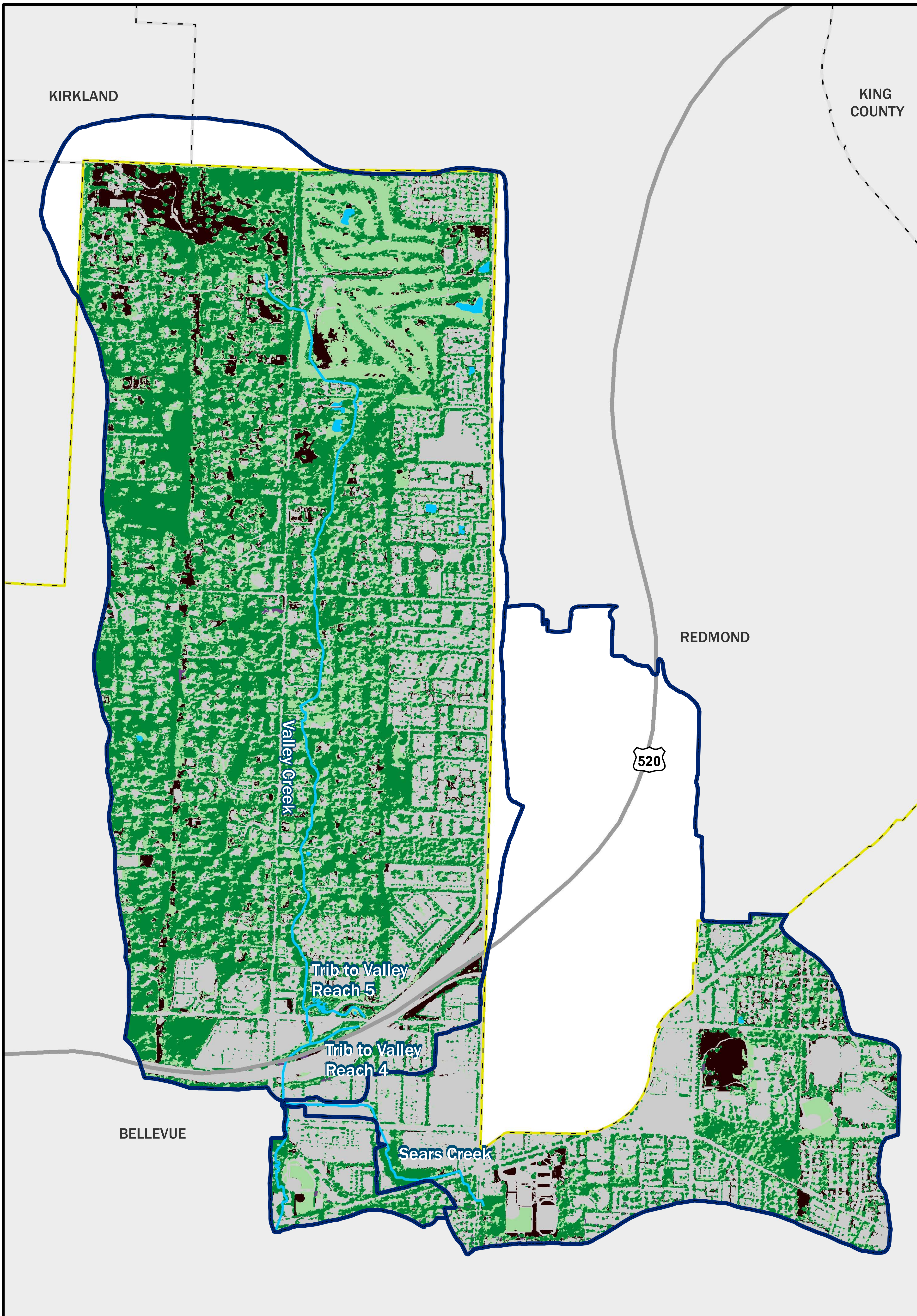
Figure 24. West Tributary and Goff Creek Subbasins Land Cover/Tree Canopy.

N

0 750 1,500 3,000 Feet

City of Bellevue Washington Jacobs Herrera

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_LandCover_GoffWest.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Highway (City of Bellevue 2020)
- Stream (City of Bellevue 2020)

Landcover Class

- Bare Soil and Dry Vegetation
- Impervious
- Non-Canopy Vegetation
- Tree Canopy
- Scrub/Shrub
- Water

Note: Open Stream Conditions Assessment Database (OSCA).

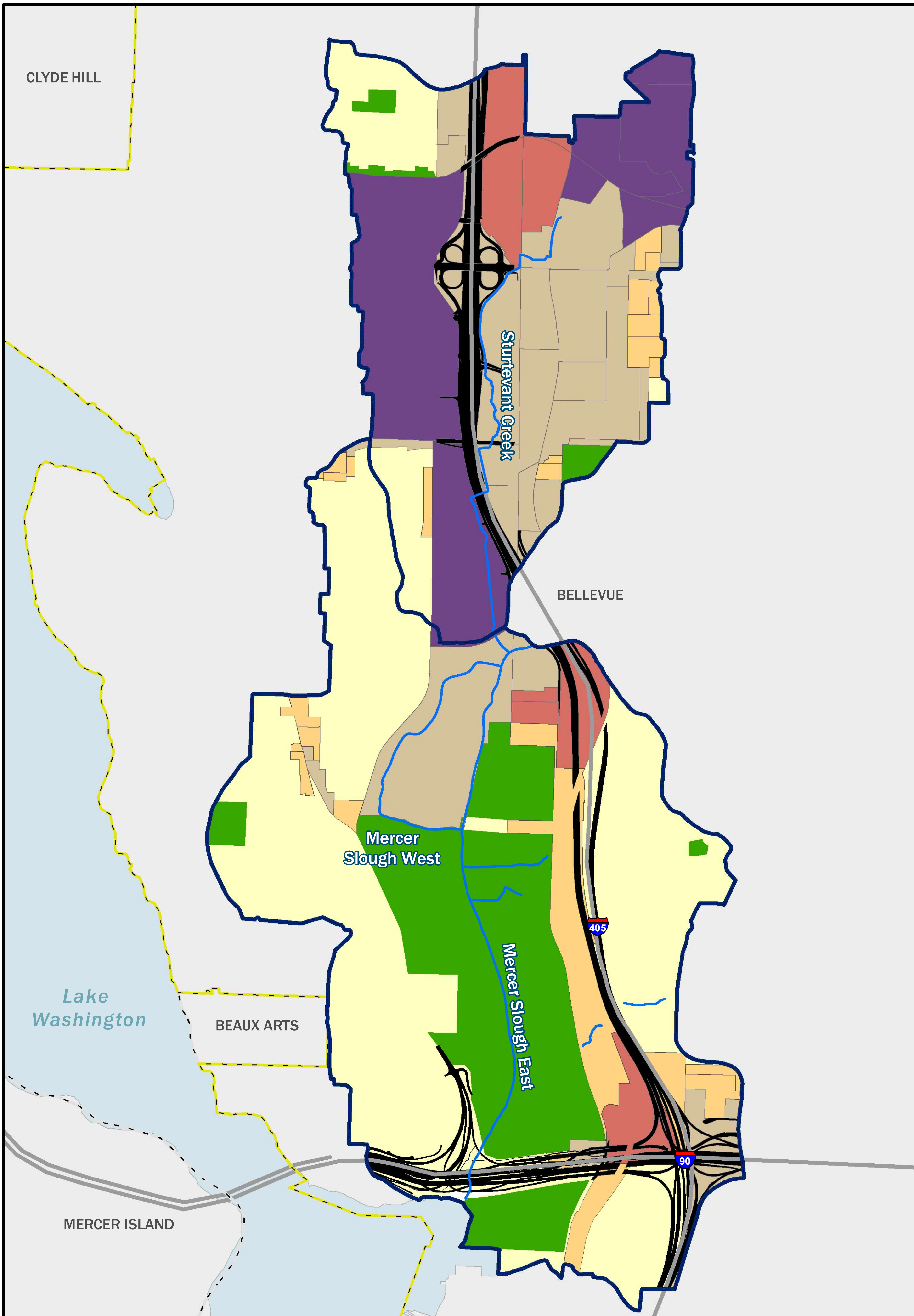
Figure 25.
Valley Creek and Sears Creek Subbasins Land Cover/Tree Canopy.

N

0 550 1,100 2,200 Feet

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_LandCover_Richard_Sunset.mxd

Figure 26.
Mercer Slough and Sturtevant Creek Subbasins Land Use.



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Stream (City of Bellevue 2020)
- Highway (City of Bellevue 2020)

Land Use (City of Bellevue 2020)

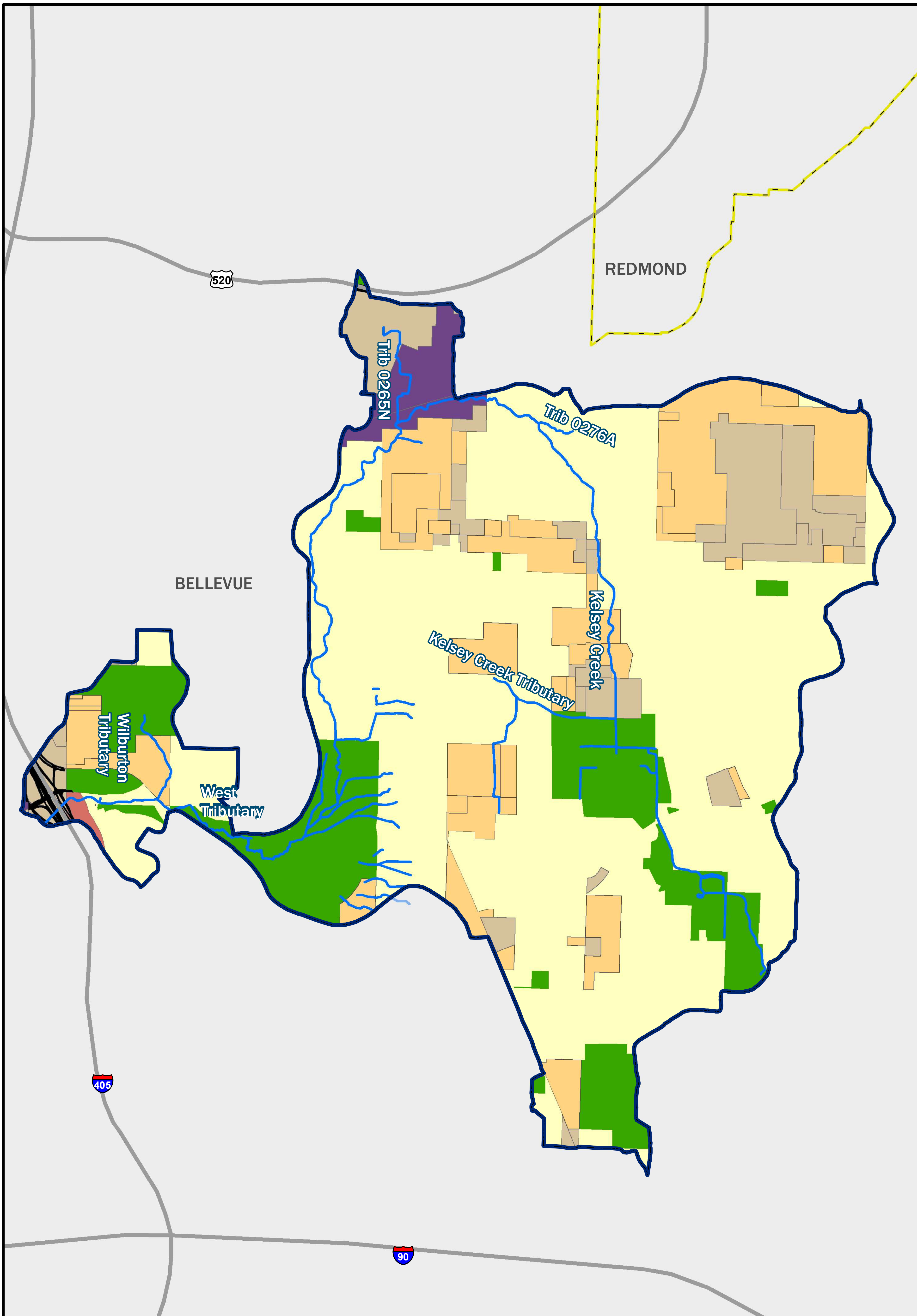
- Commercial/Office
- Industrial/Medical
- Mixed-Use
- Multi-family
- Highway
- Single-family
- Park

Note: Open Stream Conditions Assessment Database (OSCA).

0 700 1,400 2,800 Feet

Jacobs
HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_LandUse_SturMercer_.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Stream (City of Bellevue 2020)
- Highway (City of Bellevue 2020)

Land Use (City of Bellevue 2020)

- Commercial/Office
- Industrial/Medical
- Mixed-Use
- Multi-family
- Highway
- Single-family
- Park

Note: Open Stream Conditions Assessment Database (OSCA).

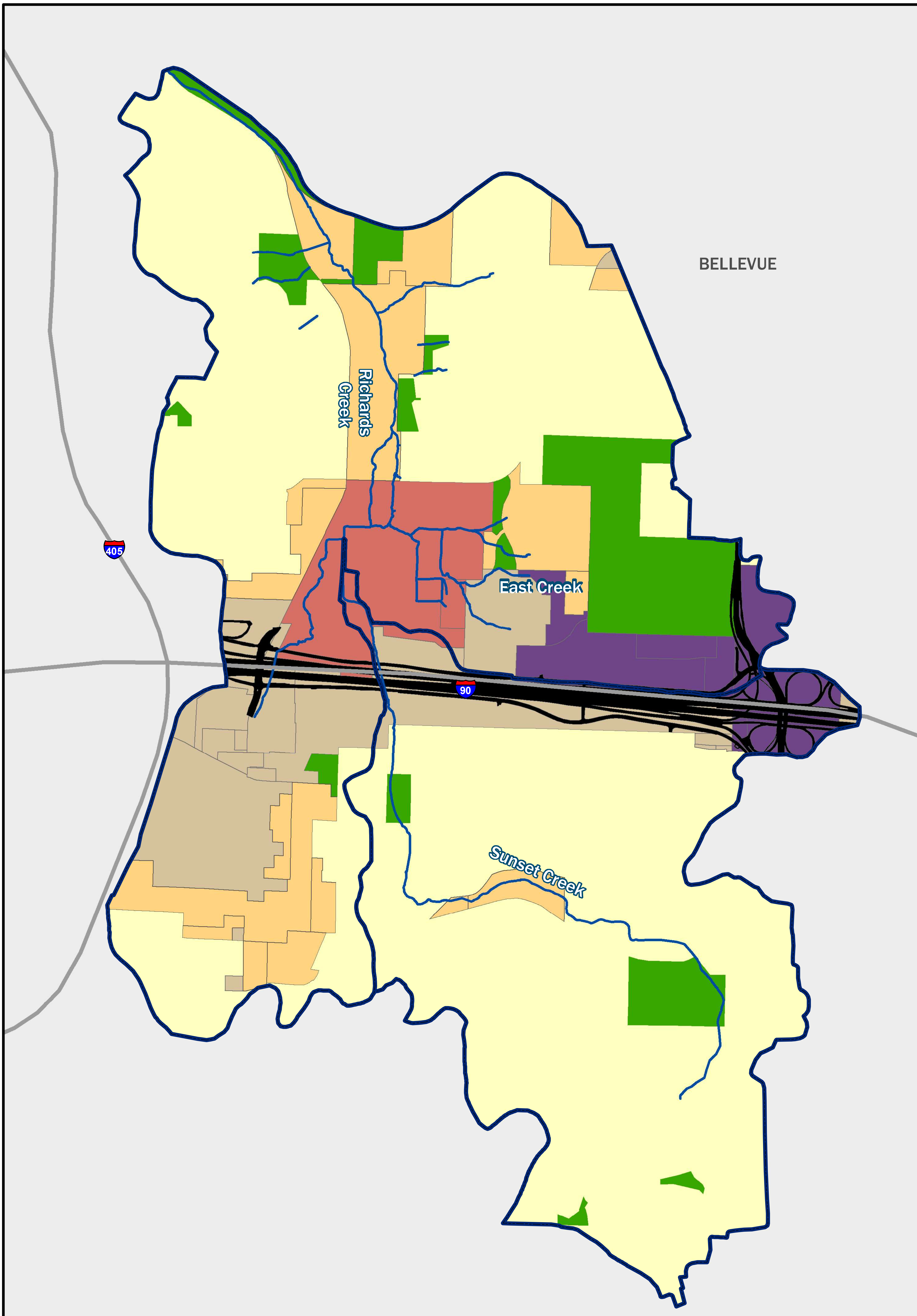
Figure 27.
Kelsey Creek Subbasin Land Use.

N

0 875 1,750 3,500 Feet

Jacobs HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_LandUse_Kelsey.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Stream (City of Bellevue 2020)
- Highway (City of Bellevue 2020)

Land Use (City of Bellevue 2020)

- Commercial/Office
- Industrial/Medical
- Mixed-Use
- Multi-family
- Highway
- Single-family
- Park

Note: Open Stream Conditions Assessment Database (OSCA).

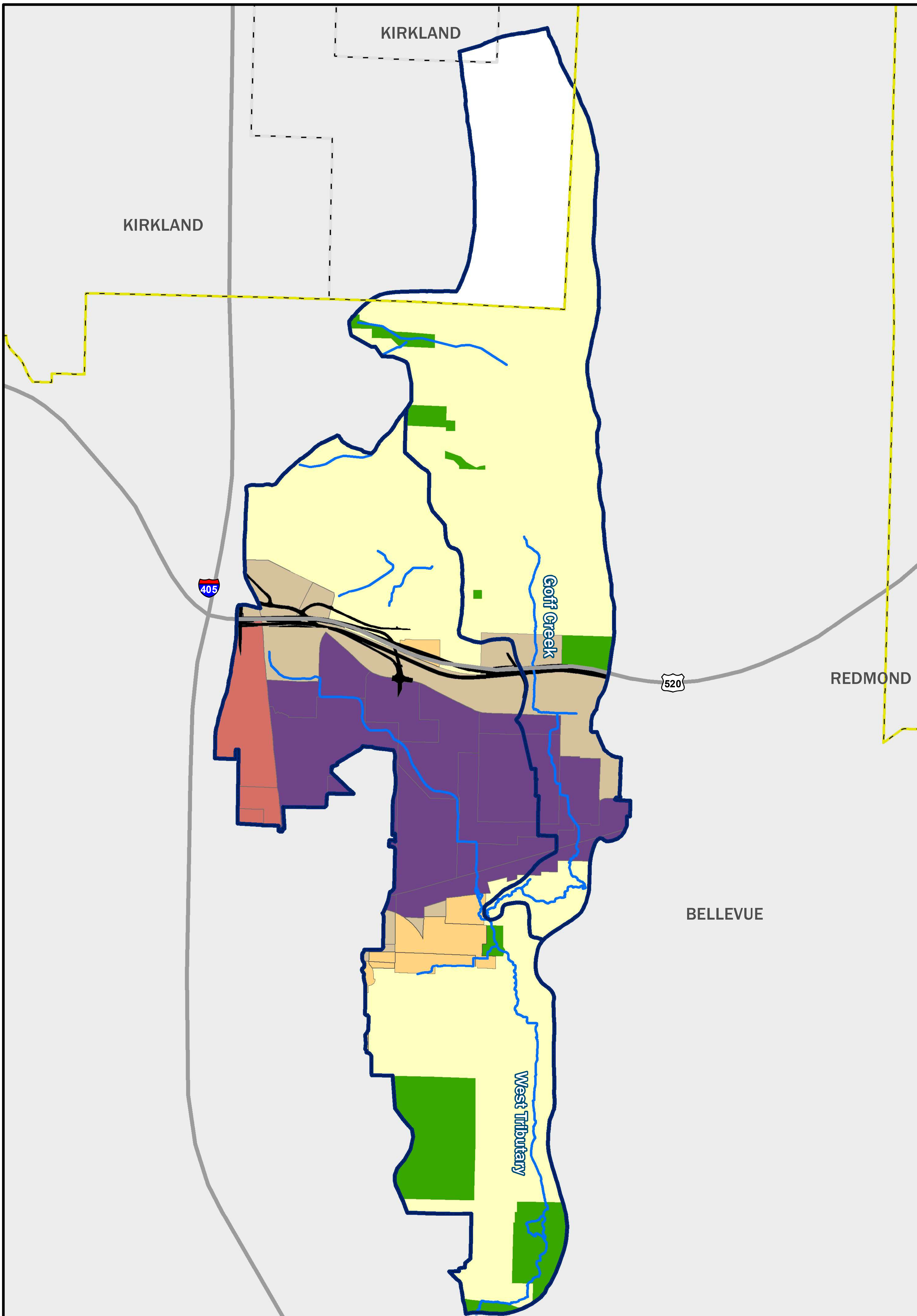
**Figure 28.
Richards Creek and Sunset Creek
Subbasins Land Use.**

N

0 625 1,250 2,500
Feet

Jacobs
HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_LandUse_Sun_Valley.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Stream (City of Bellevue 2020)
- Highway (City of Bellevue 2020)

Land Use (City of Bellevue 2020)

- Commercial/Office
- Industrial/Medical
- Mixed-Use
- Multi-family
- Highway
- Single-family
- Park

Note: Open Stream Conditions Assessment Database (OSCA).

Figure 29.
West Tributary and Goff Creek Subbasins Land Use.

N

0 750 1,500 3,000 Feet

City of Bellevue Washington Jacobs Herrera

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_LandUse_GoffTrib.mxd

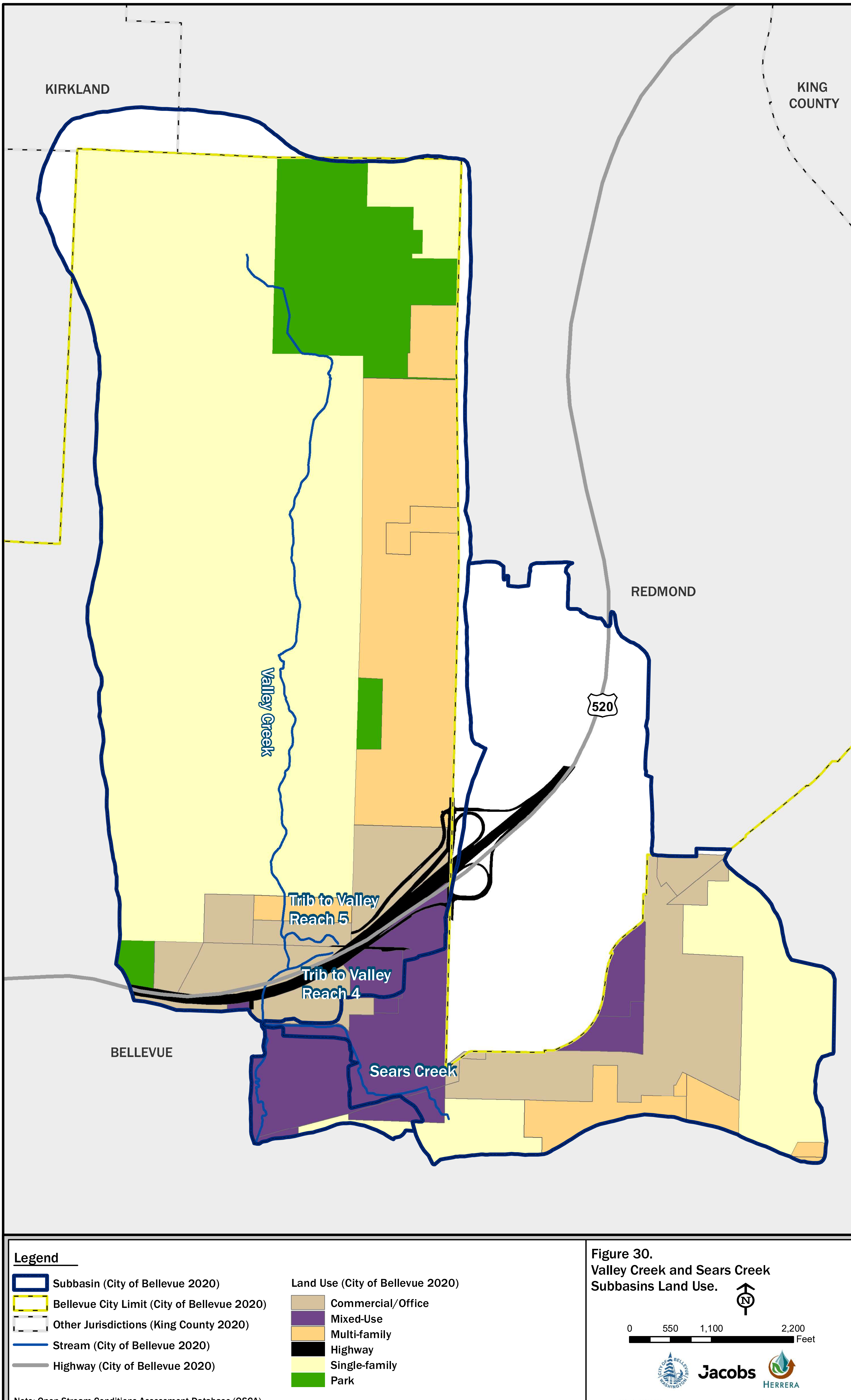


Figure 30.
Valley Creek and Sears Creek Subbasins Land Use.

2.2.2 Built Stormwater Infrastructure

Built stormwater infrastructure, including pipes, curb inlets, catch basins, curb-and-gutter drainage, outfalls, and culverts can cause and/or exacerbate impacts from urbanization by increasing stormwater velocity and by concentrating rather than dispersing runoff. Streams that flow through pipes move at faster velocities than their open-channel counterparts. Stormwater infrastructure built before and during the 1970s was typically built to address flooding concerns and tends to be very effective at sending that stormwater downstream quickly. Built stormwater infrastructure also provides benefits, including preventing flooding (or reducing flood risk), and/or providing flow control and water quality treatment.

While built stormwater infrastructure has had negative effects on streams, stormwater infrastructure can also be used as a watershed management tool to address urbanization by providing the following benefits:

- Promote hydrologic processes that naturally occurred prior to urbanization such as infiltration, filtration, storage, and evaporation (on-site stormwater management or low impact development)
- Reduce the peak flow rate and volume of stormwater that is delivered to a water body (flow control)
- Remove pollutants from stormwater (runoff treatment)

Stormwater infrastructure in developed areas of the Greater Kelsey Creek Watershed is primarily comprised of formal curb and gutter conveyance with some areas drained by more informal drainage with roadside ditches and driveway culverts. Runoff from impervious surfaces is collected and discharged through numerous outfalls along Kelsey Creek and its tributaries. Table 8 shows the percentage of stream length that flows through pipes for each subbasin within the Greater Kelsey Creek Watershed. Sturtevant Creek has by far the largest percentage of stream length in a pipe with 47.1 percent, followed by Sunset Creek at 23.8 percent.

Table 8. Piped Stream Channel Percent by Subbasin

Subbasin	Percent of the Stream Channel that is Piped
Mercer Slough Subbasin	<0.05%
Kelsey Creek Subbasin	12.10%
Sturtevant Creek Subbasin	47.10%
Richards Creek Subbasin	10.10%
Sunset Creek Subbasin	23.80%
West Tributary Subbasin	17.80%
Goff Creek Subbasin	16.40%
Valley Creek Subbasin	15.10%
Sears Creek Subbasin	41.00%
Total Greater Kelsey Creek Watershed	14.90%

The Greater Kelsey Creek Watershed also has a number of regional stormwater facilities and high-flow bypasses (Table 9). High-flow bypasses are designed to divert excess streamflow out of the main channel and into storm drainage pipes during extreme flow events. The high-flow bypasses in the Greater Kelsey Creek Watershed were implemented to reduce erosion and flooding downstream but may have potential negative effects on fish populations, particularly when sediment accumulation or streambed aggradation result in base flows being diverted out of the stream channel. Additionally, high-flow bypasses can substantially alter sediment transport dynamics and channel morphology where the bypass outfalls back into the stream channel as well as in the portion of stream that is bypassed. Current flood control and stream restoration practice is to implement process-based designs that simulate the resiliency of natural systems to those high flows and reduce maintenance as compared to high-flow bypasses.

Table 9. Existing Stormwater Facilities in the Greater Kelsey Creek Watershed

Facility Type	Facility Name	Subbasin	Location
Regional (in-stream) detention	DMP 149 – Larsen Lake Facility	Kelsey Creek	Located just south of the shopping center at 170 148th Avenue SE.
Regional (in-stream) detention	DMP 133 – Kelsey Creek Facility	Kelsey Creek	920 148th Avenue NE
Regional (in-stream) detention	DMP 179S – Commissioner's Waterway Facility	Sears Creek	1669 148th Avenue NE
Regional (in-stream) detention	DMP 179N – Overlake Facility	Sears Creek	14433 NE 20th Street
Regional (in-stream) detention	DMP 197 – Valley Creek Facility	Valley Creek	14040 NE 24th Street
Regional (in-stream) detention	DMP 165 – West Tributary Facility	West Tributary	1770 124th Avenue NE
Regional (in-stream) detention	DMP 164 S – Lower West Tributary Facility	West Tributary	12670 NE 10th Place
Regional (in-stream) detention	DMP 164 N – Goff Creek Facility	Goff Creek/ West Tributary	On West Tributary just downstream of Goff Creek confluence. 12700 NE 10th Place
High-Flow Bypass	Goff Creek Bypass	Goff Creek	Begins at 13000 NE 28th Pl; Ends 2406 130th Place NE (130th Avenue Pipeline) – Manhole asset # 330829 Ends at 2406 130th Place NE, pipe end asset # 332481; constructed in 1987
High-Flow Bypass	Valley Creek Bypass	Valley Creek	Begins at just downstream of NE 21st culvert - Inlet asset #s 332476, 332475, & 332474. Diverts to Kelsey Creek just south of Bel-Red Road and 140th Avenue NE -discharge point asset #333134. (NE 21st Street culvert replacement is in design right now for 2022 or -23 construction at this point bypass to remain). Constructed in 1987

Facility Type	Facility Name	Subbasin	Location
High-Flow Bypass	Sunset Creek Bypass	Sunset Creek	Begins at 13801 Allen Road -storm drainage structure asset # 326603 and ends just south of I-90 in Sunset Ravine (13389 SE 36th St., storm discharge point asset # 325510); constructed in 1998

Instream regional stormwater facilities were designed to address flooding issues caused by development that occurred prior to the requirement for stormwater control. The regional facilities were built in the 1980s and the bypasses in the 1980s and 1990s. These facilities were built for a specific purpose (flood control) and not to meet multiple objectives (such as habitat or water quality). These facilities are approaching 50 years old, which is their assumed design life (defined as the length of time that the designers envisioned the facility providing the benefit for which it was designed).

A 2002 study by Northwest Hydraulic Consultants showed the theoretical benefit from the regional detention facilities located in the Greater Kelsey Creek Watershed (Northwest Hydraulic Consultants, 2002). This study utilized a citywide model to characterize the flow control benefits provided by the facilities. The study found that the facilities can reduce the frequency of a specific flow (750 cubic feet per second) from a 20 percent chance of occurrence (without the facilities) to a 10 percent chance of occurrence. This study is now nearly 20 years old. Therefore, The City plans to evaluate the current condition, function, and benefits provided by these facilities under existing conditions, and may decide to alter these facilities to maximize benefits across a variety of objectives including both people and ecosystem function.

Facilities designed and built in the mid-1970s through the mid-1990s provide little or no benefit to the stream in terms of flow control to protect from stream erosion and other negative effects of runoff. These facilities and parts of the City that were developed prior to any stormwater control requirement make up approximately 86 percent of the current *developed* area in the Bellevue portion of the Watershed.

In addition to the facilities described in Table 9, there are many smaller flow control and water quality facilities (both publicly-owned and privately owned) in the Watershed. The City, through its NPDES permit, is required to maintain the publicly-owned facilities and inspect the privately-owned facilities.

The year in which a parcel was developed has a significant influence on the amount and types of infrastructure present for managing stormwater, especially on-site stormwater management, flow control, and runoff treatment. In general, older development was either built with no stormwater infrastructure or facilities that do not meet current standards. To understand the adequacy of stormwater management in the Greater Kelsey Creek Watershed, the age of development was used to classify specific areas into one of five categories that indicate when requirements for improved stormwater management infrastructure became effective in the City (Table 10). This information illustrates the relative degree of flow control and water quality treatment within the Watershed, and highlights where stormwater retrofits may be useful. Note that water quality treatment of stormwater runoff was not required in the City until 2010. This means that water quality treatment facilities were not required for approximately 94 percent of the current *developed* area in the Bellevue portion of the Greater Kelsey Creek Watershed, including road projects.

More than 37 percent of the Greater Kelsey Creek Watershed was developed before 1974 with more than half (57.6 percent) developed before the mid-1980s, at which point multiple regional flow control facilities (discussed earlier in this section) were built. The subbasins with the greater percentage of their development pre-1975 are Kelsey, Sunset, and West Tributary subbasins with Sears and Valley subbasins experiencing the smallest percentage of their development previous to 1974. The subbasins developed the least before 1975 were Sears and Valley (17.4 percent and 26.4 percent, respectively), with those areas experiencing a boom in residential development (in the case of Valley) and commercial development (in the case of Sears) in the late 1970s and early1980s. The development that occurred in the City in the late 1980s and early 1990s changed the land use in the Sturtevant and Richards Creek subbasins most dramatically as compared to the other subbasins in the City. By 1996, 95 percent of the land area within the Greater Kelsey Creek Watershed had been developed.

Figures 31-35 show the age of development for the Mercer Slough and Sturtevant Creek subbasins, the Kelsey Creek Subbasin, the Richards Creek and Sunset Creek subbasins, the West Tributary and Goff Creek subbasins, and the Valley Creek and Sears Creek subbasins, respectively. Figure 36 shows the regional stormwater facilities in the Kelsey Creek Watershed.

Note that the City's stormwater management regulations have met the minimum requirements established by the Washington State Department of Ecology (Ecology) at all times. These regulations have changed over time and the City's regulations have changed accordingly. The current version of Ecology's *Stormwater Management Manual for Western Washington* (Ecology 2019), however, states:

> "Ecology understands that despite the application of appropriate practices and technologies identified in this manual, some degradation of urban and suburban receiving waters will continue, and some beneficial uses will continue to be impaired or lost due to new development. This is because land development, as practiced today, is incompatible with the achievement of sustainable ecosystems. Unless development methods are adopted that cause significantly less disruption of the hydrologic cycle, the cycle of new development followed by beneficial use impairments will continue."

Currently, Sturtevant Creek is the only subbasin in the Greater Kelsey Creek Watershed with an alternate stormwater flow control requirement as a result of the 2011 study titled Citywide Assessment of Eligibility for the Washington State Department of Ecology Flow Control Standard for Highly Urbanized Drainage Basins (RW Beck 2011). Ecology recognizes that under some circumstances, streams within heavily urbanized basins can, over time, become equilibrated to a new hydrologic regime. As such, the streams are assumed to not currently experience significant erosion or sedimentation problems attributed to existing flows from urbanized areas. Ecology proposed an alternative flow control standard for urbanized basins that have had at least 40 percent total impervious area (TIA) for at least 20 years, referred to herein as the "40 percent TIA/20-year" criteria. To be eligible, the local jurisdiction must be able to demonstrate, via mapping or other quantitative analyses, that the basin was at least 40 percent covered by impervious surface as of 1985.

The RW Beck memorandum demonstrated the Sturtevant Creek Subbasin met these criteria for an alternate flow control standard. This alternative flow control standard requires all new development and redevelopment within the eligible areas to detain to the existing land use condition, rather than the historic, forested condition. This results in smaller detention facilities that are intended to control flows to existing levels. It should be noted that, while Sturtevant Creek does have that alternate stormwater flow control requirement, recent observations during the OSCA show erosion and channel incision from flashy stream flows is still occurring (and has not reached an equilibrium).

Table 10. Development Age Categories for Assessing Stormwater Management Infrastructure Requirements

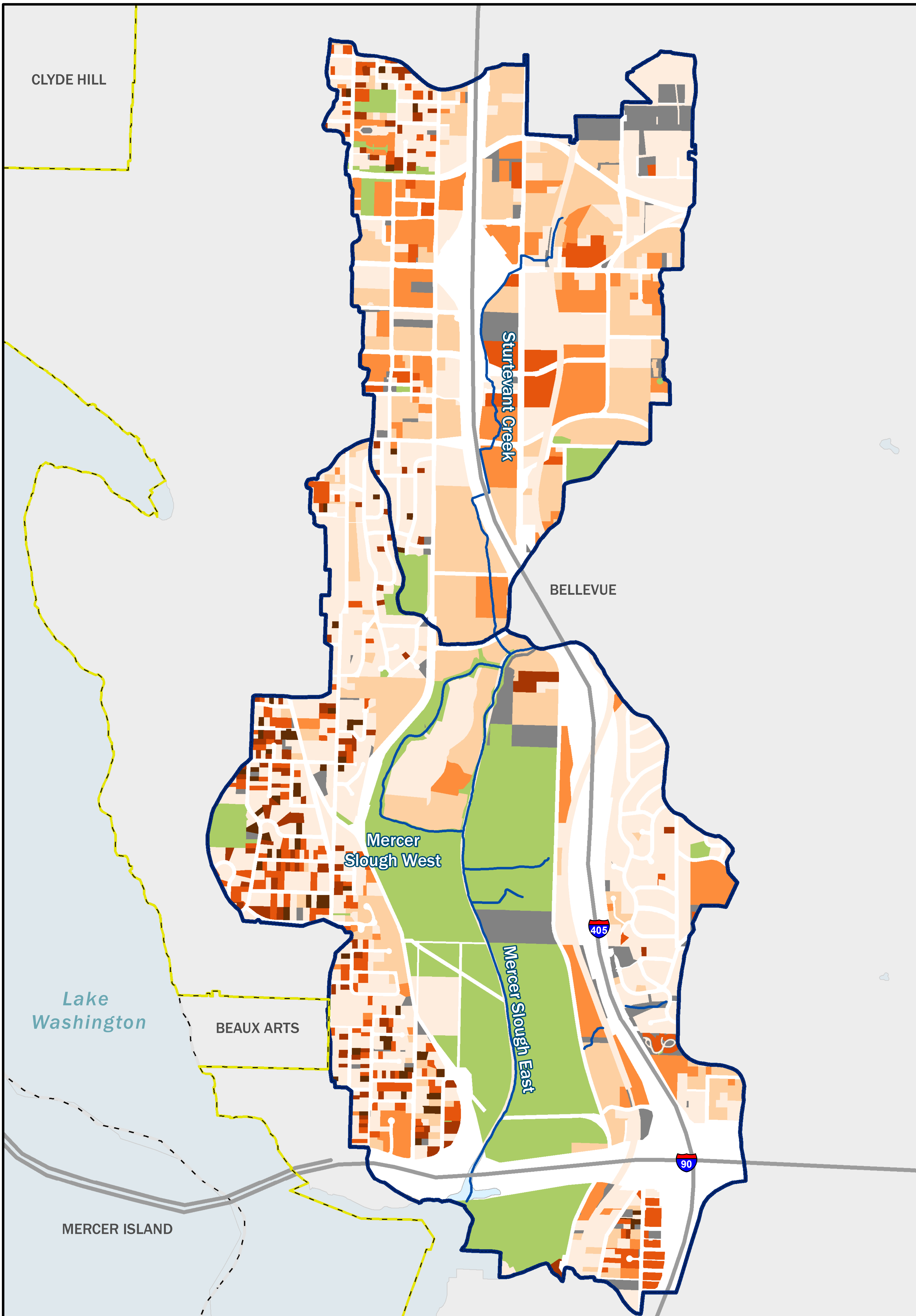
Category	Stormwater Management Requirements	Total, Greater Kelsey Creek Watershed	Mercer Slough	Kelsey Creek	Sturtevant Creek	Richards Creek	Sunset Creek	West Tributary	Goff Creek	Valley Creek	Sears Creek
2017-Current	The 2017 Surface Water Engineering Standards updated the On-site Stormwater Management requirements (List #1, List #2, or LID Performance Standard) and adopted the 2012/14 Department of Ecology Stormwater Management Manual for Western Washington.	0.5%	1.3%	0.4%	0.3%	0.3%	0.7%	0.4%	0.8%	0.4%	0.0%
2010-2016	The 2010 Surface Water Engineering Standards added water quality requirements, flow control requirements, and continuous modeling per the 2005 Department of Ecology Stormwater Management Manual for Western Washington. On-site Stormwater Management was also included either applying default LID credits or deriving LID credits with demonstrative modeling.	1.0%	2.4%	0.7%	1.0%	1.2%	0.4%	2.1%	0.9%	0.4%	0.2%
1996-2009	Bellevue adopts the Department of Ecology's 1992 Stormwater Management Manual for the Puget Sound Basin (Technical Manual) ▪ 2-year peak develop flow matches 50% of 2-year pre-developed flow ▪ 10-year peak developed flow matches 10-year pre-developed flow ▪ 100-year peak developed flow matches 100-year pre-developed flow ▪ Unit-hydrograph method required for detention sizing ▪ 1.18 to 1.5 safety factor required for pond sizing dependent on percent impervious area	4.7%	4.5%	3.9%	7.3%	3.9%	5.7%	3.4%	5.4%	5.3%	5.4%

Category	Stormwater Management Requirements	Total, Greater Kelsey Creek Watershed	Mercer Slough	Kelsey Creek	Sturtevant Creek	Richards Creek	Sunset Creek	West Tributary	Goff Creek	Valley Creek	Sears Creek
1988-1995	Bellevue introduces Large Site stormwater controls for sites serving more than 5 acres and within ¼-mile of a stream: ▪ 10-year peak developed flow matches the 2-year peak pre-developed flow (using computer modeling), 24-hour event ▪ 100-year peak developed flow matches the10-year peak pre-developed flow (using computer modeling), 24-hour event	6.7%	4.0%	5.3%	15.6%	11.6%	5.8%	6.5%	3.6%	4.6%	6.4%
1975-1987	The first set of Storm and Surface Water Utility Engineering Standards (published in 1975) focused on detention that could store the difference in runoff volume between the post-development 100-year, 4-hour storm and the pre-development 10 year, 4-hour event. To meet this requirement, a maximum allowable release rate of 0.2 cfs per acre and a storage requirement of 1.0 inch per impervious acre and 0.5 inch per pervious acre were required (Also known as the "Cookbook Method").	20.2%	10.1%	14.7%	26.6%	23.2%	18.5%	20.9%	20.7%	34.8%	20.6%
Prior to 1975	No stormwater management required.	37.4%	30.9%	45.6%	31.6%	39.4%	45.1%	44.6%	40.4%	26.4%	17.4%

LID: low impact development

cfs: cubic feet per second

Source: City of Bellevue Age of Development and Land Classifications 2013, 207 received 2020



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Waterbody (City of Bellevue 2020)
- Highway (City of Bellevue 2020)
- Stream (City of Bellevue 2020)

Note: Open Stream Conditions Assessment Database (OSCA).

Age of Development Rating (City of Bellevue 2020)

- 6 (2017-Current)
- 5 (2010-2016)
- 4 (1996-2009)
- 3 (1988-1995)
- 2 (1975-1987)
- 1 (1974 and earlier)
- Park, Open or Tract
- Vacant or Undeveloped

Figure 31.
Mercer Slough and Sturtevant Creek Subbasins Age of Development Ratings.

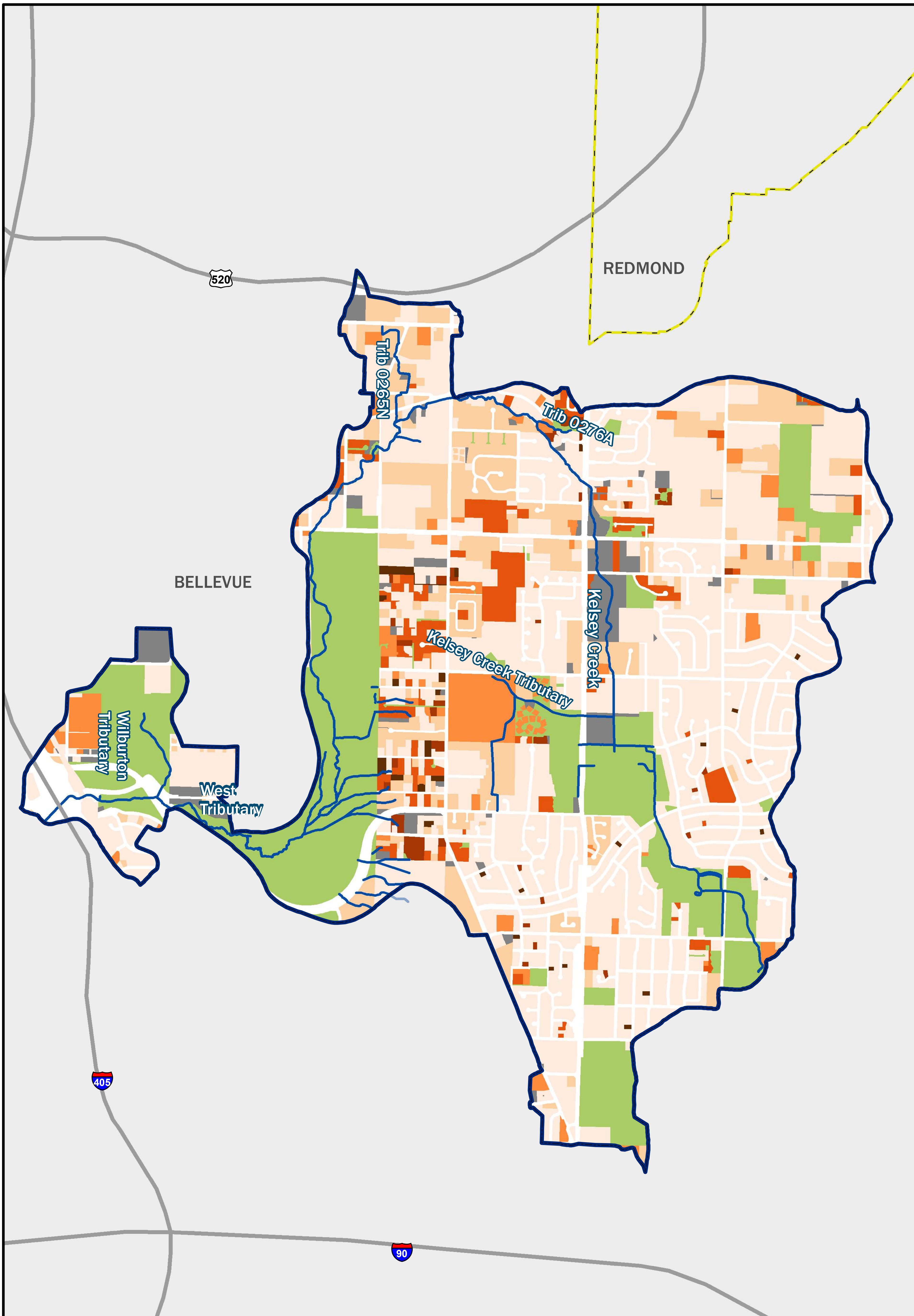
N

0 700 1,400 2,800 Feet

Jacobs

HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_AgeDevelop_SturMercer.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Stream (City of Bellevue 2020)
- Highway (City of Bellevue 2020)

Age of Development Rating

- 6 (2017-Current)
- 5 (2010-2016)
- 4 (1996-2009)
- 3 (1988-1995)
- 2 (1975-1987)
- 1 (1974 and earlier)
- Park, Open or Tract
- Vacant or Undeveloped

Note: Open Stream Conditions Assessment Database (OSCA).

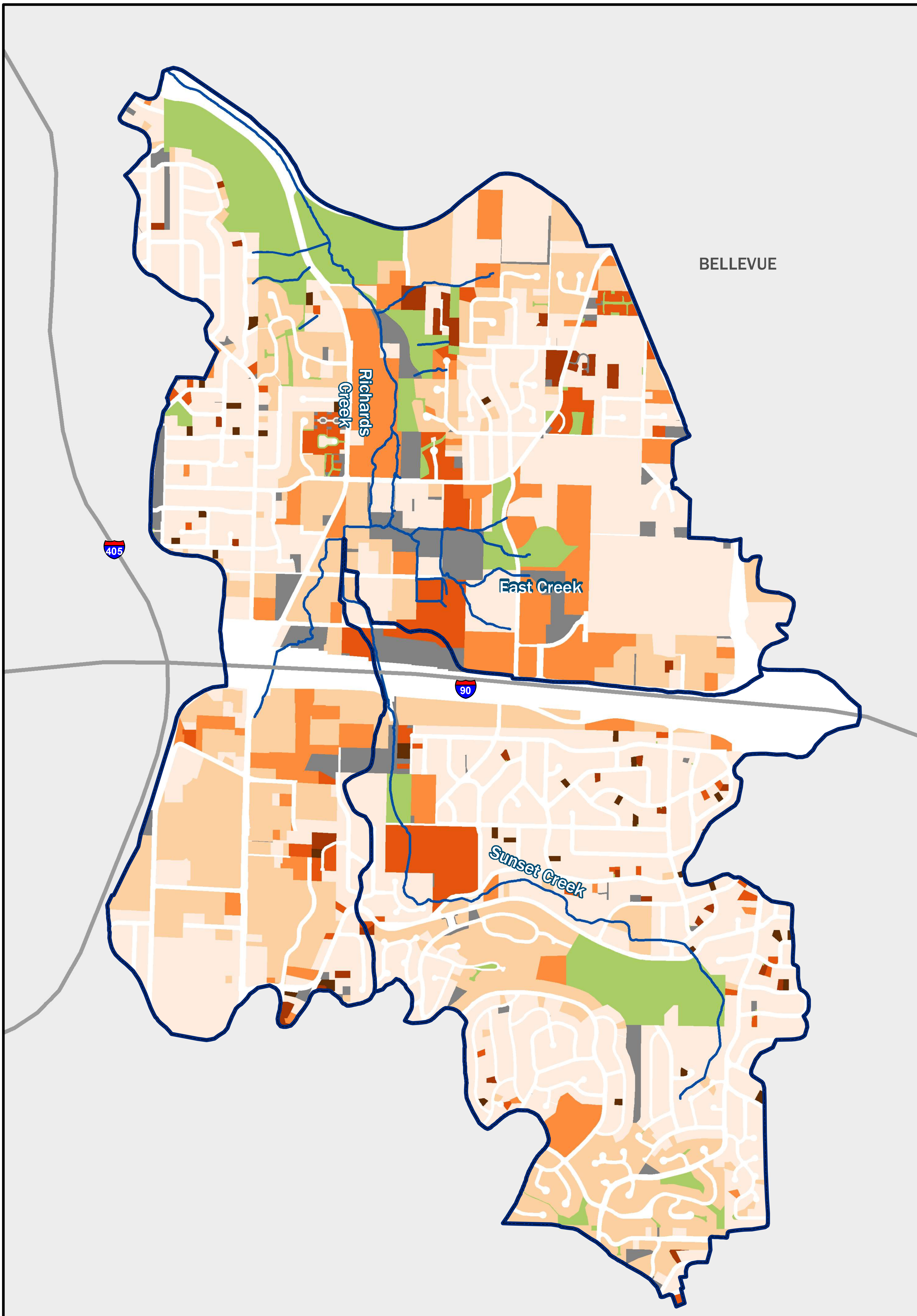
Figure 32.
Kelsey Creek Subbasins Age of Development Ratings.

N

0 875 1,750 3,500 Feet

Jacobs HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_AgeDevelop_Kesley_.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Stream (City of Bellevue 2020)
- Highway (City of Bellevue 2020)

Age of Development Rating (City of Bellevue 2020)

- 6 (2017-Current)
- 5 (2010-2016)
- 4 (1996-2009)
- 3 (1988-1995)
- 2 (1975-1987)
- 1 (1974 and earlier)
- Park, Open or Tract
- Vacant or Undeveloped

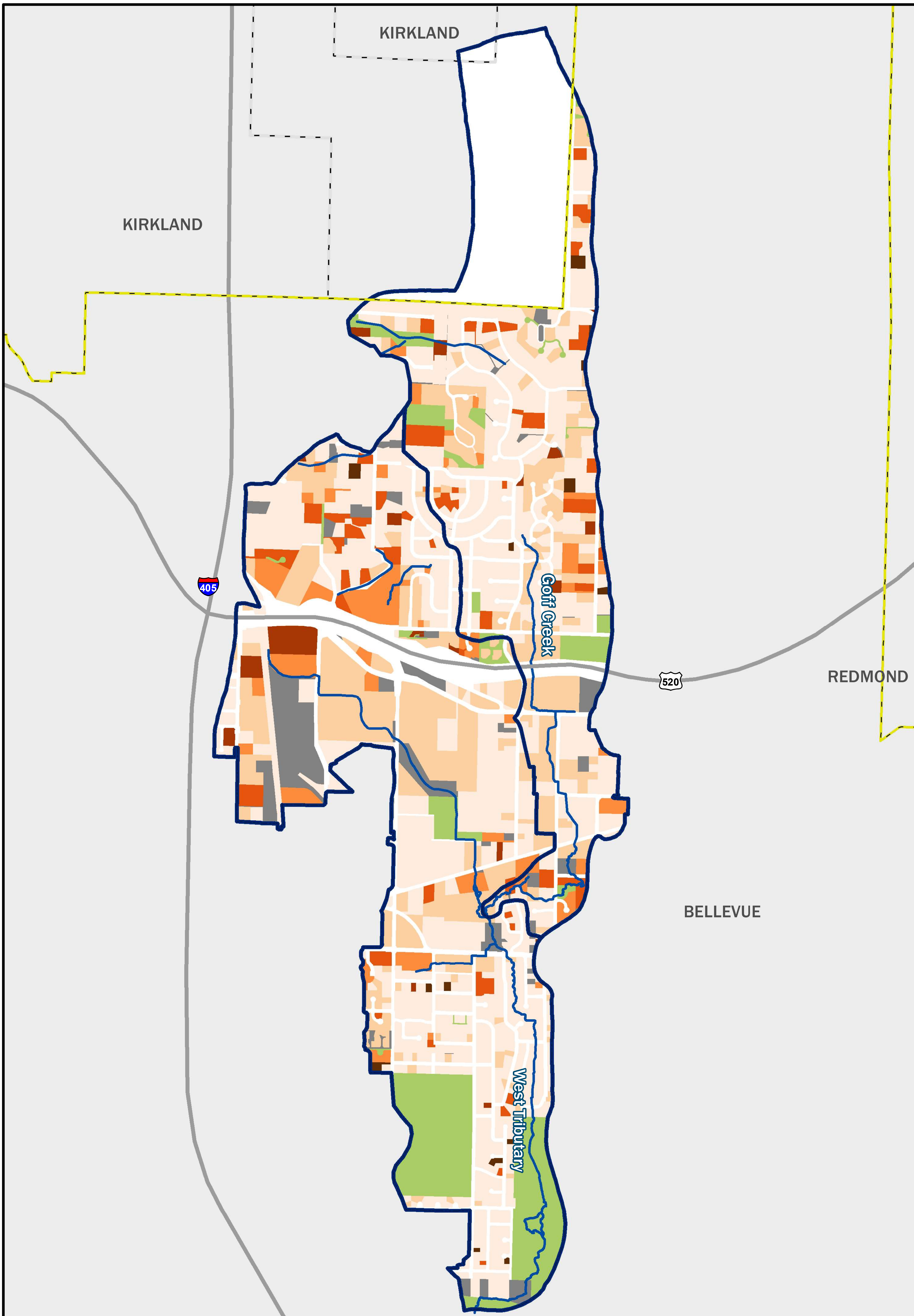
Note: Open Stream Conditions Assessment Database (OSCA).

Figure 33.
Richards Creek and Sunset Creek Subbasins Age of Development Ratings.

N

0 625 1,250 2,500 Feet

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_AgeDevelop_Sunset_Valley.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Highway (City of Bellevue 2020)
- Stream (City of Bellevue 2020)

Age of Development Rating (City of Bellevue 2020)

- 6 (2017-Current)
- 5 (2010-2016)
- 4 (1996-2009)
- 3 (1988-1995)
- 2 (1975-1987)
- 1 (1974 and earlier)
- Park, Open or Tract
- Vacant or Undeveloped

Note: Open Stream Conditions Assessment Database (OSCA).

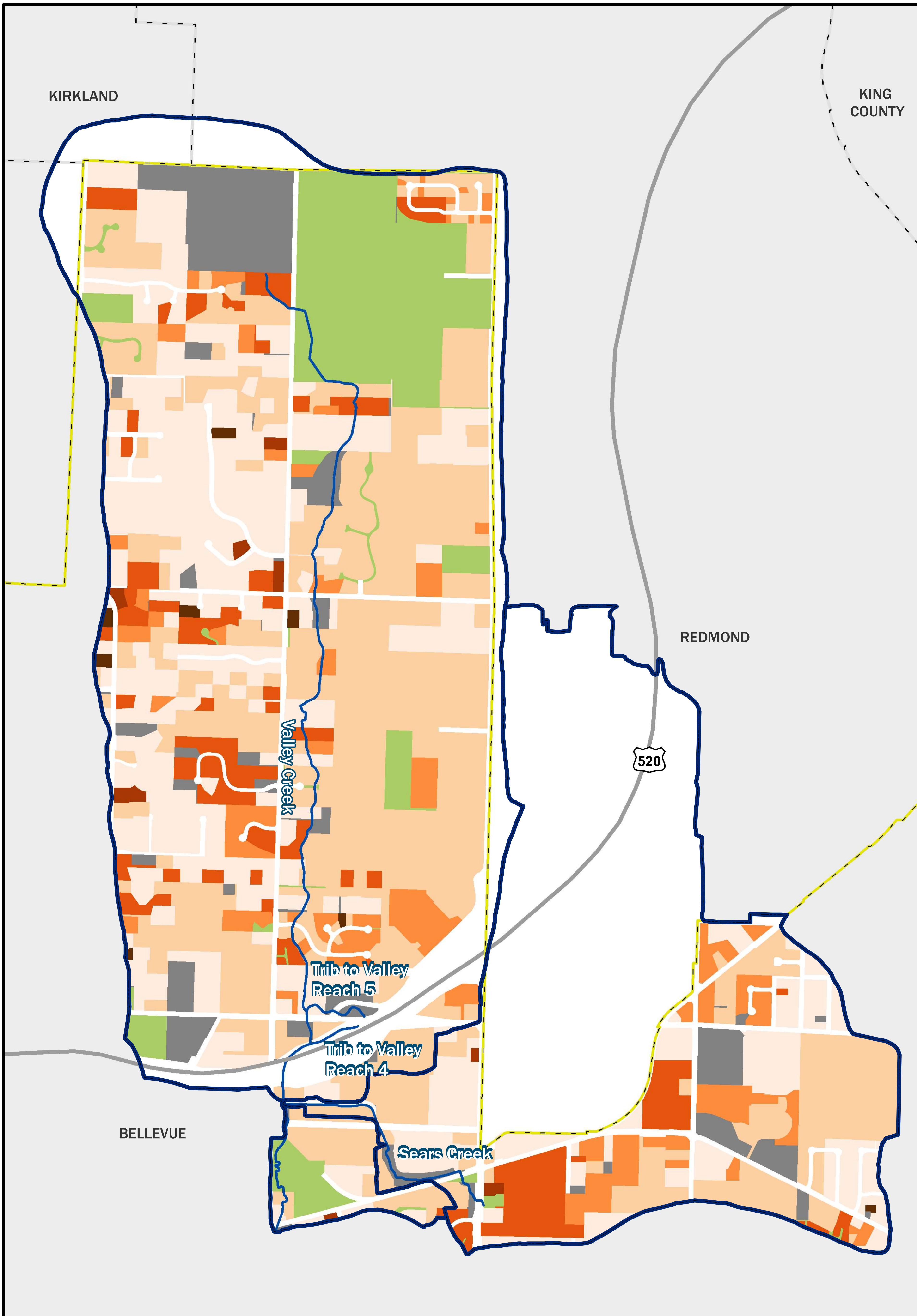
Figure 34.
West Tributary and Goff Creek Subbasins Age of Development Ratings.

N

0 750 1,500 3,000 Feet

Jacobs HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_AgeDevelop_GoffWest_.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Stream (City of Bellevue 2020)
- Highway (City of Bellevue 2020)

Age of Development Rating (City of Bellevue 2020)

- 6 (2017-Current)
- 5 (2010-2016)
- 4 (1996-2009)
- 3 (1988-1995)
- 2 (1975-1987)
- 1 (1974 and earlier)
- Park, Open or Tract
- Vacant or Undeveloped

Note: Open Stream Conditions Assessment Database (OSCA).

**Figure 35.
Valley Creek and Sears Creek
Subbasins Age of Development Ratings.**

N

0 550 1,100 2,200 Feet

Jacobs HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_AgeDevelop_Sunset_Valley.mxd

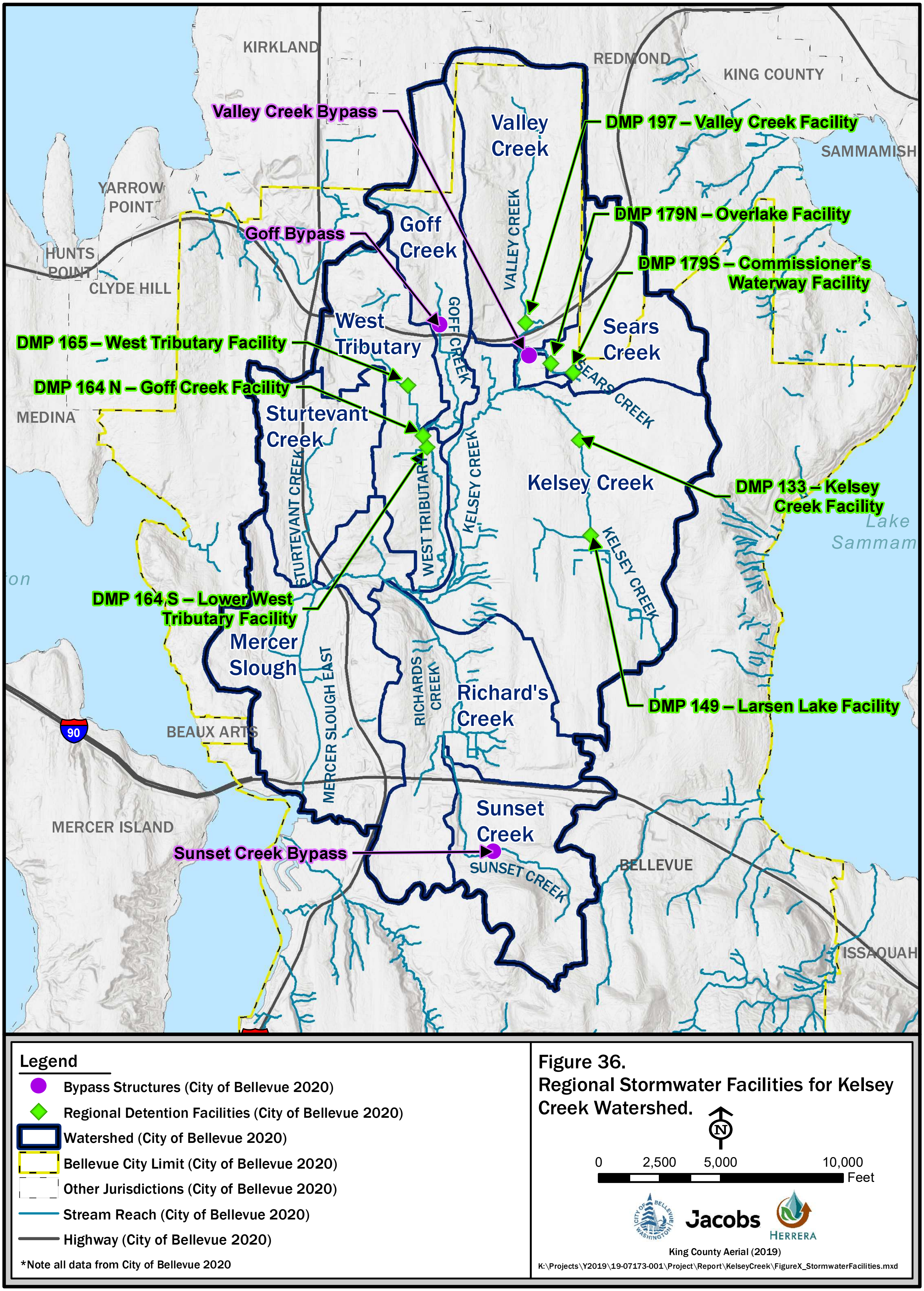


Figure 36.
Regional Stormwater Facilities for Kelsey Creek Watershed.

2.2.3 Other Non-Stormwater Built Infrastructure

As is true in all of Puget Sound, power lines, transportation corridors (roads, rail, trails), sewer lines, and other types of infrastructure exist throughout the Greater Kelsey Creek Watershed and impact natural stream and hydrologic processes and function. One such piece of built infrastructure is the Olympic Pipeline, which crosses the Greater Kelsey Creek Watershed carrying jet fuel to Seattle-Tacoma (SEA-TAC) Airport. Other examples include the Washington State Department of Transportation (WSDOT) that has invested in addressing fish passage including a current project to remove a fish-barrier culvert on Sunset Creek under I-90 (planned for construction 2023-2026) and Sound Transit (ST), which has implemented stream restoration on Sturtevant Creek.

The presence of this built infrastructure may limit where investments in stream and watershed health may be located. When potential investments in stream and watershed health are identified during future phases of this WMP development, the locations of this existing built infrastructure will be identified. These built infrastructure systems may also present opportunities for partnerships in future investments in stream and watershed health.

2.3 Natural Systems

Existing conditions are summarized below for the following natural system attributes: stream flow, surface water quality, groundwater quality, riparian corridor, instream habitat, and aquatic species.

2.3.1 Stream Flow

As watersheds urbanize, natural vegetation and forest is replaced by impervious surfaces such as buildings, driveways, roadways and other hard surfaces. These impervious surfaces cause rainfall to quickly flow toward local streams instead of infiltrating into the ground where it can slowly migrate to the stream via shallow interflow or groundwater flow. One consequence is that streamflow becomes increasingly “flashy” as their response to rainfall is more immediate when compared to a forested watershed. Commensurate with these changes to the hydrograph form are increases in peak flows within the stream and the duration of higher flows. As shown in Figure 2, these and other related changes in streamflow characteristics can negatively impact stream habitat in several ways including decreased channel stability, increased channel erosion and/or aggradation, and decreased floodplain connectivity.

Streamflow data are available from three stream gauges in the Greater Kelsey Creek Watershed that are or were operated and maintained by King County (2020a). All three of these gauges are located upstream of I-405 and the confluence with Sturtevant Creek. Gauge COB-MCF (See Figure 5) was a United States Geological Service (USGS) gauge installed during the 1950s. King County took over that gauge in October 2019. The gauge is located on Kelsey Creek just upstream of I-405 at the corner of 121st Avenue SE and SE 8th Street. Approximately two miles upstream from Gauge COB-MCF and upstream of the confluences of Richards Creek, Sunset Creek, West Tributary and Goff Creek, is COB-KCF. Gauge COB-KCF was installed on January 1st, 2011 and is currently active; the gauge is located just north of NE 8th Street, near the intersection with 132nd Avenue. Note that this gauge was out of service during construction of the new culvert under NE 8th Street with a replacement gauge installed in approximately 2018. Approximately one mile upstream from the COB-KCF gauge is Gauge COB-VCF. Gauge COB-VCF was installed on January 1st, 2012 and was removed in early 2017. The gauge is located on Valley Creek just upstream from the confluence with Kelsey Creek, north of the intersection of 140th Avenue NE and Bel-Red Road.

Although there are additional stream gauges within the Greater Kelsey Creek Watershed, the COB-MCF, COB-KCF, and COB-VCF were the only gauges that provided data for the entirety of the water year and allowed for a complete Hydrologic Metric Score Analysis (Table 11). Data from COB-MCF is summarized in

Figure 37. The resultant hydrograph from this data shows the characteristic flashy signal described above that is typical for streams in an urban setting.

To evaluate the effects of urbanization on the hydrology of Kelsey Creek, scores for the following stream hydrologic metrics were computed using data from all three gauges for individual years having a complete dataset: High Pulse Count, High Pulse Range, Richards-Baker Flashiness Index (RBI), and TQ mean. Table 12 provides a definition for each stream hydrologic metric with their expected response to urbanization. Gauges COB-MCF and COB-KCF had datasets available for one year (2020) while from COB-VCF was available for two years (2013, and 2015).

The computed stream hydrologic metrics are summarized in Table 11 with a comparison to metrics obtained from a highly urbanized watershed and a forested watershed. The highly urbanized watershed is Tyler's Creek in the City of Redmond. The Tyler's Creek Watershed has a drainage area of 168 acres with 35 percent of this area covered by impervious surfaces. This Watershed is a control site for a long-term study of Redmond's watersheds (Herrera 2015). The forested Watershed is Big Beef Creek in Kitsap County. The Big Beef Creek Watershed has a drainage area of 8,649 acres with 2.7 precent of this area covered by impervious surfaces (Rosburg *et al.* 2017). It serves as the forested reference watershed for the Ecology Watershed Health Monitoring Program. For comparison, the Greater Kelsey Creek Watershed has a drainage area of approximately 10,950 acres; 42 percent of this area is covered by impervious surfaces. To aid in the interpretation of these results, Table 11 also provides representative TQ mean values from Konrad et al. (2002) from watersheds categorized as urban (road density 9.1 to 11.3 kilometers per square kilometer [km/km^2]), suburban (road density 4.7 to 7.9 km/km^2), and rural (road density 2.1 to 2.6 km/km^2).

As shown in Table 11, scores computed for the streams within the Greater Kelsey Creek Watershed more closely aligned with the urbanized Tyler's Creek than the forested Big Beef Creek. In predictable fashion, the scores for Tyler's Creek are biased towards the expected responses from urbanization shown in Table 12 whereas the scores from Big Beef Creek are biased in the opposite direction. The one exception was the scores for TQ mean where the median scores for Tyler's Creek and Big Beef Creek were relatively similar at 0.29 and 0.30, respectively. The TQ mean values for creeks in the Greater Kelsey Creek Watershed were within the range of scores for both Tyler's Creek and Big Beef Creek, and as predicted Valley Creek had a slightly higher TQ mean. Collectively, these data generally suggest there is a high degree of hydrologic alteration in the Greater Kelsey Creek Watershed relative to these other creeks with highly urbanized and forested watersheds, respectively.

Additional stream flow data documenting flow rates measured at the USGS MCF Gauge in Kelsey Creek from 1956 to 2019 were provided by the Washington State Department of Ecology. Flow metrics for this data set, including the High Pulse Count, High Pulse Range, Richards-Baker Flashiness Index (RBI), and TQ mean can be found in Appendix C. Over the period from 1956 to 1996, the RBI steadily increases from an initial score of 0.22 to a high of 0.60. The long-term increase of the RBI is indicative of an increase in watershed flashiness, which is to be expected given the increase in urbanization during this time. However, from 1996 to 2019 we see a decrease in the RBI. The trendline for the period from 1995 to 2019 shows an average decrease of 0.39 percent per year. Similarly, TQ mean data—which is expected to decrease with urbanization—decreased at an average rate of 0.25 percent from 1956 to 1996 and then increased at a rate of 0.17 percent from the period 1996 to 2019—with a lowest record TQ mean score of 0.21 in 1988. The recent decrease in the RBI and increase in the TQ mean indicate that stream flow conditions have been less flashy, and trending towards their pre-development state, over the past 24 years. A similar trend, although less pronounced, can be observed in the High Pulse Count data. These data suggest that although the flow rates in Kelsey Creek have changed drastically due to urbanization, current efforts to reduce our impact on the Watershed may have some effect.

Table 11. Hydrologic Metrics from the Greater Kelsey Creek Watershed Compared to Metrics from Other Watersheds

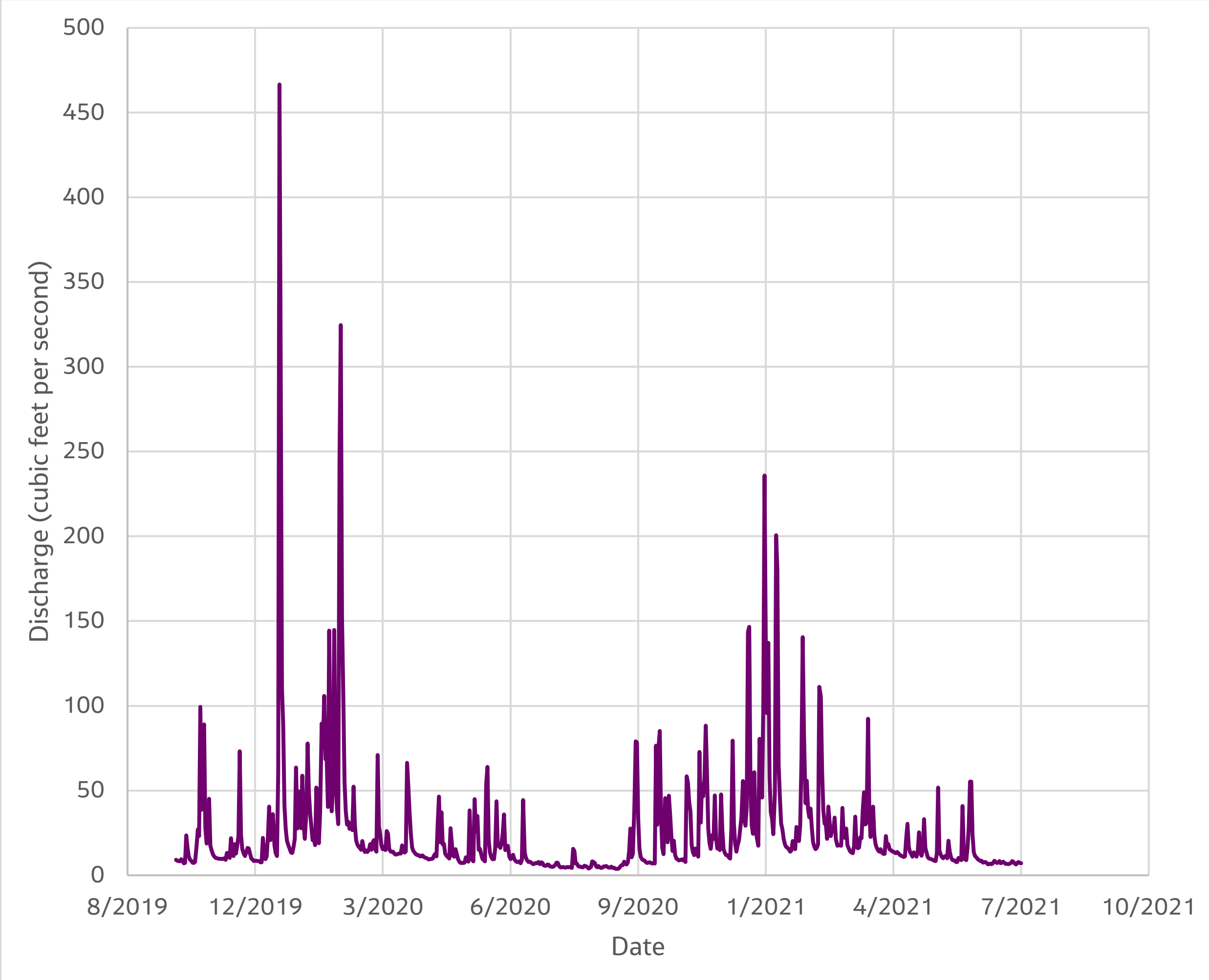
Water Year	Watershed Type	High Pulse Count (number per year)	High Pulse Range (days)	Richards-Baker Flashiness Index	TQ Mean (fraction of the year)
Mercer Creek: COB-MCF Station					
2020	Urbanized	18	225	0.50	0.24
Kelsey Creek: COB-KCF Station					
2020	Urbanized	16	342	0.46	0.24
Valley Creek: COB-VCF Station					
2013	Suburban	25	346	0.36	0.33
2015	Suburban	11	330	0.24	0.27
Median	Suburban	18	338	0.30	0.30
Tyler's Creek: TYLMO Station					
2019	Urbanized	16	317	0.57	0.30
2018	Urbanized	27	243	0.57	0.30
2017	Urbanized	33	221	0.76	0.28
2016	Urbanized	30	326	0.82	0.24
Median (Range)	**Urbanized**	**29 (16 – 33)**	**280 (221 – 326)**	**0.67 (0.57 – 082)**	**0.29 (0.24 – 0.30)**
Big Beef Creek					
2019	Forested	5	57	0.23	0.24
2018	Forested	9	174	0.20	0.30
2017	Forested	12	140	0.24	0.39
2016	Forested	4	109	0.23	0.30
2015	Forested	6	135	0.23	0.33
2014	Forested	7	113	0.18	0.30
Median	**Forested**	**7 (4 – 12)**	**124 (57 – 174)**	**0.23 (0.18 – 0.24)**	**0.30 (0.24 – 0.39)**
Konrad et al. 2002					
Medan (Range)	**Urban**	**ND**	**ND**	**ND**	**0.29 (0.25 – 0.30)**
Medan (Range)	**Suburban**	**ND**	**ND**	**ND**	**0.33 (0.31 – 0.39)**

Water Year	Watershed Type	High Pulse Count (number per year)	High Pulse Range (days)	Richards-Baker Flashiness Index	TQ Mean (fraction of the year)
Medan (Range)	**Rural**	**ND**	**ND**	**ND**	**0.35** **(0.27 – 0.35)**

https://green2.kingcounty.gov/hydrology/GaugeMap.aspx

Table 12. Definitions for Hydrologic Metrics

Component	Metric Name	Definition	Units	Expected Response to Urbanization
Frequency	High Pulse Count	Number of high pulse events per year. A high pulse event occurs when daily flow exceeds twice the water year average daily flow. A single event covers all consecutive days when this condition is met. Thus, consecutive high pulse days comprise a single event.	Count	Increase
Duration	High Pulse Range	Number of days between the first and last pulse event of the water year.	Days	Increase
Flashiness	Richards-Baker Index	An index of flow oscillations relative to total flow based on daily average discharge during the water year.	Unitless	Increase
Flashiness	TQ mean	The fraction of the time during the water year that the daily average flow rate is greater than the annual average flow.	Fraction of the year	Decrease



(source: https://green2.kingcounty.gov/hydrology/SummaryDataGraphs.aspx)

Figure 37. Mercer Gauge Hydrograph

2.3.2 Surface Water Quality

Stormwater runoff from impervious surfaces that is untreated is a primary cause of pollutant loading and transport to surface waters (See conceptual model shown in Figure 2). As described earlier in this report, the majority of the Greater Kelsey Creek Watershed was developed prior to the requirement for water quality treatment; hence, most runoff that enters Kelsey Creek and its tributaries is untreated. Common pollutants from urbanized areas that are detrimental to aquatic health include nutrients (i.e., nitrogen and phosphorus), heavy metals (i.e., Pb, Zn, Cu, Cd), organics (e.g., petroleum hydrocarbons), pathogens, suspended solids, and salts. Many of these pollutants can cause acute toxicity in fish and other aquatic organisms. Runoff from warm impervious surfaces on sunny days can raise stream temperatures causing a host of negative impacts to streams from altering the benthic invertebrate community to the making it difficult for native salmonids to thrive.

Recent studies have shown a compound found in automobile tires is responsible for Coho Salmon (*Oncorhynchus kisutch*) mortality in urban creeks (Tian *et al.* 2020). Pollutants can also cause chronic toxicity that may be directly lethal or produce sublethal effects such as decreased growth, reduced reproduction, or behavioral changes. In a study of streams in the Puget Sound lowlands, May *et al.*

(1997) found concentrations of pollutants (primarily metals) were insufficient to produce these adverse effects during baseflow conditions and storm events in streams with a low to moderate percentage of effective impervious surfaces in their watersheds; however, the potential for these effects increases markedly in highly urbanized basins when effective impervious surfaces occupy greater than 45 percent of the total watershed area. For reference, impervious surfaces occupy approximately 42 percent of the total Greater Kelsey Creek Watershed area and have increased by 3.8 percent over the period from 2006 to 2017.

Water quality data for the Greater Kelsey Creek Watershed are available from sampling conducted by King County, the City, and Ecology. Water quality impairment is assessed herein based on the following data and information:

- Washington State Department of Ecology's 303(d) list
- Water Quality Index (WQI) scores that were computed by King County

2.3.2.1 Stream Water Quality Impairments

Section 303(d) of the Clean Water Act requires Ecology to assess water bodies in Washington State to determine if their quality is adequate to fully support designated beneficial uses (such as for drinking, recreation, aquatic habitat, and industrial use). The assessed water bodies are placed into one of five categories on the 303(d)-list based on their water quality status. Water bodies that are not supporting beneficial uses are placed in the polluted water category (Category 5) and prioritized for water cleanup plans. The most recent assessment for the 303(d) list was completed in 2014.

Four segments withing the Greater Kelsey Creek Watershed are identified as Category 5 water bodies on the 303(d)-list, three of which are located in the Kelsey Creek Subbasin. As shown in Table 13, the Category 5 Sites are located in the lower reaches of the Kelsey Creek Subbasin and Mercer Slough and were placed on the 303(d) list because temperatures, bacteria levels, dissolved oxygen concentrations, pH levels and bioassessments did not meet water quality standards for Washington State (WAC 173-201A). The data are from 2014 and may not be representative of current conditions. High concentrations of bacteria such as fecal coliform pose a risk to public health, recreational activities, and shellfish harvesting. Adequate concentrations of dissolved oxygen are essential to support aquatic life. Low dissolved oxygen can be caused by several factors including excessive algae growth caused by phosphorus that is carried into streams from human sources. As the algae die and decompose, the process consumes dissolved oxygen. The loss of shade providing riparian canopy cover may also contribute to low dissolved oxygen because high water temperature reduces the amount of oxygen that can remain dissolved in water. The listing for dissolved oxygen in Kelsey Creek was derived based on monitoring conducted over the period from 2004 through 2018. As described in the next subsection, more recent data collected by King County also indicates that dissolved oxygen concentrations are at levels that warrant concern.

The bioassessment score is assessed using Benthic Index of Biotic Integrity (B-IBI) scores that are calculated from samples of benthic macroinvertebrates. These scores provide a broad indication of stream health that integrates potential impairment from multiple sources (e.g., poor water quality and/or physical habitat). As shown in Table 13, one segment of Kelsey Creek was placed on the 303(d)-list due to biotic impairment because B-IBI scores indicate stream health conditions were poor (see additional details in Section 2.3.6 Aquatic Species). The data are from 2014 and may not be representative of current conditions. The segment is located on the mainstem of Kelsey Creek extending from NE 8th Street to NE Bellevue-Redmond Road.

Illicit discharges have occurred in the Greater Kelsey Creek Watershed, though are difficult to quantify (in terms of both amount discharged and impact). Discharges and spills that are the result of traffic accidents occur frequently within the Greater Kelsey Creek Watershed, with portions of both I-405 and I-90 within the boundaries of the Watershed. In addition to spills from traffic accidents, illicit discharges in the form of dumping and foot waste have also been documented.

2.3.2.2 Water Quality Index

The WQI is computed using data from the following parameters: fecal coliform bacteria, dissolved oxygen, pH, total suspended solids, temperature, turbidity, total phosphorus, and total nitrogen. It provides a broad assessment of water quality that can be used to categorize waters in terms of the 'level of concern' for potential impairment. In general, stations scoring 80 and above are meeting water quality standards or guidelines and are of "low concern", scores 40 to 80 indicate “moderate concern”, and scores below 40 are of "high concern."

While the WQI provides an easy method for categorizing water quality and for comparing between water bodies, like all indices it has weaknesses. For example, a parameter that has a high degree of variability, such as fecal coliform bacteria, can easily skew the results based on one or a few high values. The WQI also does not provide any evidence for why a water body may be rated low. For this reason, it continues to be important to evaluate the individual parameters that comprise the WQI. Finally, it should be noted that sampling conducted by King County to obtain data for computing WQI scores has not explicitly targeted storm events. Hence, the scores may underestimate the true level of impairment from parameters that are commonly associated with stormwater runoff.

King County (2020b) computed WQI scores based on data from monthly grab samples that were collected at Site 0444 on Kelsey Creek over the period from 2004 to 2008 and 2014 to 2020. This station is located at the gaging station near I-405, under the trestle near the Richards Road exit, at the mouth of Kelsey Creek (see Figure 5 for location of the gaging station, which is proximate to the water quality monitoring station). Site 0444 is located upstream of I-405 therefore results from this sampling do not reflect potential influences on water quality from pollutants that are associated with the interstate highway. Each monthly grab sample was analyzed for the suite of parameters used to calculate WQI scores.

Average annual WQI scores from this station are shown in Figure 38 for the period extending from 2004 through 2020. The median value from these data (45) generally indicates water quality is a “moderate concern” in Kelsey Creek, with some years as a “high concern.” As shown in Table 14, high fecal coliform bacteria concentrations, low concentrations of dissolved oxygen (DO) and high total phosphorus concentrations (with a median WQI score of 42 over the 2014 to 2020 time period) were the primary factor driving the low-moderate score for the stream; all other parameters generally scored very near or above 90. Sources of fecal coliform bacteria in urban streams include pet waste, homeless encampments, cross connections between sewer and stormwater conveyance systems, septic systems, and urban wildlife.

In connection with Ecology’s Stormwater Action Monitoring (SAM) program, data for computing WQI index scores were collected from 52 sites in streams located in the Puget Lowland ecoregion from January to December 2015; 24 of these sites were located in streams outside the urban growth area (UGA) in more rural settings while 28 of these sites were located in streams within the UGA in more urban settings. These data provide a good frame of reference for comparing the scores from Kelsey Creek to scores from other streams in the region. As reported in DeGasperi *et al.* (2018), a greater proportion of stream length outside the UGA was in good condition (67 percent) relative to streams within the UGA (43 percent). Median annual WQI scores for streams within and outside the UGA were 75.3 and 86.9, respectively. These data suggest water quality in Kelsey Creek is poor, based on recent WQI scores relative to conditions in comparable streams located within the UGA from this study.

Table 13. Category 5 Segments of Kelsey Creek on the 303(d) List.

Parameter	Listing ID	Year Listed	Location
Temperature	4812	2004-2014	Mercer Slough – Lake Washington to SE 8th Street
Bacteria	13145	2004-2014	Mercer Slough – Lake Washington to SE 8th Street
Temperature	7026	2004-2014	Kelsey Creek – Sturtevant Creek to Richards Creek
Dissolved Oxygen	12674	2004-2014	Kelsey Creek – Sturtevant Creek to Richards Creek
Bacteria	13126	1998-2014	Kelsey Creek – Sturtevant Creek to Richards Creek
Bacteria	46931	2008-2014	Kelsey Creek – SE 7th Place to NE 8th Street
pH	51279	2014	Kelsey Creek – SE 7th Place to NE 8th Street
Bioassessment	70089	2014	Kelsey Creek – NE 8th Street to NE Bellevue - Redmond Rd
Temperature	73128	2014	Kelsey Creek – SE 7th Place to NE 8th Street

Table 14. Water Quality Index Scores by Year and Parameter for Kelsey Creek

Year	WQI Score	WQ Concern	Fecal Coliform	DO	pH	TSS	Temperature	Turbidity	TP	TN
2020	54	Moderate	73	37	94	94	75	90	39	100
2019	42	Moderate	83	8	92	89	76	86	23	100
2018	52	Moderate	74	32	93	87	66	89	50	100
2017	55	Moderate	61	41	94	95	76	90	47	100
2016	40	Moderate	59	32	91	74	73	87	43	100
2015	35	High	47	37	86	83	70	86	43	100
2014	17	High	35	8	74	92	67	87	49	100
2013	N/A	N/A	N/A	--	--	--	--	--	--	--
2012	N/A	N/A	N/A	--	--	--	--	--	--	--
2011	N/A	N/A	N/A	--	--	--	--	--	--	--
2010	N/A	N/A	N/A	--	--	--	--	--	--	--
2009	N/A	N/A	N/A	--	--	--	--	--	--	--
2008	57	Moderate	61	57	97	94	74	93	63	95
2007	42	Moderate	38	57	93	93	76	91	56	97
2006	57	Moderate	60	44	88	91	79	87	54	95
2005	48	Moderate	57	54	96	100	77	95	61	96
2004	39	High	48	46	86	96	74	91	63	92
Median	45	Moderate	60	39	93	93	75	90	50	100

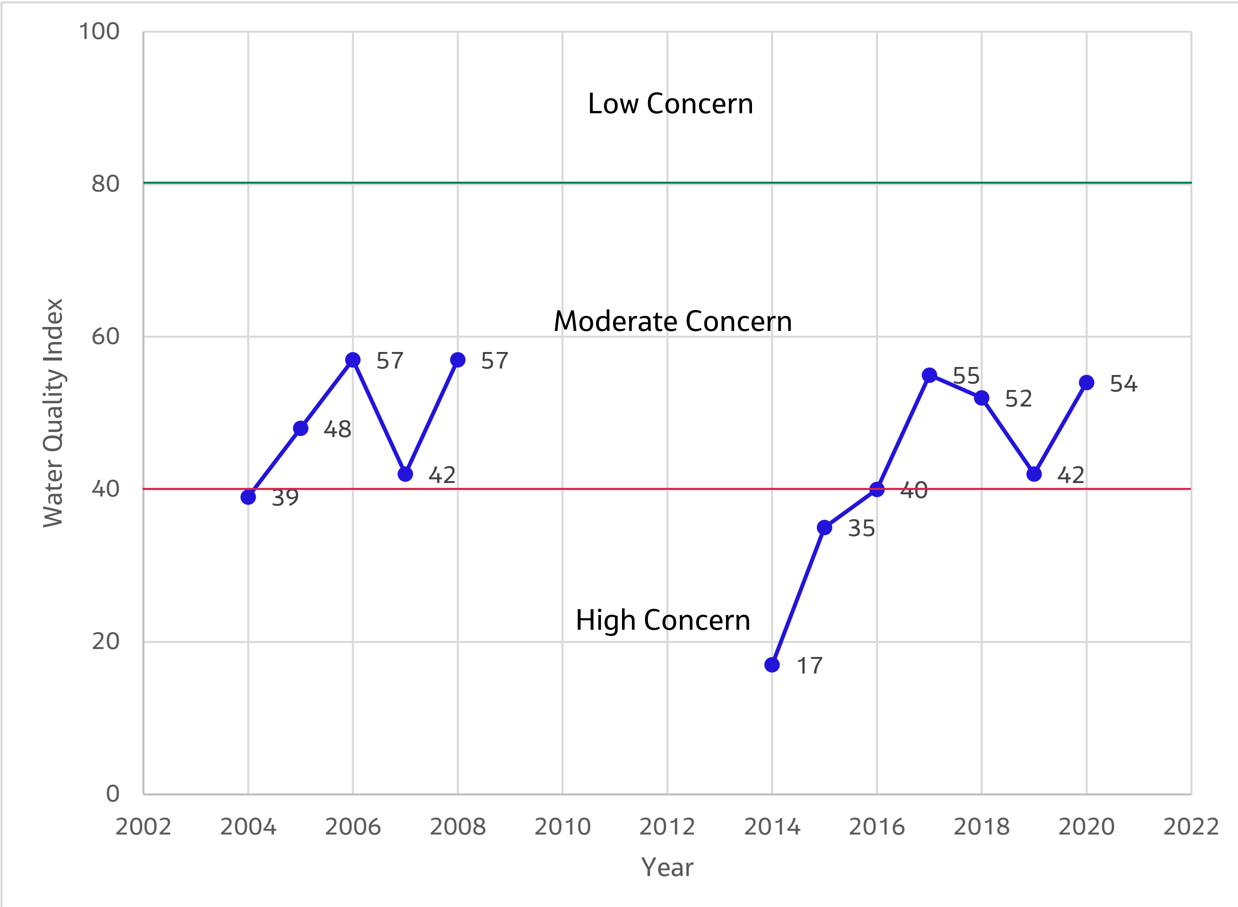


Figure 38. Water Quality Index Scores

2.3.3 Groundwater Quality

The Greater Kelsey Creek Watershed has two Group A City drinking water wells and wellhead protection areas located in the Valley Creek Subbasin. The Valley Creek Subbasin has the highest density of parcels that are connected to septic tanks. Water Quality Information provided by King County indicates that the two Class A wells have a history of nitrate contamination dating from 1991 to 2003. Nitrate contamination may be associated with the use of septic tanks. No additional ground water quality information was found to assess the quality of the groundwater or the remainder of the Greater Kelsey Creek Watershed.

2.3.4 Riparian Corridor

Riparian corridors are complex ecological systems located at the land-water interface adjacent to streams, rivers, lakes, ponds, and wetlands. Riparian corridors serve important functions related to nutrient cycling, soil and bank stabilization, soil and water chemistry and quality, and provide both terrestrial and aquatic habitat. As described in the conceptual model (Figure 2), reductions in riparian corridor width and loss of riparian vegetation due to urbanization is associated with decreased stream wood inputs, decreased riparian habitat, and increased bank instability and stream temperatures.

Tree canopy cover and impervious cover in the riparian corridor of the Greater Kelsey Creek Watershed was assessed based on land cover data from 2013 and 2017, including the area within 100 feet on both sides of the stream (Bellevue 2018) for all open stream reaches in each subbasin (excluding reaches that are completely piped or those that were not assigned a SegmentID). Within the Greater Kelsey Creek Watershed area, riparian tree canopy cover across subbasins ranges from a low of 23.5 percent in Sturtevant Creek Subbasin to a high of 61.8 percent in Sunset Creek Subbasin (Table 15). In addition, riparian impervious cover across subbasins ranges from a low of 6.8 percent in Mercer Slough Subbasin to a high of 48.6 percent in Sears Creek Subbasin (Table 15). Overall riparian cover in the Greater Kelsey Creek Watershed is underperforming compared to Coal and Newport Creek. These riparian cover percentages are indicators of overall stream condition. The OSCA summary in Appendix B summarizes how riparian cover varies at the reach level.

Table 15. Riparian Canopy Cover and Riparian Impervious Surface Cover in the Greater Kelsey Creek Watershed by Subbasin

Subbasin	Riparian Canopy Cover (%)	Riparian Impervious Surface Cover (%)
Kelsey Creek	41.0	16.4
Sturtevant Creek	23.5	42.7
Richards Creek	53.7	20.7
Sunset Creek	61.8	24.6
West Tributary	35.7	25.8
Goff Creek	52.9	40.8
Valley Creek	53.4	23.3
Sears Creek	49.3	48.6
Mercer Slough	40.3	6.8

As a comparison to the Greater Kelsey Creek Watershed, the upper range for riparian canopy cover in other subbasins in Bellevue is 82 to 86 percent in the Coal Creek, Ardmore Area, and Newport Creek subbasins. For example, the Coal Creek Watershed has excellent riparian canopy cover in large part because much of the mainstem channel corridor lies within public conservation lands (i.e., the Coal Creek Natural Area and the King County Cougar Mountain Region Wildland Park). Not surprisingly, these subbasins with high riparian cover also have correspondingly low impervious cover (e.g., 1 to 10 percent).

In addition to the quantity of riparian cover, the quality of riparian cover is also important. Forest managers from Bellevue's Parks department are investigating species diversity and forest succession throughout the riparian corridor through ongoing monitoring efforts. Data from these efforts have generally shown that cover in the riparian corridor is provided primarily by deciduous species, such as Black Cottonwood (*Populus trichocarpa*), Red Alder (*Alnus rubra*), and Bigleaf Maple (*Acer macrophyllum*) (Bellevue 2006). Increased coniferous species and riparian diversity are needed to reduce the extents of invasive and noxious vegetation, to maintain a sustainable forest canopy, and also to provide natural recruitment of woody material to the stream channel.

Several invasive plant species are prevalent within the riparian corridor along Kelsey Creek and its tributaries, including Himalayan blackberry (*Rubus armeniacus*), English ivy (*Hedera helix*), reed canarygrass (*Phalaris arundinacea*), bittersweet nightshade (*Solanum dulcamara*), and field bindweed (*Convolvulus arvensis*), as the most frequently encountered. Knotweed species (*Persicaria wallichii* or *Fallopia* spp.), listed in King County as a Class B noxious weed, have been identified along Kelsey Creek and Richards Creek (Bellevue 2021a). Immediate control is recommended to manage this aggressive and rapidly spreading noxious weed, which is already forming dense monoculture stands along portions of the streambank. Knotweed serves as a catalyst for streambank erosion (Colleran et al. 2020), which is why it is so detrimental to stream health.

2.3.5 Instream Habitat

Instream habitat conditions for eight subbasins (excluding Mercer Slough) in the Greater Kelsey Creek Watershed were assessed by the City between 2019 and 2020 as part of the citywide OSCA surveys (Bellevue 2021a). The OSCA surveys followed the US Forest Service Region 6 Level II Stream Inventory Protocol (USFS 2012), with some minor modifications as described in Appendix B. All surveys were performed during low or base stream flows and included assessment of channel morphology and riparian corridor conditions, instream and off-channel habitat composition, LWM, substrate composition, streambank conditions, aquatic habitat conditions and fish passage barriers, as well as identification of potential opportunities that could improve instream habitat conditions. The data presented here are summarized at the watershed level. Stream- or subbasin-level summaries can be found in Appendix B (Bellevue 2021a) and detailed stream reach-level summaries will be included in the forthcoming Greater Kelsey Creek Watershed OSCA Reach Reports (Bellevue 2022) currently under development. Habitat and substrate composition data presented below do not include the West Tributary, which was surveyed under a reduced protocol.

2.3.5.1 Channel Morphology

Channel morphology, or the shape of the channel, is described by a variety of metrics, such as the width and depth of the channel, the bed material size and overall bed form (cascade, riffle/pool, etc.), floodplain height and characteristics, bank materials and stability, sinuosity, bar formation. This morphology is the result of the interaction of three principal landscape drivers – hydrology, sediment supply, and vegetation (Barnard *et al.* 2013). Native species have evolved over time to utilize habitat that results from natural channel morphologies. Human alterations to the landscape have often resulted in changes to the landscape drivers, which in turn changed the channel morphology, often to the detriment of stream habitat. In an urbanized setting such as the Greater Kelsey Creek Watershed, understanding the present channel morphology and how it differs from a more natural morphology can help identify the extent to which the channel has been altered by human activity, and provide insight into what might be done to restore it to a condition more beneficial as habitat for native species and resilient to a changing climate.

The most pertinent geomorphic characteristics of each of the subbasins in the Greater Kelsey Creek Watershed are summarized in Table 16. One of these subbasins, Mercer Slough, is at the downstream end of the system, and receives streamflow from all the other subbasins before entering into Lake Washington. Prior to 1917, Mercer Slough was part of Lake Washington. When the Chittenden Locks were completed, Lake Washington was lowered 9 to 12 feet, and Mercer Slough was dredged to support agriculture on the former lakebed. Mercer Slough is too deep to be wadable and was therefore not included in the OSCA survey.

The combination of non-typical topography and human alterations makes it difficult to neatly classify the sediment dynamics of the streams using the Montgomery and Buffington (1993) categories of Source, Transport, and Response. Source reaches are reaches where sediment erosion is the dominant factor, and therefore where sediment largely originates (typically in steep headwaters areas). Transport reaches are reaches where erosion and deposition are generally in balance, and sediment largely passes through over time. Response reaches are reaches where sediment deposition is the driving factor of stream morphology and where sediment tends to accumulate or be deposited.

Human alterations have created the need for a few additional classifications, such as “Forced Transport”, “Transport/Source”, and simply “NA” to describe channels that would not fit into other typical categories.

The average gradient of the Greater Kelsey Creek Watershed is approximately 1.8 percent, and this low gradient results in nearly 70 percent of the channels being classified geomorphically as Response reaches. This is largely a result of the City's topography, and the lack of steep foothill streams in this Watershed.

Because many of the headwater streams in the Greater Kelsey Creek Watershed originate in wetland areas on a relatively flat plateau, source reaches are rare in the Watershed. Several long, piped segments were classified as "Forced Transport" reaches because their gradient is typical of a Response reach, but the confinement and smooth walls of the culvert allow the reaches to pass sediment more like a Transport reach. Combined, the Response and Forced Transport reaches make up over 80 percent of the surveyed channel length in the Watershed.

The average gradient in Richards Creek (0.5 percent slope (ft/ft)), West Tributary (0.7 percent slope), and Kelsey Creek subbasins (0.8 percent slope) are well below the watershed average, while the average gradient in Sunset Creek (4.3 percent slope) and Goff Creek (3.0 percent slope) subbasins are considerably steeper than the Watershed average and include reaches as steep as 8.6 percent. The predominant bedform in the Watershed is Plane-Bed, at nearly 38 percent, followed by Wetland (a stream type that was created to describe many of the low-lying, marshy areas in this Watershed with diffuse and braided stream channels) at 27 percent. Riparian conditions (i.e., 100 feet from the streambank) are highly variable, ranging from over 90 percent vegetated to over 90 percent impervious, with a median of about 50 percent vegetated and 25 percent impervious (see Section 2.3.4 Riparian Corridor for summary of riparian cover by subbasin; see Appendix B for a summary of riparian cover by reach).

The prevalence of naturally erosive soil types at the ground surface sitting above consolidated glacial material present opportunities for soil slippage and high erosion potential in those reaches that are steep. Other common sources of erosion and sediment supply in the Watershed result from streambank and terrace erosion, streambed and bar incision, and hydrologic changes from land clearing activities and development. The existing geomorphic conditions within the Greater Kelsey Creek Watershed are a product of the topography, geology and soil conditions, combined with the hydrologic changes and hydromodifications associated with land cover and land use change within the last century.

Table 16. Geomorphic Characterizations by Subbasin

Subbasin	Geomorphology Characterization
Mercer Slough	▪ Was not assessed as part of OSCA survey efforts.
Kelsey Creek	▪ Higher gradient riffle/pool and plane-bed channels sandwiched between two large wetland reaches. Upper portions highly modified - stormwater detention, ditching, piping.
	▪ Best riffle/pool ratio (1.7) with highest pool frequency and deepest pools.
	▪ Generally good riparian conditions (excluding piped reaches) but lacking in LWM, much of which is placed.
	▪ Streambed materials are generally gravel to cobble, and streambank armoring is about average (28%).
Sturtevant Creek	▪ Most highly urbanized subbasin, lacking in riparian buffer and subject to flashy flows and subsequent incision. Most confined stream due to entrenchment and modifications.
	▪ Relatively good riffle/pool ratio (2), but pools are generally shallow and concentrated in Reach 4, where incision is highly evident. Glide habitat percentage is high.
	▪ LWM is largely absent (4 per 100 m) with minimal recruitment potential.
	▪ Streambed material is predominately gravel, and streambank armoring is above average (32%).
Richards Creek	▪ Historic headwater seeps and wetlands have largely been filled or piped.
	▪ Lowest gradient stream in Watershed (0.5%), dominated by plane-bed channel and glide habitat.
	▪ LWM is lacking, and 34% of it was placed. Reaches 1, 3, and 4 offer some recruitment potential.
	▪ Substrate has highest percentage of fines, with all reaches > 40% fines. Steam banks are generally unarmored (lowest % in basin).
Sunset Creek	▪ Highest gradient stream (4.3%). Headwaters in drainage ditches and flows through two steep-walled ravines.
	▪ Hardpan cascades in upper reach; Overall subbasin dominated by riffles, with little pool habitat, and most pools below I-90.
	▪ LWM is generally lacking, but better than most other subbasins (10 per 100m) and is effective at creating pools.
	▪ Substrate evenly distributed between gravel, cobble and fines, but with areas scoured to hardpan. Bank armoring is lower than most subbasins (11%).

Subbasin	Geomorphology Characterization
West Tributary	▪ Large wetland reaches with little channel definition interspersed with piped conveyances. What little channel exists is limited in complexity.
	▪ Riffle and glide habitat dominate, with few pools (2%), but wetland areas with active beavers provide deep water and complex off channel areas.
	▪ One of the lowest LWM densities, with recruitment potential in the wetlands associated with beaver activity.
	▪ Substrate dominated by gravels, but with >30% fines and sporadic boulders (riprap). Bank stability is high, but bank armoring is also high.
Goff Creek	▪ Highly variable stream and riparian conditions, from regional detention facility to highly modified commercial areas, to moderately good conditions in residential areas.
	▪ Moderate gradient (2.9%) dominated by riffle. Pool habitat is 11% and mostly associated with weirs.
	▪ Wood loading is low (124 pieces per mile) and appears to be natural. Recruitment potential is limited, but landowner outreach could help increase potential.
	▪ Substrate dominated by gravel, but with 33% fines. Boulders and some of the cobble likely from bank armoring, which is the highest percentage in the subbasin.
Valley Creek	▪ Two distinct regions: Lower - altered/confined channel, varying gradient, low riparian & high impervious; Upper - Good canopy and little impervious area.
	▪ Moderate gradient (1.6%) with riffle (45%) and glide (35%) dominating. Pools are limited (12%), but channel has second highest wetted-width/depth ratio (unconfined).
	▪ LWM loading is low (103 pieces per mile) but average for the basin and is nearly all natural. Recruitment potential is low to moderate.
	▪ Substrate is smaller than average, with 52% fines in fast-water habitat. Bank armoring is lowest in the Watershed.
Sears Creek	▪ Highly urbanized, simplified, confined, and intermittently piped.
	▪ Average gradient (2.7%) with riffle dominating. Pool habitat limited (9%). Lowest wetted-width/depth ratio (confined).
	▪ LWM loading lowest in the Watershed (34 pieces per mile), and mostly natural. Some recruitment potential in Reaches 3 and 5.
	▪ Fines in riffles is lower than all other subbasins in the Watershed, with Reaches 1 and 3 having ideal spawning material. Reach 5 is 100% fines. Bank protection is overall highest in the basin (34%), but mostly limited to Reach 1.

2.3.5.2 Habitat Unit Composition and Off-Channel Habitat

While all watersheds in the City are predominately composed of riffle, or fast-water, habitat streams in the Greater Kelsey Creek Watershed have a lower percentage of riffle habitat (52 percent) than the other City watersheds. They also have a higher percentage of pool habitat (25 percent) than the other City watersheds, and the number of pools per mile (27) is nearly twice that of the next closest watershed, Coal Creek, with 15 pools per mile. The Kelsey (40 pools per mile), Sturtevant (26 pools per mile) and Sunset (23 pools per mile) subbasins are the top three subbasins in the Watershed and in the City in terms of pools per mile but are all well below the 70 (Kelsey) to 164 (Sunset) pools per mile needed to be considered “properly functioning” for their stream sizes (NOAA 1996). The Sears, Goff and Richards Creek subbasins have 20 pools per mile, the lowest in the Watershed.

Overall, the ratio of riffle to pool habitat area in the Greater Kelsey Creek Watershed is 2.1, which falls short of the ideal ratio of approximately 1.0 for juvenile salmonid productivity (Naman *et al*. 2018) yet is the best riffle to pool ratio observed in the City. However, the Richards Creek Subbasin, despite only having 20 pools per mile, has the best riffle/pool ratio in the Watershed, at 0.9. The Richards Creek Subbasin also has the highest median residual pool depth (1.8 feet) in the Watershed, and 15 percent of the pools have a residual depth of over 3 feet. Nearly 40 percent of these pools are the result of beaver activity, and beavers are responsible for much of the habitat diversity found in the Richards Creek Subbasin (Appendix B). The median residual pool depth in the Greater Kelsey Creek Watershed is 1.4 feet. This is less than can be considered “properly functioning” (NOAA 1996), but better than all but the Coal Creek Watershed within the City. Pool habitat in the Greater Kelsey Creek Watershed appears to be a limiting factor that may impact adult salmon migration and juvenile rearing habitat throughout the Watershed.

Given the generally low and flat topography and prevalence of lower-gradient, wetland and response/forced-transport reaches, off-channel habitat is an important consideration in the Greater Kelsey Creek Watershed. Observations during the OSCA surveys indicate that there are opportunities to improve off-channel habitat and access by reconnecting the channel with its floodplain. Channelization, downcutting, and piping of streams has likely reduced off-channel habitat in the Watershed significantly. Wetland reaches are common in the Watershed, but many have been altered or simplified, increasing the potential for downcutting and limiting the potential for off-channel habitat creation in areas that have access to the floodplain. Richards, Goff, Valley, and portions of Sturtevant Creek have relatively low floodplain benches that could be hydraulically reconnected to be off-channel habitat. Historically, beavers played an important role in creating off-channel habitat and wetlands in the Pacific Northwest (Pollock *et. al.* 2015) and were likely historically important habitat drivers in the Greater Kelsey Creek Watershed. Beaver dams help to maintain the connection between the stream and its floodplain, allowing fish to use the floodplain to escape high flows, and providing access to the abundant food resources that the floodplain offers. High flows on the floodplain allow sediment and nutrients (including pollutants) to be dispersed over the floodplain rather than transported downstream, reducing downstream sediment loads and improving water quality.

Figures 39 and 40 show the habitat unit composition by percent area and percent length, respectively, in the subbasins of the Greater Kelsey Creek Watershed.

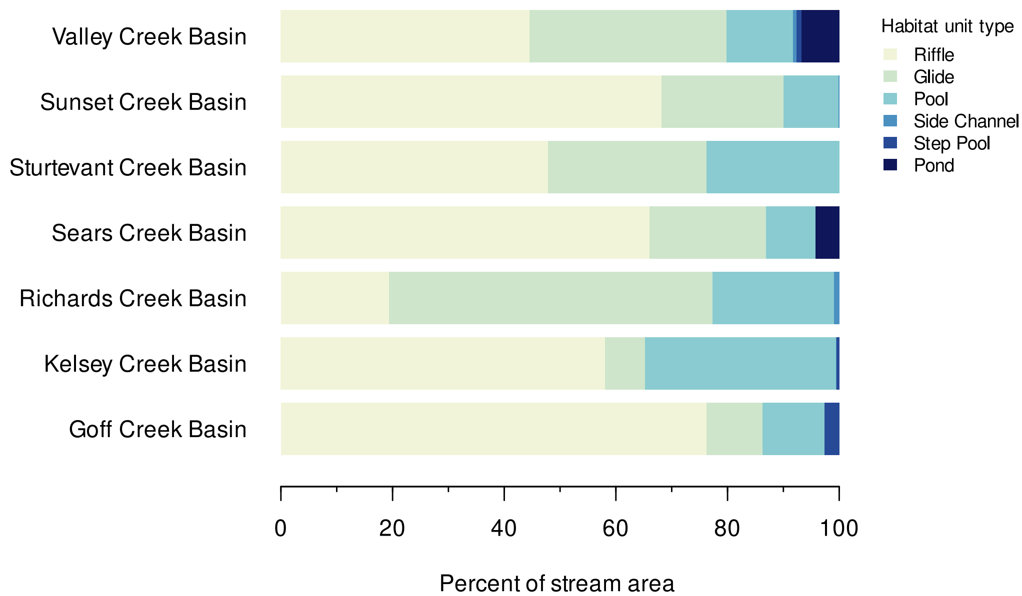


Figure 39. Habitat Unit Composition (by percent area) of the Subbasins in the Greater Kelsey Creek Watershed

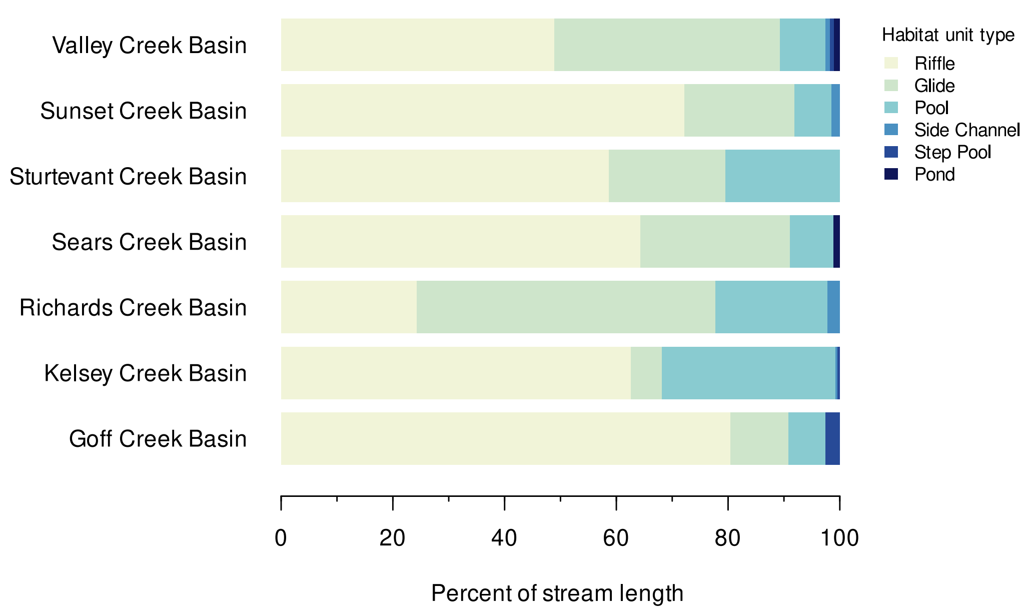


Figure 40. Habitat Unit Composition (by percent length) of the Subbasins in the Greater Kelsey Creek Watershed

2.3.5.3 Large Woody Material

The Greater Kelsey Creek Watershed has the lowest frequency of LWM in the City, at 143 pieces per mile of stream length, well below the median frequency of 467 pieces per mile for similarly sized streams (Fox and Bolton 2007). LWM in the Greater Kelsey Creek Watershed is a limiting factor. Within the Greater Kelsey Creek Watershed, the Richards Creek Subbasin has the highest concentration of LWM at 222 pieces per mile, while the Sears Creek Subbasin has just 35 pieces per mile. In total, 166 of the pieces of LWM in the Greater Kelsey Creek Watershed were likely placed, indicating that some effort has been made to correct the LWM deficiency. Over half of these placed pieces (86) were observed in the Kelsey Creek Subbasin, with both Richards (34) and Sunset (28) Creek subbasins making up the bulk of the others. The Kelsey, Richards, and Sunset Creek subbasins also lead the Watershed in the number of natural pieces. Fourteen placed pieces of LWM in the Sturtevant Creek Subbasin result in the highest percentage of placed LWM (41 percent), but only because there are so few natural pieces that it would have ranked below the Sears Creek Subbasin otherwise.

LWM recruitment potential varies greatly through the Watershed but is in general a limiting factor. Using percent riparian tree canopy cover as a surrogate for recruitment potential, the Sunset Creek (61.1 percent) and Valley Creek (58.9 percent) subbasins have the highest recruitment potential, while Sturtevant Creek (27.5 percent) and West Tributary (40.1 percent) subbasins have the lowest recruitment potential. The other subbasins range between 49.3 and 54.6 percent.

Figure 41 shows the frequency of large woody material in the Greater Kelsey Creek Watershed subbasins as compared to reference levels.

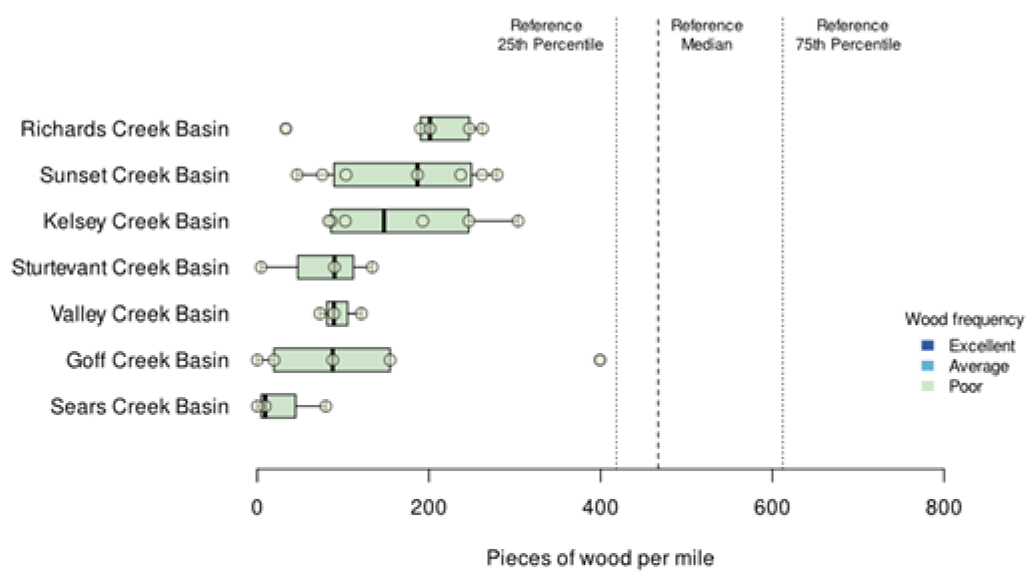


Figure 41. Large Woody Material Frequency in Greater Kelsey Creek Subbasins compared to reference levels (Fox and Bolton 2007)

2.3.5.4 Substrate Conditions

Streambed substrate composition in the Greater Kelsey Creek Watershed is dominated by fines and gravel. Only the Lake Washington Watershed had a higher percentage of fines or gravels in the City. Fines make up 39 percent of the surveyed substrate in the Greater Kelsey Creek Watershed, and gravels make up 36 percent. Cobbles (33 percent), boulders (20 percent), and bedrock or hardpan (3 percent) make up the remainder.

The proportion of fines to gravel varies significantly between bed types – in glide beds, 66 percent of the substrate is fines, and 20 percent is gravel, while in riffles only 28 percent of the substrate is fines, and 42 percent is gravel. The high percentage of gravel, especially in the riffles, is encouraging, because salmonid fish need clean gravel to spawn in. However, excessive fines in the spawning gravels can be detrimental to eggs incubating in the gravel, which need water flow through the gravel to bring in fresh oxygen. The Washington Department of Fish and Wildlife (WDFW) Water Crossing Design Guidelines (Bernard et. al 2013) recommend limiting fines in spawning material to no more than 10 percent. With nearly three times the concentration of fines in the riffles of the Greater Kelsey Creek Watershed, fines may limit spawning success.

The subbasins within the Greater Kelsey Creek Watershed vary considerably in substrate composition, ranging from the Richards Creek Subbasin, with 74 percent fines, to the Kelsey Creek Subbasin with 24 percent fines. Looking only at riffles, fines are somewhat less prevalent in the Richards Creek Subbasin (58 percent) but essentially the same in Kelsey Creek Subbasin (23 percent). The Valley, Goff and Richards Creek subbasins all have over 30 percent fines in the riffle habitat, and all of the subbasins have more than 20 percent fines in the riffles. Overall, the sediment composition in the Greater Kelsey Creek Watershed is too rich in fines to be ideal for salmonid spawning.

Figure 42 shows the substrate composition of rifle habitat for the different Greater Kelsey Creek subbasins, determined by visual observation.

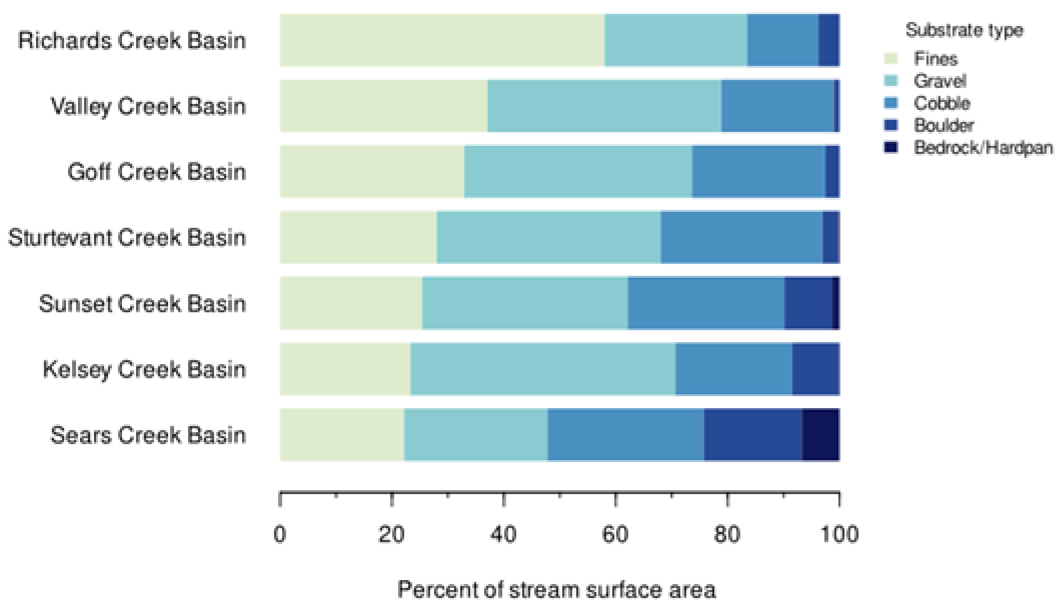


Figure 42. Substrate Composition of Riffle Habitat in the Subbasins of the Greater Kelsey Creek Watershed

2.3.5.5 Streambank Conditions

Streambank armoring is prevalent in the Greater Kelsey Creek Watershed, with 20 percent of the streambanks surveyed being armored, the highest percentage in the City. Rock and riprap combine to make up over 80 percent of the armoring in the Greater Kelsey Creek Watershed, with logs, root wads and bioengineering only accounting for 5 percent of the armoring (the remaining being concrete (5 percent), gabion baskets (2 percent) and other (4 percent)). The Sears, Goff and Sturtevant Creek subbasins are 32 percent or more armored, followed closely by the Kelsey Creek Subbasin at 28 percent armored. The Richards and Valley Creek subbasins are tied for least armoring at 7 percent, while the Sunset Creek Subbasin has 11 percent armoring.

Along with the most armoring, the Greater Kelsey Creek Watershed has the least bank erosion in the City, with just 11 percent of banks being eroded and 7 percent being undercut. Most of this erosion is along low banks (i.e. toe scour). Somewhat surprisingly, the armoring and bank erosion are not always correlated. The Sturtevant Creek Subbasin, among the most armored subbasins, and the most urbanized and confined, has the highest proportion of bank erosion, at 24 percent. By contrast, the Goff Creek Subbasin, with slightly more armoring, has the least erosion, at 3 percent. The rest range from 8 percent to 16 percent.

Streambank erosion in the Watershed is generally low scour with undercutting banks at the water line, often associated with flashy flows. This often results in stable undercut banks that provide good fish habitat. Significant areas of downcutting were also observed, such as in the Sunset Creek Ravine, where erosion extends 10 feet or more up the bank and is associated with significant mass wasting and hillslope failures. The Sturtevant Creek Subbasin also has reaches where significant downcutting has occurred. Such extensive downcutting and bank failure is often a major source of fine sediment in streams.

Figure 43 shows the proportion of armored streambank for the streams in the Greater Kelsey Creek Watershed. Figure 44 shows the percent of each stream within the Greater Kelsey Creek Watershed that is experiencing erosion.

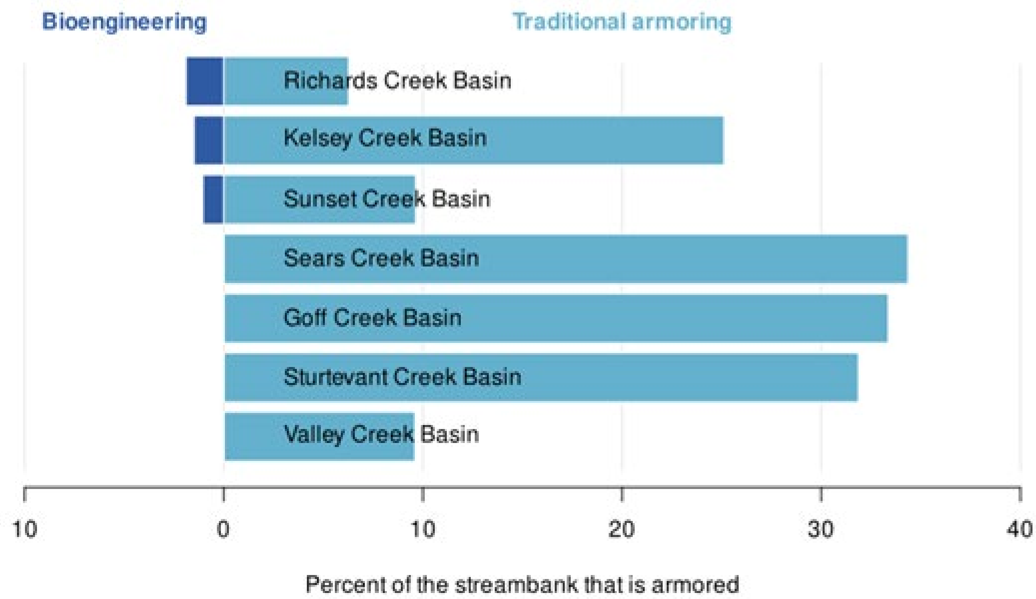


Figure 43. Diverging Bar Chart Showing the Proportion of Armored Streambank Using Traditional Materials (right) and Bioengineering (left) for the streams in the Greater Kelsey Creek Watershed

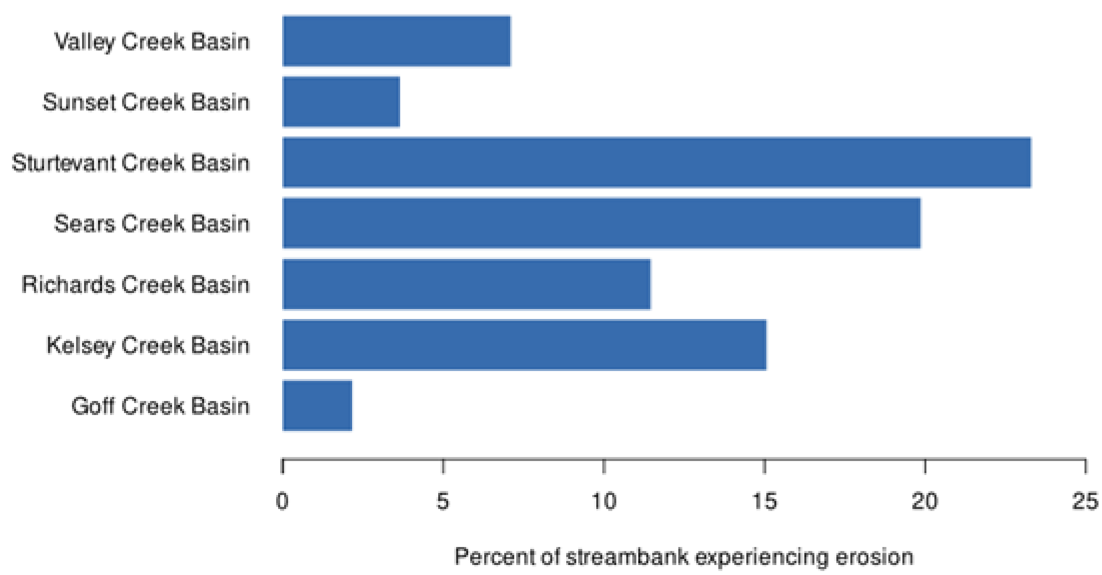


Figure 44. Percentage of Each Stream in the Greater Kelsey Creek Watershed that is Experiencing Erosion.

2.3.5.6 Fish Habitat and Passage Barriers

Historically the Greater Kelsey Creek Watershed supported spawning Sockeye, Chinook, and Coho salmon. The number of returning spawners has dwindled dramatically in the last 15 years (WDFW 2021a). The cause of this decline is certainly multifaceted, but degraded fish habitat and the presence of fish passage barriers likely play a key role. Additionally, water quality is a primary concern. In 2013 and 2014, surplus Coho Salmon adults that returned to the Issaquah Hatchery were transported and released into Kelsey Creek, but this effort was abandoned following very high rates of pre-spawn mortality presumably related to toxicity from stormwater runoff.

Fish habitat in the Greater Kelsey Creek Watershed ranges from very good to poor. Fish passage has been formally documented by WDFW (2021a) in the mainstem of Kelsey Creek, in addition to other undocumented barriers and potential impediments to fish passage, including weirs and habitat degradation associated with regional infrastructure. Additionally, beavers are active in most subbasins and their dams may impede fish passage during low flow periods. A total of 35 blockages to fish passage (19 partial blockages and 16 total blockages) have been identified by WDFW in the Greater Kelsey Creek Watershed. These are summarized by subbasin in Table 17 and shown in Figures 45 through 49. See Appendix D of this report for a complete inventory of the crossings documented by WDFW in the Watershed.

Fish habitat and passage barriers are briefly described for the nine subbasins of the Greater Kelsey Creek Watershed:

- Overall, the habitat character of **Mercer Slough** would be best described as lake or lacustrine habitat. There are no riffles or glides to characterize as with the other eight subbasins in the Watershed. No formal fish or habitat surveys have occurred in Mercer Slough, therefore this is a data gap. According to CH2M HILL (2011), the stream channel in Mercer Slough averages about 40 feet wide and likely less than 8 feet deep. Although the bottom could not be observed due to turbidity during their study, the authors assumed that the bottom is composed largely of organic material and silt. The upper end of Mercer Slough, just downstream of the Kelsey Creek outlet and fish ladder, may have some gravel and sand deposits from the upstream eight subbasins. Anecdotal accounts of water depth observed throughout Mercer Slough suggests that there are several locations that range from only half a foot to one foot deep during late summer (communication with City staff). Shallow water combined with lowering of the lake level in September of each year may create an impediment to fish passage, especially for the larger Chinook Salmon that were historically common throughout the Watershed. Native and non-native aquatic vegetation are found throughout Mercer Slough and may be contributing to the sediment deposition and seasonal fish passage impediments observed here. WDFW did not identify any barriers to fish passage throughout Mercer Slough itself but did identify one partial barrier and three complete barriers on small unnamed tributaries that enter the slough from the east (WDFW 2021b).
- **Kelsey Creek** provides some of the best fish habitat found in the City. Ample pool habitat likely contributes to these successful fish populations. During OSCA surveys, fish were observed in nearly half (45 percent) of all pool habitat units. Salmon spawning habitat in the mainstem of Kelsey Creek extends upstream to a small gravel patch just east of 148th Avenue NE. There are several physical obstructions in the mainstem of Kelsey Creek that may impede fish migration. WDFW has documented three partial and one complete fish passage barrier (WDFW 2021c). The partial barriers include the City-owned culvert under 121st Avenue SE, a series of City-owned weirs on the Glendale Country Club property, and a private culvert upstream from 140th Avenue NE. The complete barrier is the City-owned culvert under the westbound lanes of Lake Hills Connector, which poses a summer low flow barrier. Barrier correction is in the planning stages for most of these structures.
- Good spawning gravels are present throughout the surveyed reaches in **Sturtevant Creek**, and the pool habitat could support resident fish. The notable lack of fish in these areas may indicate that water quality and flashy streamflow pose the biggest challenge to resident fishes. There are several physical barriers to fish migration in Sturtevant Creek. Fish passage between I-405 and Lake Bellevue is highly fragmented. WDFW (2021c) identified three partial barriers and one complete barrier on the

mainstem channel. The downstream-most partial barrier is the I-405 culvert, which is followed by a piped stream conveyance that extends for two-tenths of a mile. The complete fish passage barrier is located south of NE 2nd Place and consists of an approximately 4-foot hydraulic drop at a culvert outlet. Upstream from there is a partial barrier at the City-owned culvert under NE 2nd Place, which is downstream of a short section of stream restored by WSDOT. An undocumented fish passage barrier consisting of numerous privately-owned sections of piped conveyance extends for three-tenths of a mile from just south of the NE 6th Street and Sound Transit light rail crossing of I-405 to the new Lake Bellevue outlet channel restoration.

- The deep water, good ratio of riffle to pool habitat, and abundant wetlands make **Richards Creek** excellent rearing habitat for salmonids. Unfortunately, the high proportion of fine sediment in the streambed substrate makes most of Richards Creek unsuitable for spawning. There are a few known barriers to fish passage in Richards Creek. WDFW (2021c) has documented two partial barriers and one complete barrier. The complete barrier is City-owned and includes storm conveyance upstream of Factoria Boulevard. There is only a short portion of ditched open channel upstream of this extensive storm conveyance. Additionally, there are numerous beaver dams that could impede fish movement. However, at the time of the OSCA surveys, only one dam had created a hydraulic drop of greater than 1 foot, and many were partially breached. East Creek has not been assessed by WDFW for fish passage barriers.
- With a healthy riparian buffer and canopy cover upstream of I-90 and relatively low proportion of fines in the streambed substrate, **Sunset Creek** has the potential to provide quality fish habitat. However, there are several notable challenges. The stream is currently lacking in pool habitat as well as the LWM necessary to create and maintain pools in this higher gradient stream. Additionally, the channel is quite shallow. Adult trout and Coho Salmon generally require a minimum depth of 0.4 and 0.6 feet, respectively (Thompson 1972). However, riffle habitat in Sunset Creek has a median representative depth of only 0.1 to 0.2 feet and a median maximum depth ranging from 0.3 to 0.5 feet. At present, this is likely insufficient to sustain fish populations. Low water levels may be the result of a high-flow bypass that has been known to cause portions of the downstream reaches to dry up during summer low flow periods. Additionally, there are numerous barriers to fish migration. WDFW (2021c) has documented one partial barrier and six complete barriers (not including a natural barrier waterfall). One of the complete barriers, the I-90 culvert, is currently in final design and scheduled to be replaced by the Washington Department of Transportation with several bridges and a roughened channel. This will reconnect upper Sunset Creek with lower Sunset and Richards Creeks where there is an abundance of slow water and wetland habitat that is ideal for the rearing of juvenile trout and Coho Salmon. If habitat could be improved in upper Sunset Creek, these reaches could provide spawning habitat; however, it would first be necessary to conduct a hydrology study on the impacts of removing the Sunset Creek high-flow bypass Additionally, the middle and upper portions of Sunset Creek have gradients that range from just over 5 percent to over 8.6 percent, respectively. The threshold of 5-7 percent is generally considered to be the maximum stream gradient tolerated by adult Coho Salmon, therefore it is unlikely that salmonid species historically present in this subbasin would return.
- Fish habitat is available throughout **West Tributary**, although during low flow conditions, water depths are relatively shallow and there is a lack of riparian cover. Abundant beaver ponds and wetlands provide high quality rearing habitat for juvenile salmonids, lamprey, and other native fish species while also providing good winter refugia from flashy urban streamflow. West Tributary has limited spawning habitat, primarily restricted to the area downstream of NE 8th Street, with riffles of suitably sized spawning gravels overlaid with fine sediment that may limit survival of eggs if spawning occurs. Coho Salmon have been documented spawning in these areas, and resident and adfluvial Cutthroat Trout regularly utilize habitat upstream to Bel-Red Road (Bellevue 2020). In 2005, Peamouth Minnow were observed spawning in lower West Tributary at Kelsey Creek Park (Bellevue 2010). There are three documented partial barriers to fish passage within West Tributary. All are City-owned and include NE 8th Street, Lower West Tributary Regional Detention Facility, and Goff Regional Detention Facility

(WDFW 2021c). Several other undocumented barriers or impediments to fish passage are located throughout the Subbasin, including a long culvert at Bel-Red Road that likely prevents fish passage to upper West Tributary. Resident fish surveys in the early 2000s found no fish populations in the upper wetland areas of West Tributary, but it is possible for this habitat to sustain fish and other aquatic life should downstream barriers be corrected. Water quality is a concern for fish and overall stream health in West Tributary. Beaver dams throughout the Subbasin may create seasonal or temporary impediments to fish passage but were not considered to be barriers at the time of the 2016 habitat assessment.

- Fish habitat is limited in **Goff Creek**, particularly due to the lack of pools, lack of undercut banks that create "edge" habitat, and higher levels of fine streambed substrate. During the OSCA surveys, a small number of juvenile salmonids, presumably Cutthroat Trout, were observed in lower Goff Creek, downstream of Bel-Red Road. A lack of stream habitat complexity including pools and LWM, coupled with impacts from urban development including channel modifications, loss of riparian vegetation, and stormwater inputs, have likely all contributed to the loss of fish populations in this stream. Instream and riparian conditions improve in upper Goff Creek, north of SR 520, yet the presence of a high-flow bypass may impact sediment transport, LWM recruitment, and the safety and passage of fish. There are numerous migratory fish barriers in Goff Creek. WDFW has identified six partial barriers and seven complete barriers (WDFW 2021c). Additionally, there are numerous weirs that may impede fish migration but have not been formally surveyed as barriers.
- **Valley Creek**, especially upstream of NE 24th Street, offers surprisingly good fish habitat for a small urban stream. A healthy riparian buffer, few stormwater outfalls, and the wetland area in Reach 7 all contribute to presumably good water quality and fish habitat in middle to upper Valley Creek. During OSCA surveys, trout were observed in Reaches 6 and 7 in pool, riffle, and glide habitats. Fish were most abundant in Reach 6 where pool habitat is more frequent and where undercut banks provide good refuge. Residents in Reaches 6 report that salmon previously spawned on their properties, but the fish abruptly stopped returning in the mid-2000s. This coincides with the time period when salmon returns declined precipitously in both the Greater Kelsey Creek Watershed and the City as a whole, although downstream fish passage barriers could be a contributing factor. Channel depth may be a limiting factor for fish habitat and migration during the summer low flow period. Adult trout and Coho Salmon generally require a minimum depth of 0.4 and 0.6 ft, respectively (Thompson 1972). With a median representative depth of 0.4 ft in fast-water habitat and a shortage of pool habitat, Reaches 6 and 7 are barely suitable for migrating adult Pacific salmon. There are several potential fish passage barriers in Valley Creek that may be contributing to the disappearance of spawning salmon in this Subbasin. WDFW has identified one partial barrier (WDFW 2021c). Many undocumented barriers are on private property and were observed during the OSCA surveys but have not been formally documented in the WDFW database at this time. These barriers are primarily private road crossings (culverts or bridges) that potentially do not comply with current fish passage standards. The surveyed reaches of Valley Creek have at least 20 culverts or bridges for an average of 15.2 crossings per mile, the highest such density observed in the Greater Kelsey Creek Watershed. Additionally, a privately-owned dam with a fish ladder exists in the upper portion of Reach 6 and should be officially assessed by WDFW. This private facility presents an eligible opportunity for grant funding to restore unimpeded fish passage and enhance instream conditions through the upper portion of the reach.
- **Sears Creek** has the potential to provide fish habitat, although no fish were observed during the OSCA surveys. Streambed substrate in the lower reaches is suitable for spawning salmon and trout. The healthy riparian canopy and presence of undercut banks makes Reach 3 the most attractive fish habitat. However, the Sears Creek Subbasin drains a very urban area with a high percentage of impervious surfaces. Water quality may be a limiting factor for fish habitat in this stream, but this is currently a data gap. There are no formally documented fish passage barriers in Sears Creek (WDFW 2021c). However, fish passage may be impeded by several City-owned culverts for driveways in Reach

1 and the piped conveyances of Reaches 2, 4, and 6. The Reach 4 pipe is currently the only culvert that forms a hydraulic drop, which is slightly less than 1 foot in height.

Table 17. Partial and Complete Blockages to Fish Passage

Subbasin	Partial Fish Passage Barrier	Complete Fish Passage Barrier	Total Barriers (Partial or Complete) Documented by WDFW
Mercer Slough	1	3	4
Kelsey Creek	3	1	4
Sturtevant Creek	4	1	5
Richards Creek	2	1	3
Sunset Creek	1	6	7
West Tributary	3	0	3
Goff Creek	6	7	13
Valley Creek	1	0	1
Sears Creek	0	2	2
Greater Kelsey Creek Watershed, Total	21	21	42

Source: WDFW 2021c

Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Highway (City of Bellevue 2020)

SEGMENTID

- Reach 74_01, 75_01, 75_04, 75_07
- Reach 74_02, 75_02, 75_05
- Reach 74_03, 75_03, 75_06

- OSCA observed knotweed location (City of Bellevue 2020)

Fish Passage Barrier (WDFW 2020)

- Partial Fish Passage Barrier
- Total Fish Passage Barrier

Note: Washington Department of Fish and Wildlife (WDFW), Benthic Index of Biotic Integrity (B-IBI), Open Stream Conditions Assessment Database (OSCA).
Fish Passage Barrier WDFW Retrieved 20210224.

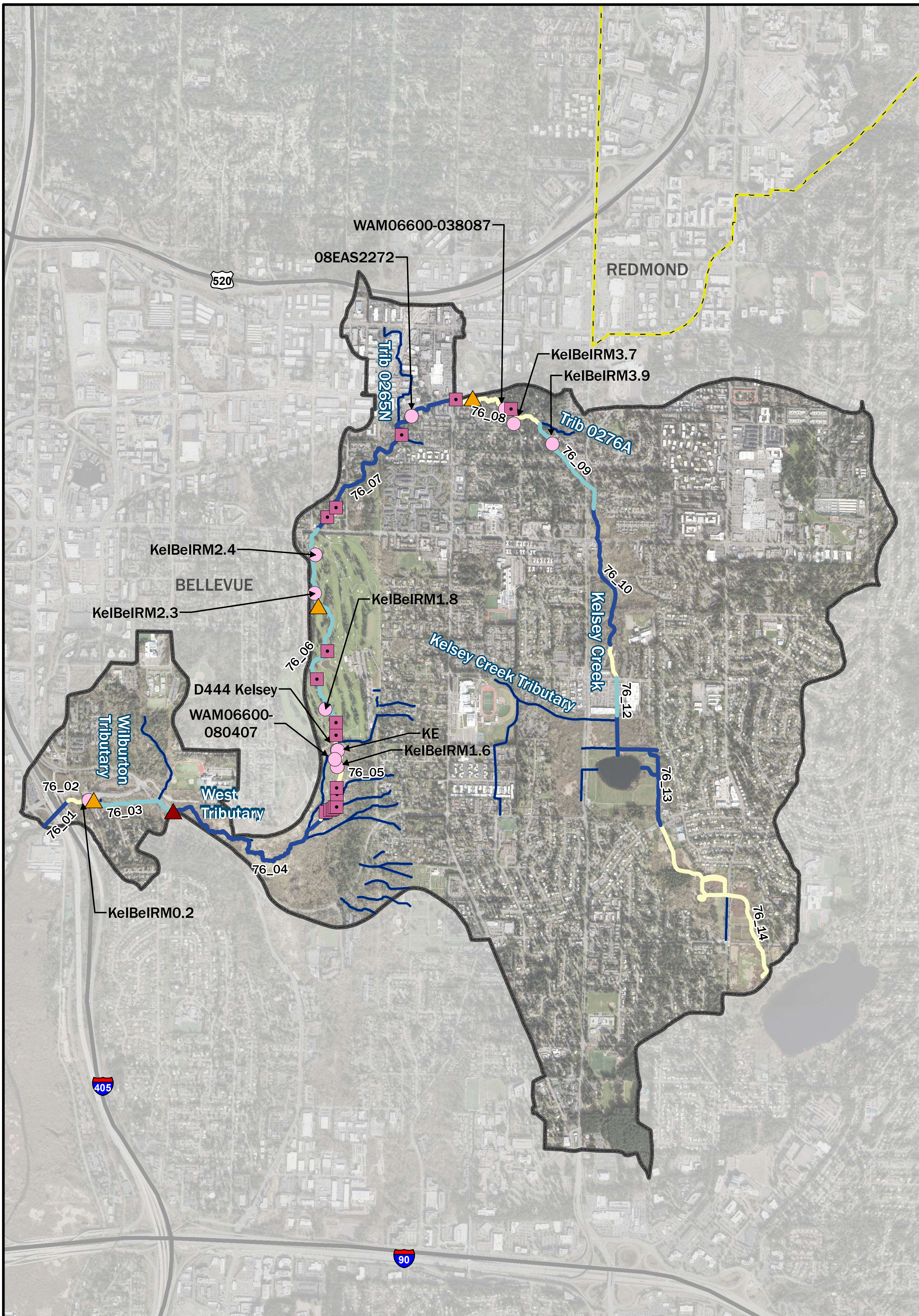
Figure 45.
Mercer Slough and Sturtevant Creek Subbasins Fish Passage Barrier sampling locations.

N

0 700 1,400 2,800 Feet

Jacobs HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_StreamEcoCondi_SturMercer_.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Stream (City of Bellevue 2020)
- Highway (City of Bellevue 2020)
- B-IBI Sample Location (Puget Sound Benthos Database 2021)
- OSCA observed knotweed location (City of Bellevue 2020)

Fish Passage Barrier (WDFW 2020)

- Partial Fish Passage Barrier
- Total Fish Passage Barrier

Approximate Stream Reaches

- Reaches 76_01, 76_04, 76_07, 76_10, 76_13
- Reaches 76_02, 76_05, 76_08, 76_11, 76_14
- Reaches 76_03, 76_06, 76_09, 76_12

Note: Washington Department of Fish and Wildlife (WDFW), Benthic Index of Biotic Integrity (B-IBI), Open Stream Conditions Assessment Database (OSCA). Fish Passage Barrier WDFW Retrieved 20210224.

Figure 46. Kelsey Creek Subbasin Fish Passage Barriers and B-IBI sampling locations.

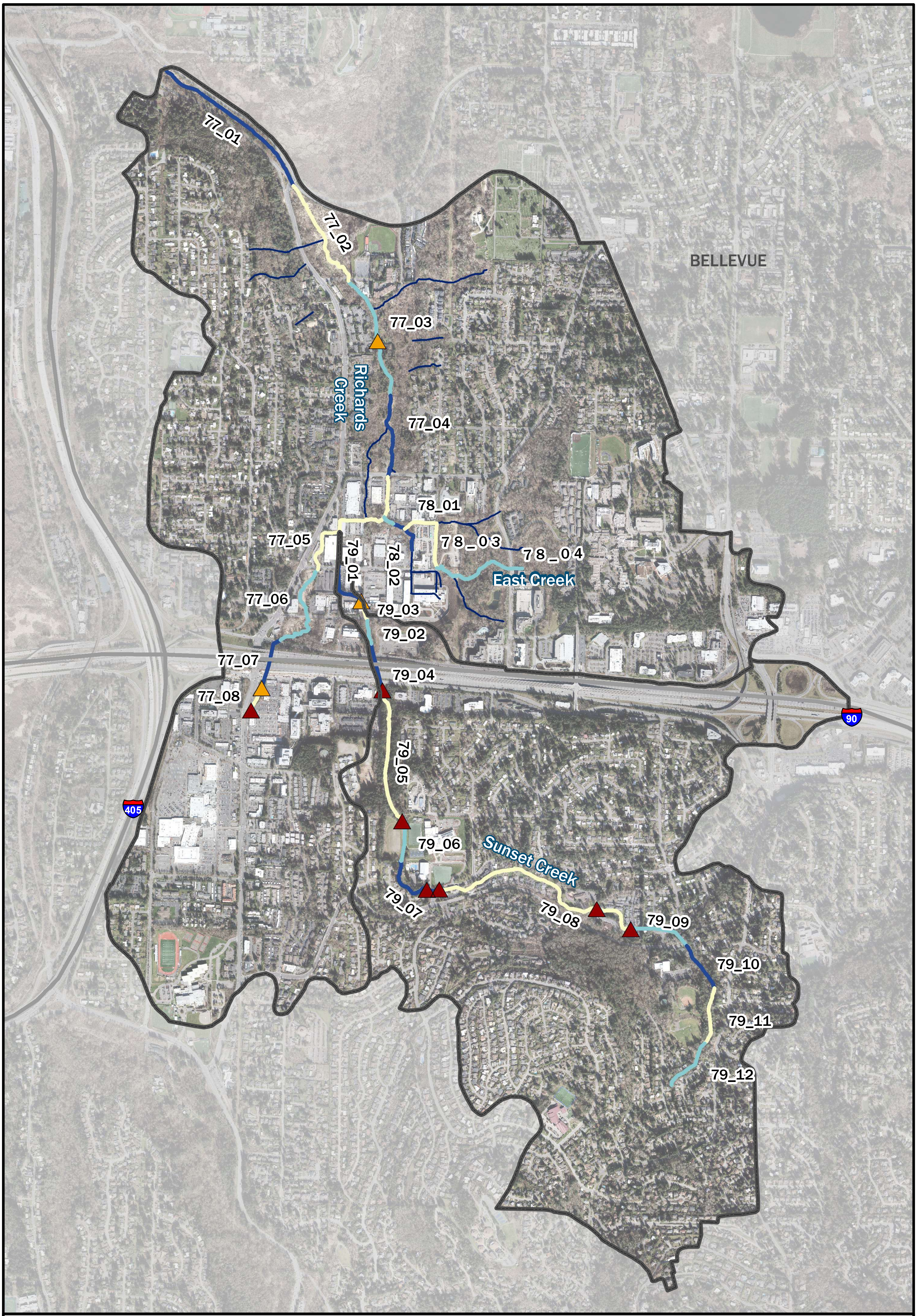
N

0 875 1,750 3,500 Feet

Jacobs

HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_StreamEcoCondi_Kelsey.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Highway (City of Bellevue 2020)
- Stream (City of Bellevue 2020)

Fish Passage Barrier (WDFW 2020)

- Partial Fish Passage Barrier
- Total Fish Passage Barrier

Approximate Stream Reaches

- Reach 77_01, 77_04, 77_07, 78_02, 79_01, 79_04, 79_07, 79_10
- Reach 77_02, 77_05, 77_08, 78_03, 79_02, 79_05, 79_08, 79_11
- Reach 77_03, 77_06, 78_01, 78_04, 79_03, 79_06, 79_19, 79_12

Note: Washington Department of Fish and Wildlife (WDFW), Benthic Index of Biotic Integrity (B-IBI), Open Stream Conditions Assessment Database (OSCA). Fish Passage Barrier WDFW Retrieved 20210224.

Figure 47. Richards Creek and Sunset Creek Subbasins Fish Passage Barrier sampling locations.

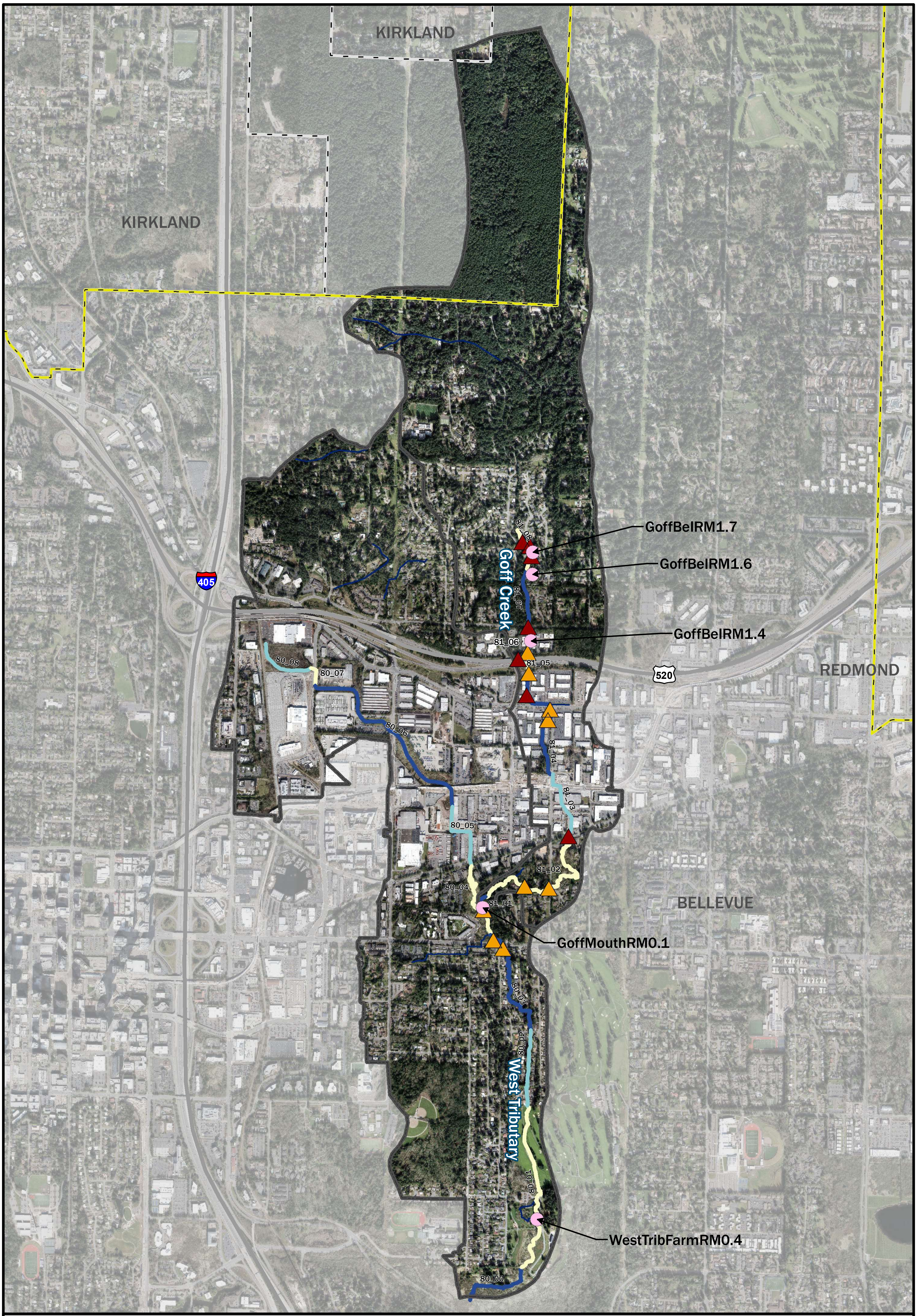
N

0 625 1,250 2,500 Feet

Jacobs

HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_StreamEcoCondi_Sunset_Valley.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Highway (City of Bellevue 2020)
- Stream (City of Bellevue 2020)
- B-IBI sample location

Fish Passage Barrier (WDFW 2020)

- Partial Fish Passage Barrier
- Total Fish Passage Barrier

Approximate Stream Reaches

- Reaches 80_00, 80_03, 80_06, 81_01, 81_04, 81_07
- Reaches 80_01, 80_04, 80_07, 81_02, 81_05, 81_08
- Reaches 80_02, 80_05, 80_08, 81_03, 81_06,

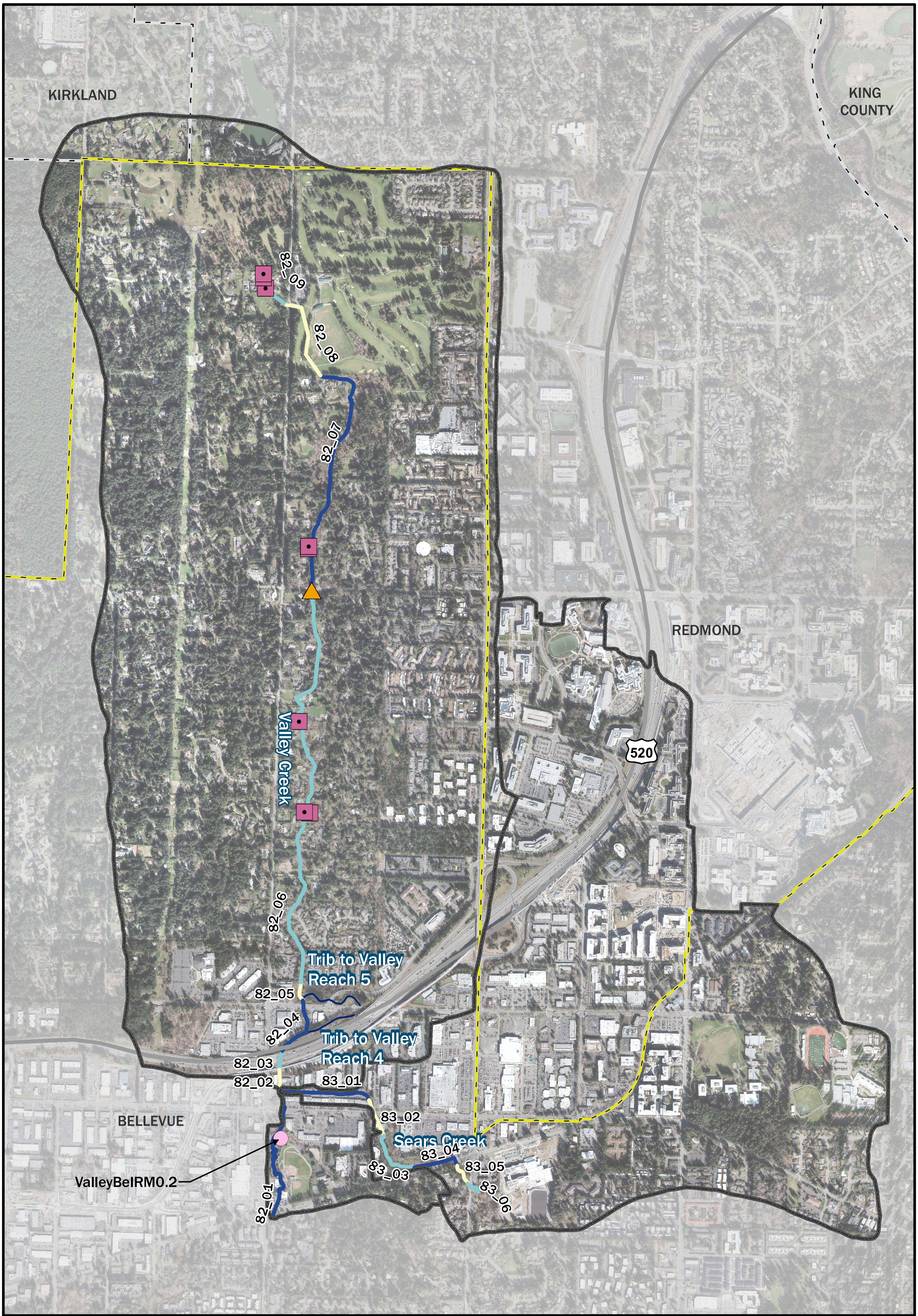
Note: Washington Department of Fish and Wildlife (WDFW), Benthic Index of Biotic Integrity (B-IBI), Open Stream Conditions Assessment Database (OSCA). Fish Passage Barrier WDFW Retrieved 20210224.

Figure 48. West Tributary and Goff Creek Subbasins Fish Passage Barriers and B-IBI sampling locations.

0 750 1,500 3,000 Feet

Jacobs HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_StreamEcoCondi_GoffTrib_.mxd



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Highway (City of Bellevue 2020)
- Stream (City of Bellevue 2020)
- B-IBI Sample Location (Puget Sound Benthos Database 2021)
- OSCA observed knotweed location (City of Bellevue 2020)

Fish Passage Barrier (WDFW 2020)

- Partial Fish Passage Barrier

Approximate Stream Reaches

- Reach 82_01, 82_04, 82_07, 83_01, 83_04
- Reach 82_02, 82_05, 82_08, 83_02, 83_05
- Reach 82_03, 82_06, 82_09, 83_03, 83_06

Note: Washington Department of Fish and Wildlife (WDFW), Benthic Index of Biotic Integrity (B-IBI), Open Stream Conditions Assessment Database (OSCA). Fish Passage Barrier WDFW Retrieved 20210224.

Figure 49. Valley Creek and Sears Creek Subbasins Fish Passage Barriers and B-IBI sampling locations.

N

0 550 1,100 2,200 Feet

City of Bellevue Washington — Jacobs — HERRERA

K:\Projects\Y2015\15-06160-011\Project\Report\KelseyCreek\FigureX_StreamEcoCondi_Sunset_Valley.mxd

2.3.6 Aquatic Species

The Kelsey Creek riparian corridor is designated as a priority habitat by WDFW and identified as a biodiversity area and corridor, including freshwater emergent, scrub-shrub, and forested wetlands (WDFW 2021d). Aquatic species within the Greater Kelsey Creek Watershed are described herein under separate subsections for fish species, invasive species, and benthic macroinvertebrates.

2.3.6.1 Fish Species

Historically, Kelsey Creek has been one of the most important streams in the City for salmon, as it has provided spawning and rearing habitat for a larger number of anadromous and migratory salmonids and other native fish species (Watershed Company 2008). Priority fish species within Kelsey Creek, as designated by WDFW, include Chinook, Coho, and Sockeye salmon and resident Cutthroat Trout (WDFW 2021d). Chinook and Coho salmon are a City of Bellevue Species of Local Importance, per Bellevue Land Use Code 20.25H.150A. Additionally, our local Chinook Salmon population is listed as threatened by the Endangered Species Act (ESA).

Salmonid species such as Chinook Salmon (*Oncorhynchus tshawytscha*), Sockeye Salmon (*Oncorhynchus nerka*), Coho Salmon, Cutthroat Trout (*Oncorhynchus clarkii*), and steelhead (the anadromous form of Rainbow Trout(*Oncorhynchus mykiss*), as well as Peamouth Minnow (*Mylocheilus caurinus*), return to Kelsey Creek from Lake Washington to spawn, via the Mercer Slough (Bellevue 2010).

The City has monitored the mainstem of Kelsey Creek, West Tributary, and lower Richards Creek for salmonid activity since 1999 via professional biologist spawning ground surveys, under contract with private consultants, and WDFW biologists who also monitor salmon returns throughout the Lake Washington Basin (WDFW 2021a). Additionally, observations made by the Salmon Watcher Program from 1996 to 2015 and those made by the City of Bellevue's Stream Team (which continued independently after the dissolution of the Salmon Watcher Program), help support an understanding of historical and current fish use in the Watershed (King County 2018, Bellevue 2021).

Within the Greater Kelsey Creek Watershed, variable salmon returns have been observed from 1999 to 2020, with relatively low returns within the past decade. These trends are similar to those seen throughout the Greater Puget Sound Region and within the Lake Washington Watershed, which contains highly urbanized freshwater systems (WDFW 2021a). Survey years that documented relatively high returns (i.e., between 2004 and 2007, 2013, 2014, and 2019) were influenced release of hatchery fish by the Issaquah Fish Hatchery. Other impacts to salmon spawning and returns within the Greater Kelsey Creek Watershed can be attributed to individual subbasin characteristics, such as physical barriers to adult migration and water quality impairments. Table 18 includes a summary of professional salmon survey results for Kelsey Creek from 1999 to 2020.

Based on periodic City-led electrofishing surveys since 1983 and salmon spawning surveys efforts since 1999, native species (in addition to the aforementioned salmon species) within the Kelsey Creek Subbasin include Cutthroat Trout, Longnose and Speckled Dace (*Rhyinichthys spp.*), Western Brook Lamprey (*Lampetra richardsom*), Sculpin (*Cottus spp.*), Three-spine Stickleback (*Gasterosteus aculeatus*), Black and White Crappie (*Pomoxis spp*.), Signal Crayfish (*Pacifasticus leniusculus*), and Largescale Sucker (*Castostomus macrocheilus*) (Hart Crowser 2014, Hart Crowser 2016, Hart Crowser 2017, Bellevue 2010). Electrofishing efforts from 2014 to 2017 revealed that non-native species including Pumpkinseed (*Lepomis gibbosus*) and Bluegill (*Lepomis macrochirus*) were found in low abundance (Hart Crowser 2014, Hart Crowser 2016, Hart Crowser 2017, Bellevue 2010). Other non-native species, such as sunfish and bass (family Centrarchidae) and Carp (*Cyprinus carpio*), have not been recorded since 2010 (Hart Crowser 2017).

As shown in Table 18, salmon returns over the last decade have been very low compared to the previous decade and historic salmon returns. This declining trend has also been observed in many other streams throughout the Lake Washington Basin.

The developed nature of the Greater Kelsey Creek Watershed impacts hydrology, water quality, and habitat (aquatic, riparian, and terrestrial) availability throughout the Watershed. Professional salmon spawning survey observations note the importance of maintaining and restoring riparian corridors throughout the Greater Kelsey Creek Watershed in order to sustain fish utilization. The majority (86 percent) of the Kelsey Creek Subbasin is developed, with some forested areas (12 percent), and limited scrub (<1 percent), wetland (<2 percent), and open water (<1 percent) land use (King County 2016). An assessment of the impact of increased development on hydrology was conducted by the University of Washington, which revealed that while the monthly average volume of streamflow had increased slightly with development, storm peaks increased nearly two to three times over the same historical period (Richey et al 1981). The effect of urbanization on storm peak streamflow led to the operation of six regional, in-stream detention facilities within the City to manage storm events (King County 2016).

The 303(d)-list, which categorizes state impaired and threatened waters, indicates that the lower reaches of the Kelsey Creek and Mercer Slough subbasins are Category 5 sites (having impaired water quality requiring improvement) due to temperatures, bacteria levels, dissolved oxygen concentrations, pH levels, and bioassessments that did not meet water quality standards for Washington State (WAC 173-201A). Kelsey Creek's location and impaired stream health contribute to potential spawning stresses including habitat limitations (i.e., limited gravel quantity and quality, as well as inadequate vegetative cover), hatchery interactions, low streamflow, and high temperatures in the early (late summer) spawning season. Additional impacts on spawning and juvenile rearing success related to urbanization include human infrastructure (such as artificial light and fish passage barriers) and human harassment/disturbance.

Table 18. Summary of Salmon Survey Results for the Greater Kelsey Creek Watershed from 1999 to 2020

Year	Chinook Salmon (*Oncorhynchus tshawytscha*)			Sockeye Salmon (*Oncorhynchus nerka*),		Coho Salmon (*Oncorhynchus kisutch)*		
	Redds	Live Fish	Carcasses	Live Fish	Carcasses	Redds	Live Fish	Carcasses
1999	76	111	117	0	0	0	0	0
2000	1	17	13	207	103	0	18	13
2001	4	9	0	46	10	3	12	7
2002	5	16	12	23	6	0	0	0
2003	0	1	6	1	0	8	14	5
2004	17	20	88	12	6	0	1	0
2005	14	27	37	3	0	1	1	2
2006	90	168	220	430	162	2	2	2
2007	77	221	155	14	5	8	5	9
2008	8	25	38	0	1	12	8	0
2009	5	11	15	4	0	6	3	0
2010	0	1	1	6	0	0	0	0

Year	Chinook Salmon (*Oncorhynchus tshawytscha*)			Sockeye Salmon (*Oncorhynchus nerka*),		Coho Salmon (*Oncorhynchus kisutch)*		
	Redds	**Live Fish**	**Carcasses**	**Live Fish**	**Carcasses**	**Redds**	**Live Fish**	**Carcasses**
2011	0	0	1	1	1	0	0	0
2012	0	0	0	0	0	9	30	2
2013	0	1	1	0	0	123*	294*	261*
2014	0	0	0	0	0	0*	138*	91*
2015	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0
2017	2	13	10	0	0	22	0	0
2018	0	0	0	0	0	4	0	0
2019	0	0	0	0	0	5	1	0
2020	0	0	0	0	0	3	0	0

* Years when returned Coho Salmon adults were released from the Issaquah Fish Hatchery.

Data Source: WDFW 2021a

Note that only the Kelsey Creek, West Tributary, and Richards Creek subbasins were surveyed as part of these efforts and therefore only data from these subbasins is included in this table

Peamouth Minnow (*Mylocheilus caurinus*) are a ubiquitous species, native to Lake Washington, but of particular interest in the Kelsey Creek Subbasin. Peamouth live most of their lives in Lake Washington, returning to small streams (such as Kelsey Creek) and lakeshores to spawn. Though Peamouth Minnow spawning in the Lake Washington basin is not well documented, it appears that this species spawns along the lakeshore on gravelly beaches and in tributaries with suitable gravel (Bellevue 2011a). Peamouth Minnow have been observed spawning one to five times each year between April and June. Such spawning events involve thousands of Peamouth Minnow, and each event generally lasts 24 to 48 hours (Bellevue 2011a). Within Kelsey Creek, spawning events have been observed near the Wilburton Railroad Trestle in lower Kelsey Creek and rarely observed within the upper reaches of Kelsey Creek (Bellevue 2011a). Peamouth Minnow are not considered a priority fish species because it is not listed under the ESA and is not identified by the City as a species of local importance.

Information on priority fish species in the Greater Kelsey Creek Watershed is provided below.

Chinook Salmon (*Oncorhynchus tshawytscha*)

The Puget Sound Chinook Salmon Evolutionarily Significant Unit (ESU) has been listed as threatened by the National Marine Fisheries Service (NMFS) under the ESA. Chinook Salmon within the Lake Washington Basin are composed of fall-run Chinook Salmon and the population present within Greater Kelsey Creek Watershed is the Sammamish population (as opposed to the Cedar River population). Migration of adults occurs from June through September, with spawning in lower reaches of Lake Washington streams occurring between August and November (Kerwin 2001). Peak Chinook Salmon spawning occurs between September and November (Kerwin 2001).

Based on survey efforts led by the City of Bellevue Environmental Monitoring Program, data from 1999 through 2020 indicate that few Chinook Salmon utilize the Greater Kelsey Creek Watershed (WDFW

2021a). When present, Chinook Salmon are primarily observed spawning in the Kelsey Creek Subbasin. Adult Chinook Salmon migration within the Kelsey Creek Subbasin starts in early September, with spawning activities running from early October to mid-November (WDFW 2021a). The lack of Chinook Salmon spawning activity since 2007 in the Greater Kelsey Creek Watershed is likely due to lower overall Lake Washington Basin returns, habitat conditions (including altered flow and water quality), and beaver activity (which is detrimental in this case because of lower Kelsey Creek's low gradient and urban flashy streamflow) (WDFW 2021a). Fish passage barriers, including undersized or perched culverts, low-flow barriers, sediment deposition, or temporary passage impediments (i.e., beaver dams or aquatic vegetation) may be contributing to the decline of Chinook Salmon within the Watershed.

According to the *Cedar/Sammamish Watershed (WRIA 8) Chinook Salmon Conservation Plan*, *10-Year Update*, Kelsey Creek is classified as a Tier 2 area or second priority habitat for protection and restoration because it is used less frequently by Chinook Salmon for spawning but contributes to the overall spatial diversity of salmon populations within Water Resource Inventory Area (WRIA) 8 (Lake Washington/Cedar/Sammamish Watershed Salmon Recovery Council 2017).

Sockeye Salmon (*Oncorhynchus nerka*)

Sockeye Salmon that use Kelsey Creek are part of the Baker River ESU but are not ESA-listed by NMFS. There are two populations of Sockeye Salmon within the Lake Washington Basin, those that spawn in the Sammamish River, and those that spawn in tributaries to the Sammamish River (which represents the larger of the two populations). In addition to the Sammamish and Cedar River populations of Sockeye Salmon, a hatchery program in the Cedar River releases hatchery fry into the Cedar River. Most adult Sockeye Salmon returning to Lake Washington are natural-origin fish from the Cedar River, with adult hatchery-origin Cedar River fish in second greatest abundance, while the Sammamish River tributary natural-origin fish represent a distant third in terms of abundance. WDFW has identified the Sammamish stock of Sockeye Salmon as "depressed" (Tetra Tech/KCM *et al*. 2006). Similar to Chinook Salmon, Sockeye Salmon adults migrate into Greater Kelsey Creek Watershed from early to mid-September and spawn from early October to mid-November (WDFW 2021a).

Based on City-led monitoring efforts between 1999 and 2020, no Sockeye Salmon were observed in the Kelsey Creek Subbasin, West Tributary Subbasin, or lower Richards Creek Subbasin in 2020. Within the last 12-year survey period (from 2008 to 2020), recordings of Sockeye Salmon in Greater Kelsey Creek Watershed have been consistently low or often zero (WDFW 2021a). However, significant numbers were seen in 2000 and 2006, which had counts of 207 and 230 live Sockeye Salmon, respectively.

Kokanee, a lake-bound form of Sockeye Salmon, have historically used Bellevue streams for spawning but have rarely been observed in tributaries to Lake Washington over the past decade. Growing regional interest in these fish have resulted in confirmed observations in other small Lake Washington tributaries including Swamp, McAleer, Lyon, and May Creeks (J. Bower, personal communication). There is little accessible information regarding the presence of kokanee within the Greater Kelsey Creek Watershed.

Coho Salmon (*Oncorhynchus kisutch*)

Coho Salmon found in the Greater Kelsey Creek Watershed are part of the Puget Sound/Strait of Georgia ESU and are listed as a "Species of Concern" under the Endangered Species Act by NMFS. WDFW has identified Coho Salmon in the Greater Kelsey Creek Watershed as part of the Lake Washington/Sammamish population, which is listed as "depressed" (Tetra Tech/KCM *et al*. 2006, R2 Resources Consultants 2016).

Throughout the Watershed, Coho Salmon migration and spawning timing occurs later than Chinook and Sockeye salmon, with adults migrating into the Greater Kelsey Creek Watershed around mid-October and spawning between mid-November and early-December (WDFW & NWIFC 2011). Compared to other salmonids in this Watershed, Coho Salmon possess the advantage of migrating into the system in mid to late October, when streamflow is greater, enabling them to more easily bypass physical barriers like dense aquatic vegetation in the Mercer Slough and the lower Kelsey Creek beaver wetland complex (WDFW & NWIFC 2011).

Coho Salmon redds are found throughout the Kelsey Creek Subbasin, with the majority being observed in mid to late December. The number of Coho Salmon spawning in Kelsey Creek has been historically low, except for in 2013 and 2014, when surplus adult hatchery Coho Salmon originating from the Issaquah Hatchery were released into the system to improve natural spawning and smolt production. This practice was discontinued after the 2014 spawning season due to exceptionally high mortality of the transplanted fish (see section 2.3.2 for water quality concerns). Coho Salmon observations subsequently dropped to previously recorded low levels (WDFW & NWIFC 2011). However, the actual number of Coho Salmon spawning in the Greater Kelsey Creek Watershed may be slightly higher than what the professional spawning ground surveys suggest, because documenting Coho Salmon spawning activity is difficult due to high streamflow and turbid viewing conditions during their spawning window (WDFW & NWIFC 2011). Additionally, the Coho Salmon spawning season overlaps with that of adfluvial and resident Cutthroat Trout that are abundant throughout the Watershed, thereby making it challenging to identify the redd to species.

Winter steelhead (*Oncorhynchus mykiss*)

Winter-run steelhead that use the Greater Kelsey Creek Watershed are part of the Puget Sound ESU and were ESA-listed as threatened by NMFS in 2007. WDFW identified steelhead in the Watershed as members of the Lake Washington stock, which is listed as “critical” (Tetra Tech/KCM *et al.* 2006). The Cedar/Sammamish Watershed in which the Greater Kelsey Creek Watershed is located has been categorized as “depressed” in terms of its winter steelhead population. Winter-run steelhead enter the Lake Washington basin in December and historically spawn within the City from late March through early June (Bellevue 2010).

Little is known about historic presence or habitat utilization by steelhead throughout the Watershed, though resident and migratory steelhead have been observed within several of the subbasins throughout the Greater Kelsey Creek Watershed, including the Mercer Slough Subbasin and Sunset Creek Subbasin (The Watershed Company 2009). Urbanization of the Lake Washington Basin has negatively impacted steelhead through loss of access to historic habitat, loss and degradation of side channel and floodplain habitat, loss of LWM, loss of pool habitat, degradation of riparian habitat, and loss of both summer and winter rearing habitat (WDFW & NWIFC 2011).

Cutthroat Trout (*Oncorhynchus clarkia*)

Cutthroat Trout found in the Greater Kelsey Creek Watershed are part of the Puget Sound ESU and are not an ESA-listed species under NMFS. Though professional spawning ground survey efforts in the Watershed do not extend through the duration for the Cutthroat Trout spawning period, small resident Cutthroat Trout inhabit much of the Greater Kelsey Creek Watershed year-round, with larger adfluvial individuals (those that live in Lake Washington and migrate seasonally into small streams for spawning) migrating into the Watershed during the winter months to spawn. Adfluvial migration begins in early-December, with spawning occurring in mid-December likely extending through the end of March (WDFW & NWIFC 2011).

Survey information collected in recent years provides evidence that the Greater Kelsey Creek Watershed supports a healthy Cutthroat Trout population. In 2013, the City conducted fish exclusion as part of a fish passage and habitat improvement project throughout 3,000 feet of the Kelsey Creek Subbasin adjacent to the Glendale Country Club. This effort revealed that Cutthroat Trout represented the most abundant species out of those observed (including lamprey, crayfish, sunfish, Rainbow Trout, Speckled Dace, and Three-Spined Stickleback), at a density of 2.8 per square meter (Wild Fish Conservancy Northwest 2021). Similarly, electrofishing results from the City's summer sampling efforts during the months of June and July 2014 showed that Cutthroat Trout were a dominant species at a sampling location in the Kelsey Creek Subbasin, in which juveniles, subadults, and adults were found (Hart Crowser 2014).

2.3.6.2 Invasive aquatic species

Invasive aquatic species are those that have been introduced to an environment outside of their native range. Some invasive aquatic species can cause environmental and economic harm, while the impact of other invasive aquatic species is lesser known (WDFW 2021b). Documented occurrences of invasive aquatic species within the City's waters include the New Zealand Mudsnail (NZMS; *Potamopyrgus antipodarum*) and Chinese Mystery Snail (CMS; *Cipangopaludina chinesis*). Other detrimental invasive species that could arrive at any time within the City waters include Zebra Mussels (*Dreissena polymorpha*) and the African Clawed Frog (*Xenopus laevis*).

New Zealand Mudsnail (*Potamopyrgus antipodarum*)

the first observance of this species in the Lake Washington Basin at Thornton Creek (Bellevue 2021). The City has monitored for the presence of NZMS in the Greater Kelsey Creek Watershed and throughout the City using environmental DNA sampling methods from 2014 to 2020 and assessed the diet and condition of native trout in the Kelsey Creek Subbasin to determine if NZMS are reducing the population size and/or health of the resident trout populations. Through this research, the City has determined that NZMS are being eaten by trout but have not yet seen a decrease in the number of fish, or their condition after five years of infestation (Bellevue 2021). NZMS are documented in the following subbasins: Kelsey Creek, Richards Creek, Sunset Creek, West Tributary, Goff Creek, and Valley Creek (Bellevue 2021).

NZMS reproduce rapidly by cloning, and in the process, crowd out and outcompete native invertebrates for food and habitat. In doing so, NZMS, which have little nutritional value, reduce native invertebrates that fish and other aquatic species feed on. While fish can consume NZMS, they are not an effective food source in comparison to other food sources (such as terrestrial and aquatic insects, fish, amphipods, crustaceans, and other invertebrates) due to their low nutritional value. In fact, NZMS can pass through the digestive tract of a fish without injury (WDFW 2021b). Diet monitoring initiated by the City in the Kelsey Creek Subbasin between 2014 and 2017 showed that a total of 42.5 percent of Cutthroat Trout fed upon NZMS in 2014, with comparatively lower levels of 8.2 percent and 9.6 percent in 2016 and 2017, respectively (Hart Crowser 2017). While there was a decline between 2014 and 2017 in percentage of Cutthroat Trout consuming NZMS, 2017 data revealed that fish that fed on NZMS had a higher proportion of NZMS in their stomachs than the proportion of NZMS in stream habitats (Hart Crowser 2017). This data demonstrates that ongoing monitoring is needed to determine the degree of NZMS infestation and predation on NZMS in the Kelsey Creek Subbasin, as well as how consumption effects fish health and populations throughout the Watershed (Hart Crowser 2017).

There is no effective method to remove NZMS from an ecosystem. Prevention will help mitigate the damaging impact of NZMS on uninfested streams. Preventative action includes keeping pets out of infested streams and lakes, scrubbing debris/mud off any materials that have come in contact with streams, lakes or mud, and draining stream or lake water collected in gear or equipment before leaving a site (Bellevue 2021). Through prevention, we can work together to mitigate the spread and harmful effects of the NZMS.

Chinese Mystery Snails (*Cipangopaludina chinesis*)

Chinese Mystery Snails (CMS) are a relatively large snail species which are commonly used in aquariums (USFWS 2011). It is likely that CMS were introduced to Washington State waters through the illegal release of aquarium pets (ANSC 2007). CMS can reach high densities, compete with native invertebrates for food and habitat resources, host parasites and carry diseases known to infect humans, clog water intake pipes, and interact with other invasives to negatively impact native species (USFWS 2018). According to the City of Bellevue, CMS have been documented at a very high density within Larsen Lake in the upper Kelsey Creek Subbasin. To prevent further infestation of CMS and other aquatic invasive species, aquarium waters and specimens should not be released into the wild and care should be taken to prevent the spread of these nonnative species through cleaning, draining, and drying boats and equipment between water bodies.

2.3.6.3 Benthic Macroinvertebrates

Benthic macroinvertebrates are aquatic animals without backbones that are visible to the naked eye, including insects, crustacea, worms, snails, and clams, that spend all or most of their lives living in or on the bottom of the streambed (King County 2002). Benthic macroinvertebrates are monitored because they are good indicators of the biological health of stream systems and play a crucial role in the stream ecosystem (Karr and Chu 1999). Since they complete most or all of their life cycle in the aquatic environment and they are relatively sedentary, benthic communities are reflective of the local sediment, water quality, hydrologic and habitat conditions (Booth *et al.* 2001). Hence, monitoring of macroinvertebrate populations provides a relatively inexpensive and powerful tool to assess short and long-term effects from the primary stressors of stream health identified in Figure 2.

B-IBI scores provide a measure of stream health that is derived from samples of benthic macroinvertebrates that are collected from the streambed. B-IBI scores are computed on a scale that ranges from 0 to 100 to indicate relative stream health as follows: 80 to 100 for “excellent”, 60 to 79 for “good”, 40 to 59 for “fair”, 20 to 39 for “poor”, and 0 to 20 for “very poor.” In a study of streams in the Puget Sound lowlands, May *et al.* (1997) showed B-IBI scores declined rapidly in early stages of watershed urbanization such that high B-IBI scores (greater than 60) were observed only at low levels of imperviousness (less than 5 to 10 percent). For reference, impervious surfaces occupy approximately 42 percent of the total basin area for the Greater Kelsey Creek Watershed. One drawback of the B-IBI is it does not identify the specific stressor responsible for the decline in stream health. Typically, a more detailed evaluation of the macroinvertebrate community assemblage or supplemental data collection for other chemical and/or physical parameters is required to make such inferences.

From 1998 to 2020, 77 macroinvertebrate samples were collected from the Greater Kelsey Creek Watershed by King County, the City, and the University of Washington (PSBD 2020) at 20 locations in the Greater Kelsey Creek Watershed (see Figures 45 through 49). Most of the samples (58) were collected from the Kelsey Creek Subbasin, 10 samples were collected from the Goff Creek Subbasin, 3 samples were collected from both the Sunset Creek and West Tributary Subbasins, 2 samples were collected from Valley Creek Subbasin, and 1 sample was collected from the Richards Creek Subbasin. Appendix E summarizes the available data from each sample by site and subbasin.

B-IBI scores from sites located on the Kelsey Creek mainstem, and streams within the Greater Kelsey Creek Watershed (including Richards Creek, Sunset Creek, West Tributary, Goff Creek, and Valley Creek), were aggregated over 23 years (1998 – 2020) to assess current stream health based on relatively recent macroinvertebrate sampling. As shown in Table 19, these data indicate stream health in the Kelsey Creek mainstem is generally “very poor”, with a median score of 9.25 (n=60). This is consistent with the overall “very poor” health for all streams monitored in the Greater Kelsey Creek Watershed (see Table 19). Data were available from one station (08EAS2272) on the mainstem of Kelsey Creek that spanned a 15-year period from 2005 to 2020 (Appendix E).

Table 19. Median B-IBI Scores Measured Over the Period from 1998 to 2020.

Subbasin	B-IBI Median Score (n=number of samples)	B-IBI Rating
Kelsey Creek	9.25 (n=58)	Very Poor
Richards Creek	15.3 (n=1)	Very Poor
Sunset Creek	1.4 (n=3)	Very Poor
West Tributary	14.6 (n=3)	Very Poor
Goff Creek	9.5 (n=10)	Very Poor
Valley Creek	6 (n=2)	Very Poor

Data Source: Kelsey Creek Watershed Benthic index of Biotic Integrity Scores (included as Appendix E)

In connection with Ecology's SAM program, data for computing B-IBI scores were collected from 104 sites in streams located in the Puget Lowland ecoregion in the summer of 2015; 45 of these sites were located outside the urban growth area (UGA) in more rural settings while 59 of these sites were located within the UGA in more urban settings. These data provide a good frame of reference for comparing the scores from the Greater Kelsey Creek Watershed to scores from other streams in the region. As reported in DeGasperi *et al.* (2018), the B-IBI scores for streams within the UGA showed a greater proportion of stream length in poor condition (82 percent) compared to streams outside of the UGA (30 percent). Median B-IBI scores for streams within and outside the UGA were 38.6 and 72.7, respectively. These data suggest that stream health in the Greater Kelsey Creek Watershed is degraded (Kelsey Creek Subbasin median score of 9.25), relative to comparable streams located within the UGA from this study.

3. Limiting Factors

The information presented in the previous sections was evaluated to identify potential factors limiting stream health in the Greater Kelsey Creek Watershed and discussed with City staff during working sessions on August 11th and August 18th, 2021 and a follow-up conversation on September 29th, 2021. The goal of these working sessions was to obtain input on potential limiting factors from City staff in departments overseeing resource management in the Greater Kelsey Creek Watershed and possessing institutional knowledge that is directly relevant to this question. The evaluation of potential limiting factors specifically focused on the "sources of stressor" elements from the conceptual model that describes the primary effects of urban runoff on stream health (Figure 50).

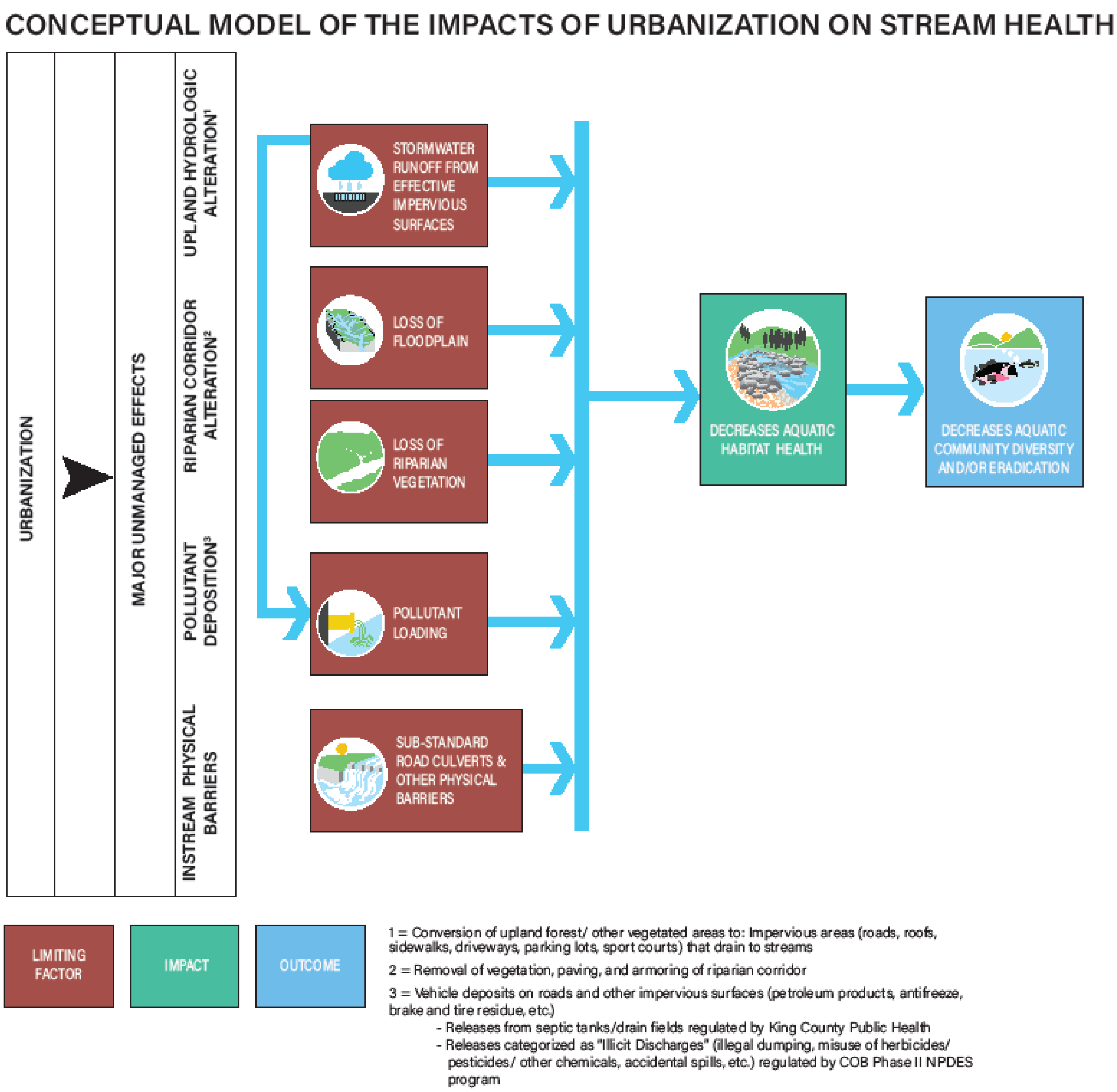


Figure 50. Source of Stressor Elements from the Conceptual Model.

These limiting factors discussions for the Greater Kelsey Creek Watershed must also acknowledge that the Greater Kelsey Creek Watershed is unique among City watersheds because it covers such a large portion of the City's land area and it has nine subbasins, each with its own unique set of characteristics and therefore its own unique limiting factors. As expected for an urbanized watershed, each subbasin in the Greater Kelsey Creek Watershed demonstrates symptoms of each limiting factor. The goal of this section is to identify and document the limiting factors that are most important for that subbasin. In future phases of the WMP, these limiting factors will be used to develop investments to promote ecological recovery and/or prevent continued degradation specific to each subbasin's unique needs.

Table 20 summarizes the limiting factors for each of the subbasins in the Greater Kelsey Creek Watershed. The rationale behind what's shown in Table 20 is provided below.

Table 20. Limiting Factors by Subbasin within the Greater Kelsey Creek Watershed

	Limiting Factors			
Subbasin	**Stormwater Runoff from Effective Impervious Surfaces**	**Loss of Floodplain and Riparian Function**	**Pollutant Loading**	**Road Culverts and Other Physical Barriers**
Mercer Slough	○		●	●
Kelsey	●		●	○
Sturtevant	●	●	●	○
Richards	●	○	●	
Sunset	●	○	●	○
West Tributary	●	○	●	
Goff	●	○	●	○
Valley	○		●	○
Sears	●	○	●	○

● = Identified as primary Limiting Factor(s) applicable across entire subbasin
○ = Identified as secondary Limiting Factor(s) (evidence points to specific location(s) in the subbasin where this limiting factor is driving existing conditions)

The evidence supporting the limiting factor designations for each subbasin is provided here, in decreasing order of importance for each subbasin:

Mercer Slough

- Pollutant Loading (evidence in support: 303d listings: Temperature, Bacteria; Sediment accumulation within Mercer Slough; receives direct discharges [no treatment] from I-90); pollutants from the other 8 subbasins enter the Slough.
- Road Culverts and Other Physical Barriers (evidence in support: sediment deposition limits water depth within Mercer Slough; invasive plant species confine the channel and exacerbate sedimentation issues in Mercer Slough), also, if fish have difficulty passing Mercer Slough, they cannot get to the other eight subbasins.
- Stormwater Runoff from Impervious Surfaces -Secondary-(evidence in support: influx of sediment moved downstream to Mercer Slough as a result of high velocity stormwater runoff; acknowledging

that the high-flows in this Mercer Slough Subbasin are the result of all upstream areas, rather than characteristics of this Subbasin in particular, which is why this limiting factor is identified as a secondary limiting factor; Note that this Subbasin's wetland habitat (with limited numbers of trees) impacts the overall riparian cover characterization of this Subbasin. Lack of canopy cover may not be problematic in the wetland reaches though may still be a problem in the non-wetland reaches.)

Kelsey Creek

- Pollutant Loading (evidence in support: 303d listings: Temperature, Bacteria, Dissolved Oxygen, pH, bioassessment; Water Quality Index (WQI) Scores: one location along Kelsey Creek (mainstem) that reflect water quality concerns for Sears, Valley, Goff, West Tributary, Sunset, and Richards subbasins, though Kelsey Creek Subbasin itself has the lowest portion of highway, industrial, and commercial land use; typically moderate with some years of high concern; Coho Salmon pre-spawn mortality)
- Stormwater Runoff from Impervious Surfaces (evidence in support: impervious surface is moderately high as compared to other Greater Kelsey Creek Watershed subbasins; 46 percent of subbasin was developed prior to 1975 (when no stormwater management was required); channel incision and streambank erosion (2nd highest in the Watershed); Note that this Subbasin's wetland habitat (with limited numbers of trees) impacts the overall riparian cover characterization of this Subbasin. Lack of canopy cover may not be problematic in the wetland reaches though may still be a problem in the non-wetland reaches.)
- Road Culverts and Other Physical Barriers (evidence in support: Three (3) specific locations of partial and one (1) location of complete blockages to fish passage; secondary limiting factor because these barriers are location-specific)

Sturtevant Creek

- Pollutant Loading (evidence in support: illicit discharges and spills prevalent in this Subbasin; large percentage of highway and commercial/industrial land uses; threats to public health and safety and to water quality (ex: illegal dumping, pet waste, encampments)
- Stormwater Runoff from Impervious Surfaces (evidence in support: impervious surface is highest as compared to other Greater Kelsey Creek Watershed subbasins, channel incision and streambank erosion (highest in the Watershed))
- Loss of Floodplain and Riparian Function (evidence in support: a relatively high percentage of the creek flows through a pipe rather than as an open channel, much of the open channel is either disconnected from its floodplain due to channel incision or the floodplain has been developed; lowest riparian cover, highest impervious surface and pollutant loading (based on land uses))
- Road Culverts and Other Physical Barriers (evidence in support: Four (4) specific locations of partial and one (1) location of complete blockages to fish passage; secondary limiting factor because these barriers are location-specific)

Richards Creek

- Stormwater Runoff from Impervious Surfaces (evidence in support: impervious surface is high as compared to other Greater Kelsey Creek Watershed subbasins; 39% of this Subbasin was developed prior to 1975 when stormwater management was first required)
- Pollutant Loading (evidence in support: Assumed heavy pollutant load due to surrounding land use and little to no stormwater detention or treatment; high percent fines in stream bed)
- Loss of Floodplain and Riparian Function (evidence in support: a relatively high percentage of the creek flows through a pipe; where the channel is open, much of the floodplain has been developed; secondary limiting factor because only applies to a portion of this Subbasin; This Subbasin's wetland

habitat (with limited numbers of trees) impacts the overall riparian cover characterization of this Subbasin. Lack of canopy cover may not be problematic in the wetland reaches though may still be a problem in the non-wetland reaches.)

Sunset Creek

- Stormwater Runoff from Impervious Surfaces (evidence in support: 45% of this Subbasin was developed prior to 1975 when stormwater management was first required; historic mass wasting was common in the ravine upstream of I-90; streambed scour and channel incision notable in lower reaches of Sunset Creek)
- Pollutant Loading (evidence in support: threats to public health and safety and to water quality (ex: illegal dumping, pet waste); high percent fines in stream bed, though pollutant loading based on land use is relatively good, with third highest score in the Watershed (behind Kelsey and Valley)
- Loss of Floodplain and Riparian Function (evidence in support: a relatively high percentage of the creek flows through a pipe; where the channel is open, much of the floodplain has been developed; secondary limiting factor because only applies to a portion of this Subbasin)
- Road Culverts and Other Physical Barriers (evidence in support: Six (6) specific locations of partial and one (1) location of complete blockages to fish passage; secondary limiting factor because these barriers are location-specific)

West Tributary

- Stormwater Runoff from Impervious Surfaces (evidence in support: high percent impervious surface; 45% of this Subbasin was developed prior to 1975 when stormwater management was first required)
- Pollutant Loading (evidence in support: large percentage of commercial/industrial land uses in lower portions of this Subbasin)
- Loss of Floodplain and Riparian Function (evidence in support: a relatively high percentage of the creek flows through a pipe; where the channel is open, much of the floodplain has been developed. Low riparian canopy cover in lower portions of this Subbasin; secondary limiting factor because only applies to a portion of this Subbasin. This Subbasin's wetland habitat (with limited numbers of trees) impacts the riparian cover characterization of this Subbasin. Lack of canopy cover is still a problem in the non-wetland reaches.)

Goff Creek

- Stormwater Runoff from Impervious Surfaces (evidence in support: 40% of the Subbasin developed prior to 1975; though overall the Subbasin is 23% impervious (relatively low), the percent impervious of the middle section in the Bel-Red area is very high)
- Pollutant Loading (evidence in support: threats to public health and safety and to water quality (ex: illegal dumping, pet waste); high percent fines in stream bed indicating erosion upstream, though pollutant loading based on land use is relatively good, with third highest score in the Watershed (behind Kelsey and Valley)
- Loss of Floodplain and Riparian Function (evidence in support: high streambank armoring and 16% of stream within a pipe; especially armored in the reach from Bel-Red Road north to SR-520); secondary limiting factor because only applies to a portion of this Subbasin)
- Physical Barriers (evidence in support: Documented physical barriers, especially in the reach from BelRed Road north to SR-520; channel modifications including many weirs, particularly just upstream from SR-520; Six (6) specific locations of partial and seven (7) locations of complete blockages to fish passage; secondary limiting factor because these barriers are location-specific)

Valley Creek

- Pollutant Loading (evidence in support: Potential water quality concerns about septic systems located in this Subbasin; high percentage of fines in most stream reaches, indicative of erosion upstream) evidence in support: threats to public health and safety and to water quality (ex: illegal dumping, pet waste, encampments)
- Stormwater Runoff from Impervious Surfaces (evidence in support: lower region has high impervious surface; secondary limiting factor because only applies to a portion of this Subbasin)
- Physical Barriers (evidence in support: Documented physical barriers (1 partial, no complete), though assumed numerous physical barriers on private property not assessed by WDFW but observed during the OSCA surveys; secondary limiting factor because only applies to a portion of this Subbasin)

Sears Creek

- Stormwater Runoff from Impervious Surfaces (evidence in support: high impervious surface; channel incision and streambed scour)
- Pollutant Loading (evidence in support: land use is industrial/commercial) evidence in support: threats to public health and safety and to water quality (ex: illegal dumping, pet waste, encampments) high percent fines in stream bed)
- Loss of Floodplain and Riparian Function (evidence in support: highest extent of streambank armoring in the City, though most is in Reach 1; Stream is confined and intermittently piped and former floodplain has been developed (particularly in Reach 1); Very low riparian canopy; secondary limiting factor because only applies to a portion of this Subbasin)
- Physical Barriers (evidence in support: No specific locations of partial and two (2) locations of complete blockages to fish passage; secondary limiting factor because these barriers are location-specific)

This ordering of limiting factors is generally consistent with the hierarchical model of stream functions that was described previously by Herrera (2013). This approach builds on the knowledge that efforts to improve physical habitat quality will be substantially more difficult if conducted in highly impacted watersheds with altered sediment budgets and a flashy hydrologic regime (Roni *et al.* 2002). Stream channel rehabilitation is most effective in watersheds that have a natural hydrograph and minimal sediment loading (Suren and McMurtrie 2005).

Figure 51 presents a Stream Functions Pyramid model prepared by Harman (2009) which, along with the hierarchical model of stream functions, suggests improved stream health (located at the top of the pyramid) is most effectively attained by first addressing stressors at the lower levels of the pyramid. The intention of the pyramid is to show the dominant cause and effect relationships. In general, biodiversity is dependent on habitat structure and quality, which are dictated by the lower levels of the pyramid beginning with hydrologic conditions.

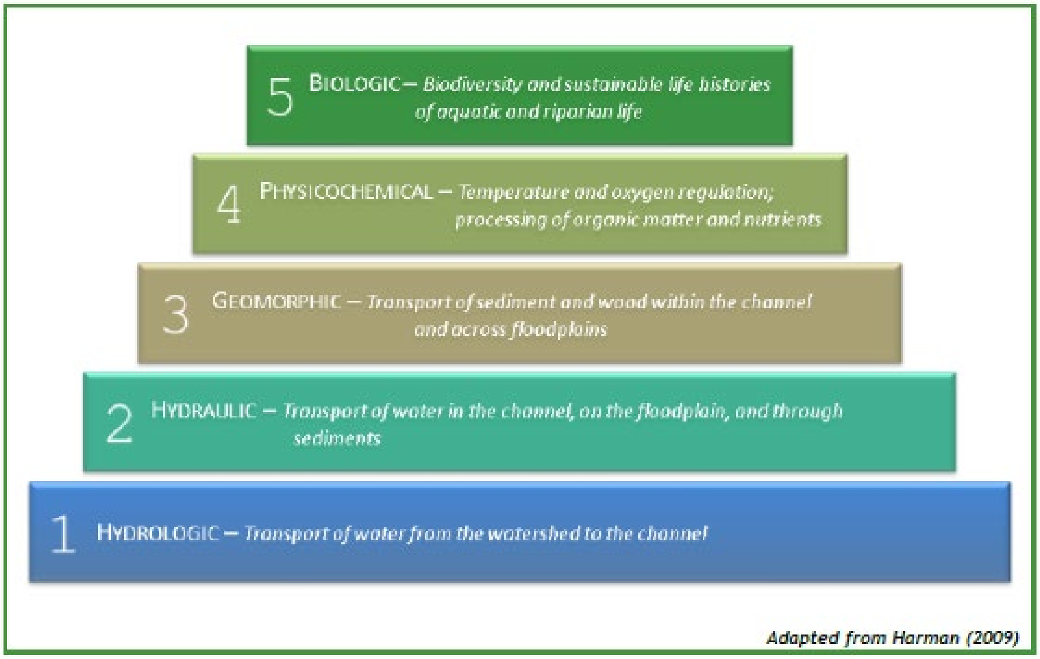


Figure 51. Stream Functions Pyramid.

4. Past and Present Investments

The City has implemented a number of investments to address stream health in the Greater Kelsey Creek Watershed. Table 21 outlines location-specific past and present investments that have been made by the City (or else by King County, before areas were annexed into the City) in the Greater Kelsey Creek Watershed. Note that the regional facilities and high-flow bypass facilities described earlier in this AR are not included in this list of investments.

In addition to those location-specific investments described in Table 21, the City has also invested in the following programmatic activities within the Greater Kelsey Creek Watershed:

- Information collection, studies, and environmental monitoring
- Maintenance activities – including conveyance system cleaning and inspection and vegetation maintenance/removal and management of beaver activities
- Education (including natural yard care and invasive species control) and Public Engagement

There have also been investments made by others to benefit stream health in Bellevue, including those by Sound Transit, WSDOT, Puget Sound Energy and the Mountains to Sound Greenway Trust. Location-specific investments by Sound Transit that are significant to the City's streams are mentioned here in Table 21.

Table 21. Past and Present Significant Investments for Stream Health in the Greater Kelsey Creek Watershed

Greater Kelsey Creek Watershed Subbasin	Description of Investment(s) by the City
Mercer Slough	Replaced culvert on Alcove Creek (by Sound Transit and City)
Kelsey	Channel restoration through Kelsey Creek Farm Channel improvements and removal of invasive vegetation in Kelsey Creek Wetland Rebuilt culvert at Main Street and 148th Avenue Repaired culvert at 121st Avenue SE Channel configuration near Lake Hills Greenbelt to address water quality in Phantom Lake Removal of culverts and addition of pedestrian footbridge at Larsen Lake Stream restoration in Reach 7 of Kelsey mainstem (east of 134th Ave) Identification and removal of invasive vegetation (knotweed and reed canary grass)
Sturtevant	Replaced culvert with bridge project over SE 6th Street
Richards	Bannerwood culvert Culvert replacements as part of the SE 30th Street/SE 26th Street
Sunset	Sedimentation pond/trap at SE 30th Street SE 32nd Street culvert repair Sunset ravine stabilization
West Tributary	Wetland restoration at the Upper Regional Facility Replacement of 124th Avenue NE and 120th Avenue NE culverts (in progress)
Goff	Culvert installation upstream of BelRed Road (by Sound Transit)
Valley	Constructed wetland (NE 24th Street) and Regional Facility Highland Park LWM installation
Sears	None known within Bellevue City limits

5. Potential Opportunities

Table 22 presents instream opportunities for improving the stream health in the Greater Kelsey Creek Watershed based on observations made during the OSCA field work and/or by previous studies conducted by the City. These opportunities will be moved forward into the WIPs where they will be used to help identify potential investments for stream health improvement.

While the City has invested in stream restoration and instream maintenance activities within the subbasins of the Greater Kelsey Creek Watershed, the City has not performed many upland projects. Upland investments might include retrofits of existing stormwater facilities (including high-flow bypasses or regional facilities) or installation of new stormwater facilities aimed at flow control and/or water quality. Both instream and upland investments will be explored in the forthcoming WIPs to address limiting factors of the Greater Kelsey Creek Watershed identified in this AR.

Table 22. Instream Opportunities for Improving Stream Health in the Greater Kelsey Creek Watershed

Greater Kelsey Creek Watershed Subbasin	Reach	Instream Opportunity
Watershed-wide (all Subbasins)	--	Prevent and/or manage invasive aquatic and vegetation species, both present and new/emerging (knotweed, New Zealand Mudsnails, Zebra Mussels, and other new/emerging invasive species)
Watershed-wide (all Subbasins)	--	Improve fish passage at known barriers and restore natural stream processes
Watershed-wide (all Subbasins)	--	Provide programs that foster good stewardship in both the residential and business communities
Watershed-wide (all Subbasins)	--	Introduce new City and community policies and programs to address impacts of human activity (human activities include pet waste, discarded needles, litter, illegal dumping, and other pollutants)
Kelsey Creek	2	Continue to inspect and maintain the fish ladder that connects Mercer Slough and Kelsey Creek to provide unrestricted fish passage
Kelsey Creek	2	Improve partial fish passage barrier under 121st Avenue SE
Kelsey Creek	4-5	Investigate potential fish passage improvements needed for man-made and natural fish passage barriers
Kelsey Creek	4, 10, and 13	Manage city owned parcels that encourage natural wetland processes such as overbank flooding, channel migration, and the natural recruitment of LWM
Kelsey Creek	5	Maintain city owned parcels that allow natural stream processes such as overbank flooding, channel migration, and the natural recruitment of LWM
Kelsey Creek	5-8	Control measures for invasive knotweed
Kelsey Creek	6	Improve fish passage at Glendale Country Club
Kelsey Creek	7	Improve fish passage at weirs associated with a regional pipeline
Kelsey Creek	7	Identify opportunities to enhance floodplain and riparian function in regional powerline corridor north of 136th Avenue NE

Greater Kelsey Creek Watershed Subbasin	Reach	Instream Opportunity
Kelsey Creek	7	Improve privately-owned fish passage barrier at 140th Avenue NE
Kelsey Creek	13 and 14	Explore land acquisition opportunities to restore aquatic/wetland habitat, improve water quality, and reduce chronic flooding
Kelsey Creek	Across Subbasin	Investigate addition of LWM and removal of streambank armoring, or replacement of armoring with "soft" armoring or bioengineering
Kelsey Creek	Across Subbasin	Manage aquatic invasive species (prevent and control knotweed, New Zealand Mudsnails, Zebra Mussels, and other new/emerging invasive species)
Sturtevant Creek	1 and 2	Investigate potential Oil Water Separator on I-405
Sturtevant Creek	2	Enhance instream fish habitat, restore riparian buffer and place LWM
Sturtevant Creek	2	Improve fish passage at I-405
Sturtevant Creek	4	Investigate actions to mitigate impacts of stormwater and reduce channel incision
Richards Creek	1, 2, 7, and 8	Protect and enhance the stream buffer and riparian corridor
Richards Creek	1, 2, 7, and 8	Manage invasive aquatic and vegetation species
Richards Creek	3-6	Investigate new policies and land acquisition to promote instream restoration efforts
Richards Creek	Across Subbasin	Provide stormwater flow control, fine sediment catchment, and wetland enhancement
Sunset Creek	5-8	Evaluate the current function and continued need of the high-flow bypass from Reach 8 to Reach 5
Sunset Creek	5-8	Restore instream habitat complexity by placing LWM
Sunset Creek	6	Improve fish passage at known barriers and restore natural stream processes
Sunset Creek	Across Subbasin	Bank stabilization projects could help reduce sedimentation and flooding that frequently occurs in the lower Sunset Creek
West Tributary	0, 4, 6, and 8	Control and maintain existing wetlands (consider experimental methods to control nonnative plant species, and the use of elevated planting mounds)
West Tributary	1, 2 and 3	Correction of documented fish barriers and undocumented impediments
West Tributary	2 and 3	Restore riparian zone and limit further encroachment
West Tributary	Locations throughout Subbasin	Replace culvert under BelRed Road and remove creek from pipe and establish open channel upstream of BelRed Road, extending approximately 1700 linear feet. (See Northwest Hydraulic Consultants 2011 for details and for other opportunities to widen stream corridor (channel plus zoned buffers) and to provide wetland, wildlife, and fish rearing habitat.)
West Tributary	Across Subbasin	Invasive species control and riparian enhancement
Goff Creek	1 and 2	Investigate process based riparian restoration

Greater Kelsey Creek Watershed Subbasin	Reach	Instream Opportunity
Goff Creek	3 and 5	Explore opportunities to improve fish passage and restore natural stream processes in piped sections where feasible
Goff Creek	Across Subbasin	Remove hard stream bank armoring or replace with bioengineering
Goff Creek	Across Subbasin	Control invasive vegetation
Valley Creek	1	Evaluate the need for the high-flow bypass
Valley Creek	1	Improve confluence with Kelsey Creek
Valley Creek	1-4	Introduce new City and community policies and programs to address impacts of human activity (human activities include pet waste, discarded needles, litter, illegal dumping, and other pollutants)
Valley Creek	1-5	Restore fish habitat and remove fish passage barriers
Valley Creek	5	Investigate potential fish passage barrier at Valley Creek Regional Detention Facility
Valley Creek	6	Work with property owner regarding privately-owned dam, including identification of potential next steps (for example: assess for fish-passibility)
Valley Creek	6 and 7	Install LWM to promote channel complexity
Sears Creek	1	Remove and/or soften stream bank armoring, and promote native riparian vegetation
Sears Creek	1 and 2	Correct potential fish passage barriers to allow access to Reach 3
Sears Creek	3 and 5	Introduce new City and community policies and programs to address impacts of human activity (human activities include pet waste, discarded needles, litter, illegal dumping, and other pollutants)
Sears Creek	5	Evaluate the efficacy and continued need of the Commissioners' Regional Detention Pond

6. Data Gaps

Missing or incomplete information that were not available to inform this Greater Kelsey Creek Watershed AR or future phases of WMP development are as follows:

- Data and information on current conditions in Mercer Slough
- Water level and streamflow information is not available for most streams, preventing hydrological comparisons to measure improvements and/or degradation in those systems
- Stream water temperature data to assess water quality impacts of loss of riparian corridor width, changes to canopy cover, or warm runoff from impervious surfaces.
- Water Quality Index information is only available for the mouth of Kelsey Creek but not for any other of its tributaries
- Resident fish population and health information is not available for several subbasins
- Macroinvertebrate data is unavailable for several subbasins
- Review of all privately and publicly-owned stormwater facilities to characterize currently-provided effectiveness against designed effectiveness

The City is currently developing an Environmental Monitoring Plan aimed at obtaining robust data to evaluate biological, chemical, physical, hydrological, and invasive species indicators of stream health. These data will inform status-and-trends, cause-and-effect relationships, management decisions, and progress towards achieving watershed and stream health goals within the framework of the WMP.

7. References

Alberti, M, D. Booth, K. Hill, B. Coburn, C. Avolio, S. Coe, and D. Spirandelli. 2007. The impact of urban patterns on aquatic ecosystems: An empirical analysis in Puget lowland sub-basins. Landscape and Urban Planning 80 (2007): 345–361.

Aquatic Nuisance Species Committee. 2007. Washington State Aquatic Nuisance Species Committee Report to the 2008 Legislature. Prepared by P. Meacham and A. Pleus Washington Department of Fish and Wildlife.

Barnard, R.J., J. Johnson, P. Brooks, K. M. Bates, B. Heiner, J. P. Klavas, D. C. Ponder, P. D. Smith, and P. D. Power, 2013. Water Crossing Design Guidelines. Washington Department of Fish and Wildlife, Olympia, WA. https://wdfw.wa.gov/sites/default/files/publications/01501/wdfw01501.pdf

Bellevue. 1994. 1994 Comprehensive Drainage Plan. City of Bellevue, WA, Utilities Department. October 1994.

Bellevue. 2006. Draft Management Plan for Coal Creek Natural Area. Prepared by the City of Bellevue. June 14, 2006.

Bellevue. 2010. Fish Use of Stream Drainage Basins in the City of Bellevue. City of Bellevue. March 2010. https://bellevuewa.gov/sites/default/files/media/pdf_document/FishUse_BellevueStreams.pdf

Bellevue. 2011. Peamouth Spawning Events in Bellevue 2005-2010. City of Bellevue. April 2011. https://bellevuewa.gov/sites/default/files/media/pdf_document/Peamouth%20Report.pdf

Bellevue. 2013. City of Bellevue Land Cover Classification. Bellevue_2013_landcover_101214Proj_NAD83_2011.tif. Provided to Herrera by City of Bellevue, June 2020.

Bellevue. 2017. City of Bellevue Land Cover and Urban Tree Canopy Classification. Bellevue_LC6Class_2017_ClassField.tif. Provided to Herrera by City of Bellevue, June 2020.

Bellevue. 2018. Urban Tree Canopy Assessment. Prepared by Plan-It Geo, LLC, Arvada, Colorado for City of Bellevue, Washington. September 2018.

Bellevue. 2020. City of Bellevue GIS Data Portal. Available at https://bellevuewa.gov/city-government/departments/ITD/services/maps/g-i-s-data-portal.https://bellevuewa.gov/city-government/departments/ITD/services/maps/g-i-s-data-portal

Bellevue. 2021a. Open Streams Condition Assessment Database. Data collected by City of Bellevue Utilities in 2018 and 2020 and provided to Jacobs in June 2021.

Bellevue. 2021b. New Zealand Mudsnails. City of Bellevue. Accessed August 9, 2021. https://cobgis.maps.arcgis.com/apps/MapJournal/index.html?appid=bce931a2a5ca4244b5d9baa7a8d466f0.

Bellevue. 2022. Kelsey Creek Watershed Open Streams Condition Assessment Reach Reports, 2019-2020. City of Bellevue, WA. Draft.

Booth, D. B., J. R. Karr, S. Schaum, Konrad, S. A. Morley, C. P., M. G. Larson, and S. J. Burges. 2002. Urban stream rehabilitation in the Pacific Northwest. Final report for U.S. Environmental Protection Agency Grant Number R82-5284-010. March 30, 2001.

Booth, D., and P. Henshaw. 2001. Rates of Channel Erosion in Small Urban Streams. Land Use and Watersheds: Human Influence on Hydrology and Geomorphology in Urban and Forest Areas. Mark Wigmosta and Stephen Burges, (eds.). American Geophysical Union, Washington, DC. pp. 17-38.

Bower, James, fish biologist, King County. Personal communication: email to Christa Heller, City of Bellevue Department of Utilities, February 18, 2021.

CH2M HILL. 2011. East Link Project, Final Environment Impact Statement, Appendix H3 Ecosystems Technical Report. Prepared for Sound Transit. July.

Colleran, B., Nozaki Lacy, S., and Retamal, Maria. 2020. Invasive Japanese Knotweed (Reynoutria japonica Houtt) and related knotweeds as catalysts for streambank erosion. River Research and Applications. September 17, 2020.

DeGasperi, C.L., R.W. Sheibley, B. Lubliner, C.A. Larson, K. Song, and L.S. Fore. 2018. Stormwater Action Monitoring Status and Trends Study of Puget Lowland Ecoregion Streams: Evaluation of the First Year (2015) of Monitoring Data. Prepared for Washington Department of Ecology Stormwater Action Monitoring program. Prepared by King County in collaboration with the Washington Department of Ecology, U.S. Geological Survey, and the Puget Sound Partnership. Science and Technical Support Section, Water and Land Resources Division, Seattle, Washington.

Fox, Martin, and Susan Bolton. 2007. "A Regional and Geomorphic Reference for Quantities and Volumes of Instream Wood in Unmanaged Forested Basins of Washington State." North American Journal of Fisheries Management, 27:342–359

GeoEngineers, Inc. 2017. Hydrogeological and Geotechnical Analysis West Tributary Stream Daylighting. April 28, 2017.

Golder Associates Inc. 2019. City of Bellevue Emergency Water Supply Plan – Aquifer–Stream Delineation and Assessment. July 12, 2019.

Harman, W.A. 2009. The Functional Lift Pyramid (Presentation). Mid-Atlantic Stream Restoration Conference. Morgantown, West Virginia. http://water.epa.gov/lawsregs/guidance/wetlands/upload/6-stream_functions_pyramid.pdf.

Hart Crowser and Associates. 2014. Bellevue Summer Electrofishing 2014. Prepared for City of Bellevue Utilities Department. October 21, 2014. https://bellevuewa.gov/sites/default/files/media/pdf_document/Bellevue_Electrofishing_Report_FINAL_rev_20141021.pdf

Hart Crowser and Associates. 2016. Bellevue Summer Electrofishing 2016. Prepared for City of Bellevue Utilities Department. October 12, 2016. https://bellevuewa.gov/sites/default/files/media/pdf_document/2016%20Bellevue%20Electrofishing%20Report.pdf

Hart Crowser and Associates. 2017. Bellevue Summer Electrofishing 2017. Prepared for City of Bellevue Utilities Department. November 20, 2017. https://bellevuewa.gov/sites/default/files/media/pdf_document/2017%20Streams%20Biological%20Assessment%20Report.pdf

Herrera. 2013. City of Redmond, Washington: Citywide Watershed Management Plan. Prepared for City of Redmond by Herrera Environmental Consultants, Inc., Seattle Washington. November 25, 2013. https://www.redmond.gov/DocumentCenter/View/11707/Watershed-Management-Plan-2013-PDF.

Herrera. 2015. Quality Assurance Project Plan: Redmond Paired Watershed Study. Prepared for the City of Redmond by Herrera Environmental Consultants, Inc., Seattle, Washington. December 31.

HRCD. 2021. High Resolution Change Detection project. Accessed November 2, 2021. https://hrcd-wdfw.hub.arcgis.com/.

Institute of Life Sciences. (2010, March 7). Caffeine Induced Effects on Heart Rate in Zebrafish Embryos. Retrieved August 25, 2021. from http://www.ncbi.nlm.nih.gov/pubmed/20415645

Karr, J. R. and E. W. Chu. 1999. Restoring live in running waters. Better biological monitoring. Island Press, Washington, D.C.

Kerwin, J. 2001. Salmon and Steelhead Limiting Factors Report for the Cedar-Sammamish Basin (Water Resource Inventory Area 8). Washington Conservation Commission. Olympia, Washington.

King County. 2014. Evaluation of Potential Climate Change Impacts on Rainfall Volume, Stormwater Facility Size and Stream Flashiness. Prepared by Jeff Burkey, Science and Technical Support Section, Water and Land Resources Division. Seattle, Washington.

King County. 2016. Stream Information Report for Kelsey Creek. Last updated November 2, 2016. Water and Land Resources. Accessed April 7, 2021. https://green2.kingcounty.gov/streamsdata/watershedinfo.aspx?Locator=0442.

King County. 2018. Salmon Watcher Program. Last updated December 6, 2018. Water and Land Resources. Accessed October 4, 2021. https://kingcounty.gov/services/environment/animals-and-plants/salmon-and-trout/salmon-watchers.aspx

King County. 2019. Contaminants of Emerging Concern in Reclaimed Water – Review of Status and Relevant Literature. Prepared by Richard Jack, Department of Natural Resources and Parks, Water and Land Resources Division. Seattle, WA

King County. 2002. Greater Lake Washington and Green-Duwamish Watersheds Wadable Freshwater Streams Benthic Macroinvertebrate Sampling and Analysis Plan. Prepared by King County Department of Natural Resources and Parks, Water and Land Resource Division. December 2002.

King County. 2020a. Hydrologic Information Center. Water and Land Resources. Accessed June 11, 2020. https://green2.kingcounty.gov/hydrology/Default.aspx

King County. 2020b. Water Quality Index for Streams and Rivers. Accessed July 10, 2020. https://green2.kingcounty.gov/streamsdata/WQI.aspx

King County. 2021. GIS Open Data: Wetlands defined from Critical Area Ordinance surveys in King County. Accessed February 26, 2021. https://gis-kingcounty.opendata.arcgis.com/datasets/wetlands-defined-from-critical-area-ordinance-surveys-in-king-county-wetlands-area.

Konrad, C. 2002. Hydrologic Trends Associated with Urban Development for Selected Streams in the Puget Sound Basin, Western Washington. U.S. Geological Survey. Water-Resources Investigations Report 02-4040.

Lake Washington/Cedar/Sammamish Watershed Salmon Recovery Council. 2017. Lake Washington/Cedar/Sammamish Watershed (WRIA 8) Chinook Salmon Conservation Plan, 10-year Update. https://www.govlink.org/watersheds/8/reports/pdf/wria-8-ten-year-salmon-conservation-plan-combined-10-25-2017.pdf

Louis Berger Group. 2016. Bel-Red Regional Stormwater Facilities Report, City of Bellevue Washington.

May, C.W., E. B. Welch, R. R. Horner, J. R. Kar, and B. W. Mar. 1997. Quality Indices for Urbanization in Puget Sound Lowland Streams. Water Resource Series Technical Report No. 154. June 199. https://www.ce.washington.edu/sites/cee/files/pdfs/research/hydrology/water-resources/WRS154.pdf.

Montgomery, D. R. and J. M. Buffington. 1993. Channel Classification, Prediction of Channel Response, and Assessment of Channel Condition. Washington State Timber/Fish/Wildlife Agreement Report TFH-S1-110-93-002, 84 p.

Morley, S.A., and J.R. Karr. 2002. Assessing and Restoring the Health of Urban Streams in the Puget Sound Basin. Conservation Biology 16(6): 1498-1509.

Naman, S.M., J.S. Rosenfeld, P.M. Kiffney, and J.S. Richardson. 2018. The energetic consequences of habitat structure for forest stream salmonids. Journal of Animal Ecology 87:1383-1394.

Northwest Hydraulic Consultants 2002. Hydrologic Study of Kelsey Creek Basin. Prepared for the City of Bellevue Utilities Department. December.

Northwest Hydraulic Consultants 2011. Bel-Red Corridor Study West Tributary and Goff Creek Final Report. Prepared for City of Bellevue. March.

NOAA. 1996. Coastal Salmon Conservation: Working Guidance for Comprehensive Salmon Restoration Initiatives on the Pacific Coast. National Oceanic and Atmospheric Administration, National Marine Fisheries Service. http://www.krisweb.com/biblio/gen_noaa_nmfs_1996_salmonconservation.pdf

NRCS. 2016. Web Soil Survey. Natural Resources Conservation Service, United States Department of Agriculture. Available online at http://websoilsurvey.nrcs.usda.gov/.

OCM Partners. 2020. 2016 - 2017 Puget Sound Lidar Consortium (PSLC) Lidar DEM: King County, WA. Created for the NOAA Office for Coastal Management (OCM). https://www.fisheries.noaa.gov/inport/item/53392.

Pollock, M.M., G. Lewallen, K. Woodruff, C.E. Jordan and J.M. Castro (Editors) 2015. The Beaver Restoration Guidebook: Working with Beaver to Restore Streams, Wetlands, and Floodplains. Version 1.0. United States Fish and Wildlife Service, Portland, Oregon. 189 pp. Online at: http://www.fws.gov/oregonfwo/ToolsForLandowners/RiverScience/Beaver.asp

PSBD. 2020. Puget Sound Benthos Database. Accessed July 2, 2020. https://pugetsoundstreambenthos.org/Default.aspx

R2 Resources Consultants. 2016. Salmonid Pre-Spawn Mortality Study, Sammamish River, King County, Washington. Prepared by R2 Resource Consultants, Redmond, WA for King County, Washington. February 2016.

Richey, J.S., M.A. Perkins, and K.W. Malueg. October, 1981. The Effects of Urbanization and Stormwater Runoff on the Food Quality in Two Salmonid Streams. Verh. Internat. Verein. Limnol., vol. 21, pages 812-818, Stuttgart.

Roni, P., T.J. Beechie, R.E. Bilby, F.E. Leonetti, M.M. Pollock, and G.R. Pess. 2002. A Review of Stream Restoration Techniques and a Hierarchical Strategy for Prioritizing Restoration in Pacific Northwest Watersheds. North American Journal of Fisheries Management 22(1):1-20.

Rosburg, T. T., P. A. Nelson, and B. P. Bledsoe, 2017. Effects of Urbanization on Flow Duration and Stream Flashiness: A Case Study of Puget Sound Streams, Western Washington, USA. Journal of the American Water Resources Association (JAWRA) 53(2):493-507. DOI: 10.1111/1752-1688.12511

RW Beck. 2011. Citywide Assessment of Eligibility for the Washington State Department of Ecology Flow Control Standard for Highly Urbanized Drainage Basins.

Snyder, D. E., P. S. Gale, and R. F. Pringle. 1973. Soil Survey for King County Area, Washington. Natural Resources Conservation Service, United States Department of Agriculture.

Suren, A. M. and S. McMurtrie. 2005. Assessing the Effectiveness of Enhancement Activities in Urban Streams: II. Responses of Invertebrate Communities. River Research and Applications 21(4):439-453.

Sutton, N.L. Scholz, J.W. Davis, M.C. Dodd, A. Simpson, J.K. McIntyre, E.P. Kolodziej. 2020. A ubiquitous tire rubber–derived chemical induces acute mortality in Coho Salmon. Science 371(6525):185-189.

Tetra Tech/KCM, Inc, GeoEngineers, Inc, & City of Bellevue, 2006. Coal Creek Stabilization Program Final Environmental Impact Statement (Environmental Impact Statement).

The Watershed Company. 2009. 2008 Salmon Spawner Surveys Kelsey Creek, West Tributary, Richards Creek and Coal Creek. Prepared for The City of Bellevue Contracting Services in March 2009.

Thompson, K. 1972. Determining stream flows for fish life. Pages 31-50 in Proceedings instream flow requirement workshop. Pac Northwest River Basin Comm, Vancouver, WA.

USFS. 2012. Stream Inventory Handbook, Pacific Northwest Region, Region 6, Version 2.12. United States Forest Service, United States Department of Agriculture.

USFWS. 2018. Chinese Mystery Snail (*Cipangopaludina chinesis*) Ecological Risk Screening Summary. March 28, 2018. https://www.fws.gov/fisheries/ans/erss/highrisk/ERSS-Cipangopaludina-chinensis-FINAL-March2018.pdf

USFWS. 2021. National Wetlands Inventory Wetlands Mapper. Accessed February 26, 2021. https://www.fws.gov/wetlands/Data/Mapper.html

USGS: 2016. Surface geology, 1:100,000, GIS data, November 2016: Digital Data Series DS-18, version 3.1, previously released June 2010. Washington Division of Geology and Earth Resources, Olympia, Washington.

Washington State Department of Ecology. 2019. Stormwater Management Manual for Western Washington. Accessed March 25, 2021. https://fortress.wa.gov/ecy/ezshare/wq/Permits/Flare/2019SWMMWW/2019SWMMWW.htm

Washington Department of Fish and Wildlife (WDFW) & Northwest Indian Fisheries Commission (NWIFC). 2011. Puget Sound Steelhead Foundations: A Primer for Recovery Planning. Puget Sound Partnership and WDFW. December 2011. https://wdfw.wa.gov/sites/default/files/publications/01512/wdfw01512.pdf

WDFW. 2021a. Bellevue Salmon Spawner Surveys (1999-2020): Kelsey Creek, West Tributary, Richards Creek, and Coal Creek. Prepared for the City of Bellevue Utilities in August 2018.

WDFW. 2021b. Invasive Species. Accessed September 29, 2021. https://wdfw.wa.gov/get-involved/educational-resources/invasive-species#

WDFW. 2021c. Washington State Fish Passage Webmap. Accessed October 1, 2021. https://geodataservices.wdfw.wa.gov/hp/fishpassage/index.html Wild Fish Conservancy Northwest. 2021.

WDFW. 2021d. Priority Habitat Species (PHS) on the Web. Report for the Kelsey Creek Watershed generated September 16, 2021. https://geodataservices.wdfw.wa.gov/hp/phs/

WDFW. 2021e. New Zealand Mudsnail (Potamopyrgus antipodarum). Accessed October 1, 2021. https://wdfw.wa.gov/species-habitats/invasive/potamopyrgus-antipodarum

Kelsey Creek Restoration & Fish Exclusion. Accessed August 12, 2021. http://wildfishconservancy.org/resources/publications/wild-fish-runs/kelsey-creek-restoration-fish-exclusion

WRIA 8. 2001. Salmonid Distribution Maps, May 2001. https://www.govlink.org/watersheds/8/reports/fish-maps/default.aspx

Appendix A
Data Sources and Methods Used to Summarize Geospatial Watershed Attributes

Appendix A. Greater Kelsey Creek Watershed Assessment Report: Data Sources and Methods Used to Summarize Geospatial Watershed Attributes

1.1 Introduction

This appendix to the Greater Kelsey Creek Watershed Assessment Report (AR) describes the spatial data sources and calculation methods employed to generate figures referenced in the main text of the document. Spatial data was predominantly sourced from the City of Bellevue; additional spatial data sources are also listed at the end of this appendix. Calculations were generally derived by intersecting spatial data within specific boundaries (entire Greater Kelsey Creek Watershed, City of Bellevue city limits, Greater Kelsey Creek Watershed Subbasins). Additional analysis methods are described in detail below. The presentation of this information is organized under the major section titles and figure/table names (and numbers) from the main text, with a final table that contains all of the referenced data sources.

1.2 Watershed Characteristics

1.2.1 Geology (Table 1; Figures 10-14) and Soils (Table 2; Figures 15-19)

Geology and soil data were intersected within the City of Bellevue and subbasin boundaries, only area falling in the City of Bellevue limits was counted towards the total area. For geology, each Geologic Type total area was calculated using USGS geology layers. For soil, each Hydrologic Soil Group total area was calculated by intersecting soil types with subbasin boundaries.

1.2.2 Surface Water Features (Table 3; Figures 4-8)

Wetland area within each subbaasin was calculated by merging King County Sensitive Ordinance Wetlands and NWI Wetlands (2020) data and intersecting wetland boundaries with subbasin boundaries and the City of Bellevue Boundary. Subbasin area falling outside of the City of Bellevue limits was excluded, as were wetlands falling outside of City limits.

1.2.3 Beaver Activity (Table 4)

Information on beaver activity from City staff observations during OSCA surveys (2019 -2020). Observations recorded in primary stream channels (excluding secondary stream channels and wetland areas). Activity categories documented included observed presence of beaver dams, beaver lodges, other beaver activity, and beaver maintenance sites.

1.3 Built Infrastructure

1.3.1 Landcover/Tree Canopy (Tables 5, 7, B-4 to B-12; Figures 21-25)

Landcover analysis was performed using a raster mosaic of the 2017 and 2013 Landcover. These data were provided by the City of Bellevue in Tag Image File Format (TIF) files. The more recent 2017 Landcover only contained data from within the City of Bellevue city limits. Due to this consideration, the more recent 2017 Landcover classifications were used as the default in the landcover analyses. To represent areas in the watershed and subbasins not covered by the 2017 Landcover, the 2013 Landcover classifications were paired to match the 2017 Landcover classifications as follows:

2013 Deciduous classification = 2017 Tree Canopy classification

2013 Evergreen classification = 2017 Tree Canopy classification

2013 Non-Woody classification = 2017 Non-Canopy Vegetation classification

Land cover layers were intersected with the subbasin boundaries in order to calculate the total area of each land cover type within each subbasin. Land cover areas were further clipped to the City of Bellevue extent in order to exclude area falling outside the City of Bellevue from analysis and reporting.

1.3.2 Land Use (Table 6; Figures 26-30)

Initial land use analysis was conducted by merging existing Land Use datasets from the City of Redmond, the City of Bellevue, the City of Kirkland, and King County. To account for detailed land use classifications and naming convention variation across three different datasets, a broad standardized land use classification was created. Each dataset specific, unique land use classification was grouped under a broad, standardized land classification.

Following this initial broad classification, highway polygons were manually extracted from the 2013 City of Bellevue impervious surface polygon dataset and intersected with the broad land use classifications in order to separately identify highway cover within subbasins.

The total area for each land classification was then calculated for all subbasin boundaries and overall watershed extents (clipped to the extent of the City of Bellevue boundary).

1.3.3 Change in Tree Canopy and Impervious Surfaces (Table 7)

Land use change data was downloaded from WDFW's High Resolution Change Detection website and then intersected with subbasin boundaries. The data were then exported to R to calculate the percent change in tree canopy and impervious surfaces for each subbasin and the watershed as a whole.

1.3.4 Percent Stream Channel Piped (Table 8)

The percent of the stream channel that is piped was computed by exporting the stream layer data to R. The SDPIPE field was used to identify stream segments that are piped and the proportion was calculated using the shape length. Segments outside the City or those with an empty SDPIPE field were omitted.

1.3.5 Regional Stormwater Detention Facilities (Table 9; Figure 36)

The Regional Stormwater Detention Facilities data was gathered using the City of Bellevue Storm Inlets layer with focused FACILITYID definition query.

1.3.6 Age of Development Ratings (Table 10; Figures 31-35)

To evaluate the adequacy of stormwater management in the Coal Creek Watershed, the age of development was used to classify specific areas into one of five categories that indicate when requirements for improved stormwater management infrastructure became effective. The age of development was determined using the existing attributes in the Parcel Time of Development and Stormwater Standards layer (YearBuiltRes) for the City of Bellevue.

1.4 Natural Systems

1.4.1 Stream Flow and Hydrologic Metric Scores (Table 11)

Stream flow data was gathered from the King County Hydrologic Information Center and analyzed in excel.

1.4.2 Category 5 Waters (Tables 13-14)

Information on Category 5 waters was gathered from the Washington Department of Ecology’s 303(d) list (2014).

1.4.3 Riparian Impervious Surface Cover and Riparian Tree Canopy Cover (Tables 15, B-4 to B-12)

To calculate the riparian impervious surface cover, a 100 ft buffer was created around the stream line by SegmentID (reach number) with capped, not rounded, ends. This buffer was then intersected with the land cover layer. The results were exported to R to calculate the percent riparian impervious surface cover for each reach and the subbasin as a whole.

1.4.4 Subbasin Fish Passage Barriers and B-IBI Sample Locations (Tables 17, 19; Figures 45-49)

BIBI Location data was downloaded from the Puget Sound Stream website and intersected with subbasin boundaries. Fish Passage Barrier data was downloaded from the WDFW SalmonScape website and intersected with subbasin boundaries.

1.4.5 Stream Gradient (Tables B-4 to B-12)

The stream gradient was calculated as follows:

- Use Dissolve tool to group stream segments by SegmentID (reach number)

- Use Feature Vertices to Points tool to create points at each end of each reach

- Use Extract Values to Points tool to get the obtain the elevation at the end of each reach

- Export data to R. Compute stream gradient as the difference between the maximum and minimum elevation divided by the stream length.

1.5 Data Sources Table

See Table on next page.

Table A-1 GIS Data Sources used in Preparation of the Greater Kelsey Creek Watershed Assessment Report

Figure / Table subject	Table number(s)	Figure number(s)	Source Data	Source	Year accessed	Notes
All	All	All	Watershed boundaries	City of Bellevue	2020	City of Bellevue boundary isolated from 2020 CITYBDY polygons
			Subbasin Boundaries (Carta.UTIL.SD_Basin)	City of Bellevue		
			Bellevue City Limit (CITYBDY)	City of Bellevue		
			Highways (lines) (SR500KLRSLinesSPS)	WSDOT		
			Streams (Utilities.UTIL.envStreams)	City of Bellevue		
Geology	1	10-14	Surface geology, 1:100,000	USGS, Washington Division of Geology and Earth Resources (accessed 2020); Citation: Yount, James (1993). Geologic map of surficial deposits in the Seattle 30' x 60' quadrangle, Washington. Open File Report 93-233. USGS.	2020	USGS geology layers (100k) were intersected with City of Bellevue and subbasin boundaries in order to calculate the total area of each geology type within each subbasin. Only area falling within the City of Bellevue limits was included in calculations
Soils	2	15-19	Soil hydrologic groups	City of Bellevue WAR	2020	Soil types were intersected with City of Bellevue and subbasin boundaries in order to calculate the total area of each soil type within each subbasin. Only area falling within the City of Bellevue limits was included in calculations.
Surface water features and monitoring sites	--	4-8	FEMA 100 year floodplain	FEMA	2020	Wetland area within each subbaasin calculated by merging King County Sensitive Ordinance Wetlands and NWI Wetlands (2020) and intersecting wetland boundaries with subbasin boundaries and the City of Bellevue Boundary. Subbasin area falling outside of the City of Bellevue limits was excluded, as were wetlands faling outside of
	3		King County Sensitive Area Ordinance Wetlands	King County		
			NWI Wetlands	US FWS National Wetlands Inventory		
Beaver activity	4	--	OSCA observed beaver activity locations	City of Bellevue	2020	Information on beaver activity from City staff observations during OSCA surveys (2019 - 2020). Observations recorded in primary stream channels (excluding secondary stream channels and wetland areas). Activity categories documented included observed presence of beaver dams, beaver lodges, other beaver activity, and beaver maintenance sites.
Land Cover/Tree Canopy	5, 7, B-4 to B-12	21-25	2017 Land Cover tif (Rasta.ENVIRO.TreeCanopyComposite_2016) 2013 Land Cover tif (Rasta.ENVIRO.Bellevue_CompositeClass_2014)	City of Bellevue	2020	Landcover analysis was performed using a raster mosaic of the 2017 and 2013 Landcover. These data were provided by the City of Bellevue in Tag Image File Format (TIF) files. The more recent 2017 Landcover only contained data from within the City of Bellevue city limits. Due to this consideration, the more recent 2017 Landcover classifications were used as the default in the landcover analyses. To represent areas in the watershed and subbasins not covered by the 2017 Landcover,
Land Use	6	26-30	Land Use Designations (Comp Plan)	City of Bellevue	2020	Initial land use analysis was conducted by merging existing Land Use datasets from the City of Redmond, the City of Bellevue, the City of Kirkland, and King County. To account for detailed land use classifications and naming convention variation across three different datasets, a broad standardized land use classification was created. Each dataset specific, unique land use classification was grouped under a broad, standardized land classification. Following this initial broad classification, highway polygons were manually extracted from the 2013 City of Bellevue impervious surface polygon dataset and intersected with the broad land use classifications in order to separately identify highway cover within subbasins.
			Comprehensive Land Use	City of Redmond	2021	
			Comprehensive Plan https://maps.kirklandwa.gov/Html5Viewer/	City of Kirkland	2021	
			2013 Impervious surface polygons (Carta.ITD.ImperviousSurface_2013)	City of Bellevue	2021	
			Land Use Comprehensive Plan	King County	2020	
Change in tree canopy and impervious surfaces	7	--	High Resolution Change Detection	WDFW	2020	Land use change data was downloaded from WDFW's High Resolution Change Detection website and then intersected with subbasin boundaries. The data were then exported to R to calculate the percent change in tree canopy and impervious surfaces for each subbasin and the watershed as a whole.
Percent stream channel piped	8	--	Streams (Utilities.UTIL.envStreams)	City of Bellevue	2021	The percent of the stream channel that is piped was computed by exporting the stream layer data to R. The SDPIPE field was used to identify stream segments that are piped and the proportion was calculated using the shape length. Segments outside the City or those with an empty SDPIPE field were omitted.
Regional Stormwater Detention Facilities	9	36	Stormwater bypass structures	City of Bellevue	2020	City of Bellevue Storm Inlets with focused FACILITYID definition query.
			Regional stormwater detention facilities (Carta.UTIL.SD_Sites)	City of Bellevue	2020	
Age of Development Ratings	10	31-35	Age of Development (V:\UtilitiesDeptGIS\ArcGIS\Watershed Planning Team\Environmental Monitoring\Habitat Assessment\SHP\Parcel_AgeofDevelopment_inBasins.shp)	City of Bellevue	2020	To evaluate the adequacy of stormwater management in the Coal Creek Watershed, the age of development was used to classify specific areas into one of five categories that indicate when requirements for improved stormwater management infrastructure became effective (Table 5). The age of development was determined using the existing attributes in the Parcel Time of Development and Stormwater Standards layer (YearBuiltRes) for the City of Bellevue.
Stream flow and hydrologic metric scores	11	--	King County stream flow gauge data (Hydrologic information center)	King County	2020	
Category 5 waters	13-14	--	303(d) list (2014)	Washington Department of Ecology	2020	
Riparian impervious surface cover	15; B-4 to B-12	--	2017 land cover (Carta.ITD.ImperviousSurface_2013)	City of Bellevue	2021	To calculate the riparian impervious surface cover, a 100 ft buffer was created around the stream line by SegmentID (reach number) with capped, not rounded, ends. This buffer was then intersected with the land cover layer. The results were exported to R to calculate the percent riparian impervious surface cover for each reach and the subbasin as a whole.
Riparian tree canopy cover			2017 Land Cover tif (Rasta.ENVIRO.TreeCanopyComposite_2016)		2021	
Subbasin Fish Passage Barriers and B-IBI Sample Locations	17	45-49	Fish Passage Barriers	WDFW	2020	BIBI Location data was downloaded from the Puget Sound Stream website and intersected with subbasin boundaries. Fish Passage Barrier data was downloaded from the WDFW SalmonScape website and intersected with subbasin boundaries.
	19		B-IBI Locations	Puget Sound Stream Benthos	2021	
	--		OSCA observed knotweed locations (Utilities.UTIL.envKnotweed)	City of Bellevue	2020	
Fish species	18	--	Salmon survey results, 1999-2020	City of Bellevue, WDFW	2021	
Vicinity map; Surface water features and monitoring sites; Fish passage barriers and B-IBI sampling locations	--	3-8, 45-49	GeoTIFF aerial orthophotos (2020)	City of Bellevue	2020	
Topography	--	20	Contours (Contour50Ft_2016)	City of Bellevue	2020	
Stream gradient	B-4 to B-12	--	Digital elevation model (Rasta.TERRAIN.DEMBareEarth_2015)	City of Bellevue	2021	The stream gradient was calculated as follows: - Use Dissolve tool to group stream segments by SegmentID (reach number) - Use Feature Vertices to Points tool to create points at each end of each reach - Use Extract Values to Points tool to get the obtain the elevation at the end of each reach - Export data to R. Compute stream gradient as the difference between the maximum and minimum elevation divided by the stream length.

1.6 Geospatial Data Sources

City of Bellevue. 2013. Bellevue_2013_landcover_101214Proj_NAD83_2011.tif. Provided to Herrera by City of Bellevue, June, 2020.

City of Bellevue. 2017. Bellevue_LC6Class_2017_ClassField.tif. Provided to Herrera by City of Bellevue, June, 2020.

Bellevue. 2020. Open Streams Condition Assessment Database. Provided to Herrera by City of Bellevue Utilities, October, 2020.

Bellevue. 2020. As Built Storm Database. Provided to Herrera by City of Bellevue Utilities, May, 2020.

Bellevue. 2020. Parcel Time of Development and Stormwater Standards layer. Provided to Herrera by City of Bellevue, August, 2020.

City of Bellevue, 2020. GIS Data Portal. Available at https://bellevuewa.gov/city-government/departments/ITD/services/maps/g-i-s-data-portal.

City of Newcastle, 2020. GIS Portal. Land Use. Available at https://data-newcastlewa.opendata.arcgis.com/search?collection=Dataset.

King County, 2020. King County GIS Open Data Portal. Available at https://gis-kingcounty.opendata.arcgis.com/.

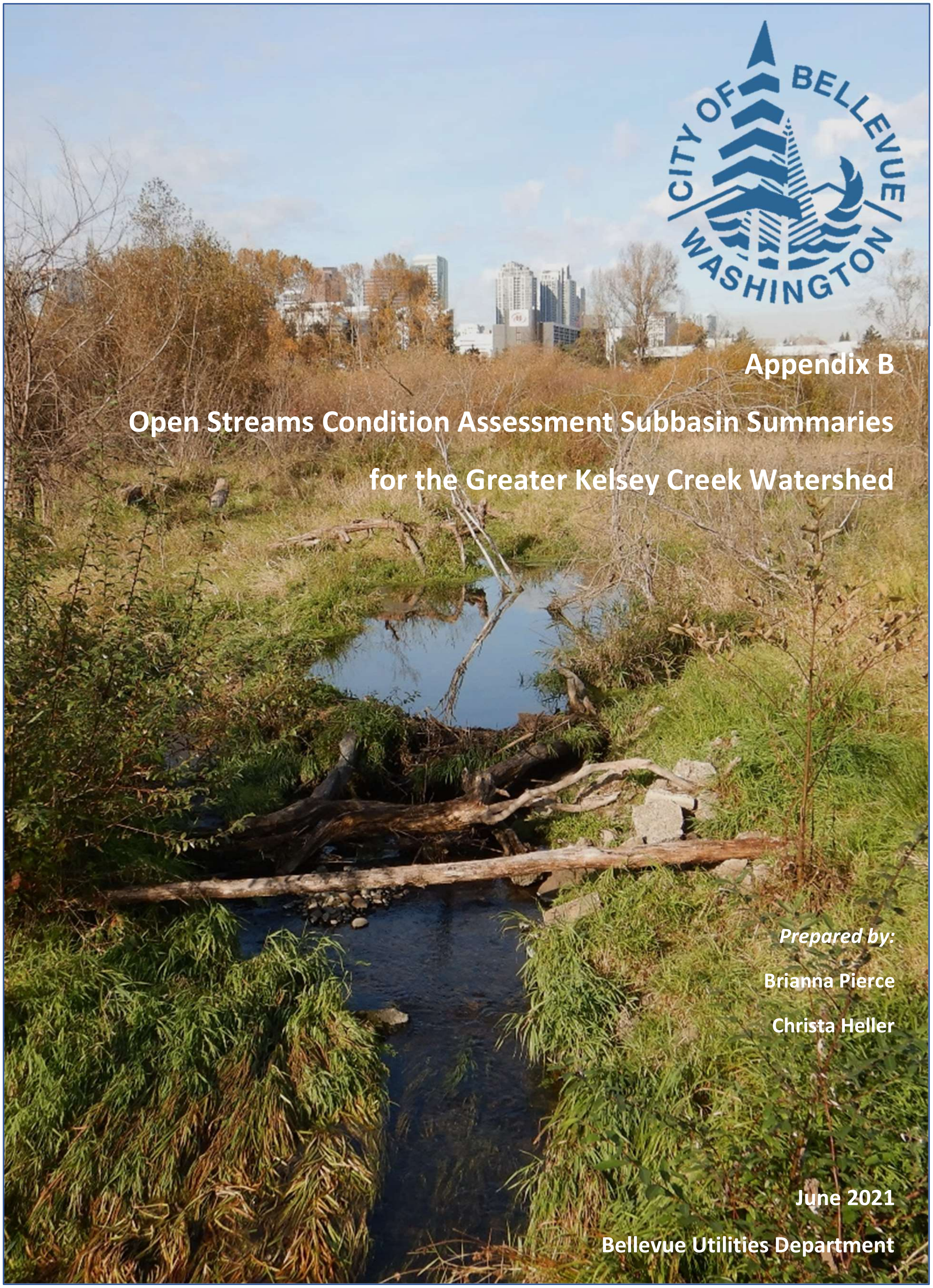
King County, 2020. King County Pictometry Basemap Aerial 2019. Available at https://gismaps.kingcounty.gov/arcgis/rest/services/BaseMaps/KingCo_Aerial_2019/MapServer.

OCM Partners. 2020. 2016 - 2017 PSLC Lidar DEM: King County, WA, https://www.fisheries.noaa.gov/inport/item/53392.

USGS, 2020. Washington Division of Geology and Earth Resources, 2016, Surface geology, 1:100,000--GIS data, November 2016: Washington Division of Geology and Earth Resources Digital Data Series DS-18, version 3.1, previously released June 2010.

WDFW. 2020. Salmonscape fish distribution. Washington State Department of Fish and Wildlife. Online mapping accessed in summer, 2020 at: http://apps.wdfw.wa.gov/salmonscape/.

Appendix B
Open Streams Condition Assessment Subbasin Summaries for the Kelsey Creek Watershed



Appendix B

Open Streams Condition Assessment Subbasin Summaries for the Greater Kelsey Creek Watershed

Prepared by:

Brianna Pierce

Christa Heller

June 2021

Bellevue Utilities Department

Table of Contents

B.1 Introduction

The Open Streams Condition Assessment (OSCA) is a strategic initiative from the City of Bellevue's Storm and Surface Water System Plan (Bellevue 2015). OSCA surveys took place during low-flow conditions between 2018 and 2020. The purpose of the surveys was to establish a baseline, and document current conditions and challenges facing Bellevue's streams. This information can then be used to inform and prioritize infrastructure enhancements and habitat restoration activities to promote stream health and function of the City's storm and surface waters. This appendix summarizes data and qualitative observations gathered during OSCA surveys for eight subbasins in the Greater Kelsey Creek Watershed.

B.2 Methods

B.2.1 Rationale for Protocol and Metric Selection

The US Forest Service Region 6 Level II Stream Inventory Protocol Version 2.12 (USFS 2012) was selected due to its rapid, repeatable, and unbiased design. Its watershed approach to habitat assessment allows a comprehensive baseline dataset to be established that will help the Utilities Department define and prioritize its role as a steward of Bellevue streams. Results from this comprehensive survey will help fill data gaps and identify project sites for capital improvement, fish habitat enhancement, and mitigation projects and opportunities. The USFS 2012 protocol does not collect physical habitat metrics for wetland reaches.

Physical habitat metrics in this study were selected based on their biological importance to stream health and/or their role as indicators of stream degradation.

- *Channel dimensions:* Altered hydrology can impact the stream size and channel dimensions, often resulting in wider, more incised channels (Chin 2006). Streams in healthy, "properly functioning" condition are expected to have a bankfull width to depth ratio of less than 10 (NOAA 1996). Conversely, channel modifications such as bank armoring can reduce the channel width. Additionally, urban streams tend to have less flow, and therefore shallower water depths, during the dry summer months. This can create low flow barriers for migratory fishes. Migrating adult trout require a minimum depth of 0.4 ft and Chinook salmon require at least 0.8 ft (Thompson 1972).
- *Pools:* Pools provide a velocity and thermal refuge as well as a refuge when steam flows decrease and water depths elsewhere in the channel become too low. For salmon, pools provide beneficial foraging habitat for juveniles (Naman *et al.* 2018) and resting areas for adults migrating to the spawning grounds. Pool frequency and volume is positively correlated to salmon production (Nickelson *et al.* 1979). Therefore, pool frequency, expressed as either pools per unit length or channel widths per pool, is a useful indicator of stream health (NOAA 1996). Pool depth is also an important metric. The residual pool depth is defined as the pool depth if stream flow was reduced to zero (i.e., maximum pool depth minus the pool tailout depth). The residual pool depth necessary for resident adult trout is one foot (Behnke 1992) and salmon are generally considered to require a residual pool depth of three or more feet (Marcotte 1984 as cited in CDFG 1998, NOAA 1996).

- *Habitat composition:* Streams impacted by urbanization tend to have reduced habitat complexity, longer habitat units, and a higher percentage of glide habitats (Riley *et al.* 2005). Channel modifications such as weirs, culverts, failed bank armoring, or sediment detention ponds can also alter the habitat composition of a stream. Having a mixture of both fast- and slow-water habitat increases the diversity of stream-dwelling organisms, and juvenile salmonid productivity is highest when there is a roughly equal proportion of riffle and pool habitat area (Naman *et al.* 2018).
- *Large woody material:* Large woody material (LWM) increases habitat complexity by aiding pool formation and providing cover, facilitates trapping and sorting of sediments, and attenuates flow velocities (Bisson *et al.* 1987). Salmonid abundance is positively correlated with LWM abundance (Hicks *et al.* 1991) and dwindling levels of LWM from land use practices have been implicated in the decline of salmon populations. Studies that have determined the LWM abundance in relatively unimpacted streams (e.g., Fox and Bolton 2007) provide a useful reference benchmark for comparing LWM abundance. Such studies often present both the abundance and volume of wood present. However, since secondary growth, urban riparian areas cannot be expected to contain the large, old growth trees present at reference sites, the present study will only compare wood abundance.
- *Substrate:* Substrate size is highly influential to stream biota, determining the algal and macroinvertebrate communities and structuring the food web. Substrate size also determines the available fish spawning habitat. Salmonids require gravel to cobble-sized substrate for spawning, and a high percentage of fine sediment can trap or suffocate the eggs and juveniles of gravel-spawning fish (Bjornn and Reiser 1991).
- *Erosion:* Erosion is a natural process; however, altered hydrology and reduced riparian vegetation in urban areas frequently contribute to increased bank instability (May *et al.* 1998). Therefore, the percent of banks experiencing erosion can be a useful indicator of degradation but should be interpreted while considering the stream's position and function in the watershed.
- *Bank armoring:* Channel hardening results in altered habitat composition, flow, erosion, and sediment deposition (Stein *et al.* 2012), frequently disconnecting the stream from its floodplain. The percent of stream banks that are armored strongly correlates with urban impact. However, the type of armoring can strongly influence its impact on the stream. Bioengineering, or "soft" armoring, that uses rounded boulders, rootwads, and logs can provide bank stabilization while mimicking and facilitating natural stream processes. Therefore, this study presents both the total percent armored banks and the percent bioengineered banks.

B.2.2 Physical Habitat Assessment

Minor modifications were made to the Forest Service (USFS 2012) protocol. Instead of estimating widths and depths and developing statistically valid correction factors for each observer on each stream, actual measurements were collected at representative locations along each habitat unit using a laser range finder, measuring tape and/or stadia rod. A minimum of two thalweg depths, representative and maximum, were collected per habitat unit. The thalweg length of every habitat unit was measured using a hip chain or measuring tape. Habitat units were categorized as a pool, riffle, glide, step pool, side channel, pond, or tributary. Other habitat features such as chutes, falls, beaver dams, or seeps/springs were noted. Streambed substrate was visually estimated for fast water units (riffles and glides) as fines, gravel, cobble, boulder, and bedrock (or hardpan). Floodprone widths, bankfull depths, and Wolman pebble counts were not collected as part of this assessment.

Three levels of assessment were established to efficiently survey the basin to the greatest extent possible. **Table B-1** details the decision matrix and level of effort associated with the three assessment levels. Level 1 inventory methods were utilized in the mainstem and significant fish bearing streams, whereas Level 2 or 3 inventory methods were used to evaluate the condition and health of steep tributaries and headwater portions throughout the basin.

Geomorphic stream reaches within the jurisdictional boundaries of Bellevue were delineated and verified as part of this stream habitat assessment. It is assumed that these same reaches will be used in future assessments to maintain consistency for their evaluation over time. All surveys took place during low or base stream flows.

Table B-1. Decision matrix for determining the level of assessment.

Assessment	Scale	Fish Use *	Summary
Level 1	Habitat Unit	F/PF	Full inventory at the habitat unit level for habitat and substrate composition; unit length, width, depth; bank instability/armoring; LWM; photo documentation; and reference points (including channel profile data).
Level 2	Reach	F/PF/NF	Simplified inventory at the reach scale. Includes quantification of LWM, armoring, bank instability with data for pool and side channel habitat types and basic channel profile data. Photo documentation and documentation of tributaries and off-channel areas.
Level 3	Reach to Basin	Primarily NF	Consists primarily of spot checks with alerts, photo documentation, and general qualitative observations.

* Fish use categories relate to water type classifications where “F/PF” denotes a stream used by fish or has the potential to support fish populations and has perennial flow; “F/PF/NF” denotes a stream that may be used by fish, but that may have reaches above a natural barrier, may be intermittent, or not have flowing water all year; “NF” denotes a stream that is not used by fish and that does not have perennial flow.

B.2.2.1 Large Woody Material

Pieces of large woody material (LWM) were categorized by length, diameter, and position within the stream channel based on protocols for Wadeable Streams of Western Washington (Ecology 2009). Wood counts by size class were converted to volume using the formula established by Robison (1998). Wood smaller than the minimum length and diameter thresholds in **Table B-2** were not counted but may have contributed to the creation of log jams with small woody material. All LWM were noted as naturally recruited or human-placed. Human-placed logs were further identified as being anchored or unanchored. Log jams were also noted, and for Level 1 surveys, the habitat type in which the wood was located was also recorded, but those data are not included in this report.

Table B-2. Size categories for large woody material.

Length	Diameter
Short (6-16 feet)	Thin (4-12 inches)
Medium (16-50 feet)	Medium (12-24 inches)
Long (>50 feet)	Wide (>24inches)

B.2.2.2 Riparian and Streambank Condition

Riparian vegetation was not quantitatively assessed during the stream habitat surveys but was generally characterized using Geographic Information System (GIS) aerial imagery and field verified at the reach scale. Stands of Japanese knotweed (knotweed) were mapped and measured as a lineal metric and density described as low (less than 10 square feet), medium (10-500 square feet), or high (greater than 500 square feet).

Streambank erosion and armoring were each mapped and measured as a linear metric and described as low (less than 5 feet), medium (5-10 feet) or high (greater than 10 feet). Undercut banks were noted and measured; a representative measurement was recorded for each incidence of erosion or scour, and the maximum was noted if it was substantially greater than the representative value. Bank armoring material was documented and specified as riprap, rocks, metal, concrete, gabion baskets, logs, rootwads, bioengineering, etc.

Anthropogenic features such as culverts, bridges, weirs, outfalls, and litter were also documented when observed but are generally not included in this report.

B.2.2.3 Fish Habitat and Passage Barriers

Fish presence was documented by species, when possible, and abundance was estimated as low, medium, or high. Field protocols for this habitat assessment did not include a formal fish survey nor a fish passage barrier assessment, although locations of potential barriers, type and material of barrier, jump heights, and photos were collected. This information will aid further investigations through Bellevue's Fish Passage Improvement Program.

B.2.3 Stream Reach Attributes

In addition to the physical stream habitat data collected during the OSCA surveys, this report also presents a table for each subbasin with metrics that describe stream attributes at the reach level. These attributes include sediment dynamics, channel type, stream gradient, drainage area, riparian canopy cover, riparian impervious surfaces cover, and reach length. Appendix A of this report provides greater detail on the methods and data sources used for the numerical calculations.

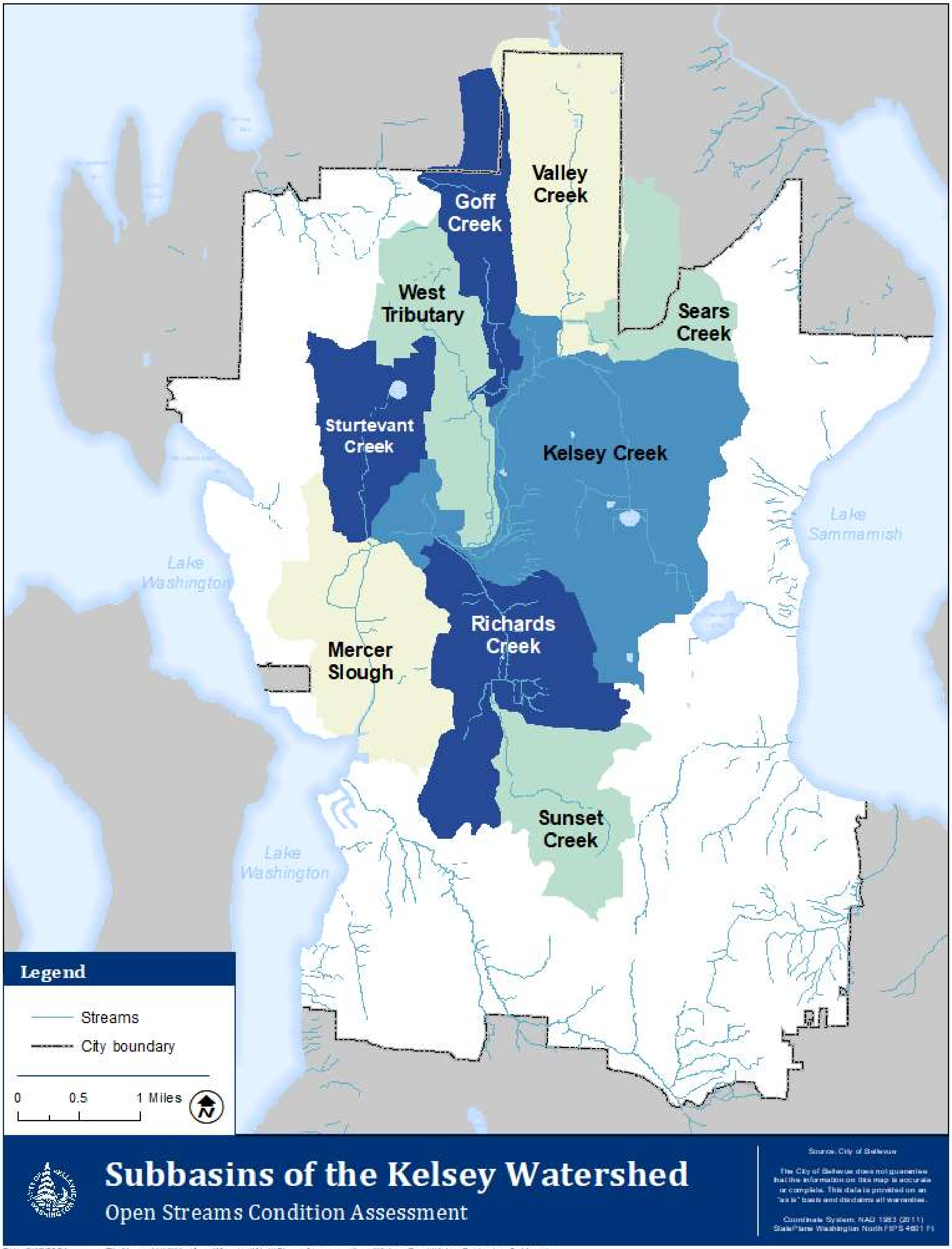
A brief description of each attribute is as follows:

- *Sediment dynamics*: Describes the relationship between sediment supply and transport capacity as described by Montgomery and Buffington (1998). Stream reaches are designated as source, transport, or response reaches. Channel modifications may alter the sediment dynamics of the reach. In such cases, the sediment dynamics classification is given the "forced" modifier. For example, piped conveyances are considered "forced transport" reaches.

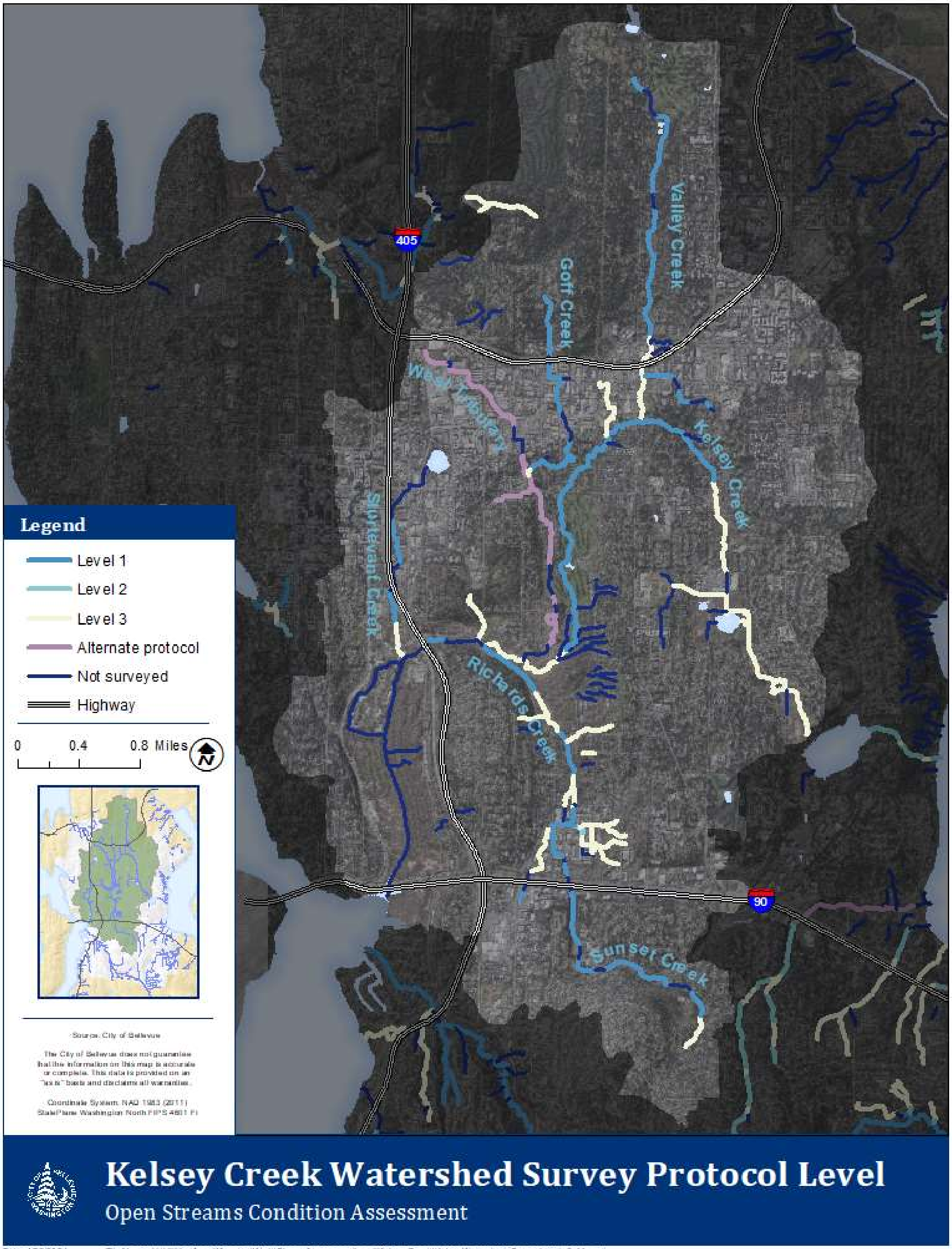
- *Channel type*: Classification given to each stream reach based on its bedform characteristics. These classifications are based on those established by Montgomery and Buffington (1998). However, due to the topography and highly modified environment throughout the City, additional channel types are defined as necessary. When a stream reach exhibits a different channel type than expected given the topography and hydrology, the classification is given the “forced” modifier. Channel types may be forced by an abundance of LWM, beaver dams, weirs, artificially confined streambanks, etc.
- *Stream gradient*: The overall gradient or percent slope of the stream reach, computed as the difference in the start and end point elevations divided by the reach length.
- *Drainage area*: The total land area that drains into each stream reach.
- *Riparian canopy cover*: Proportion of the area within 100 ft of the stream centerline that is covered by tree canopy. This metric is omitted for stream reaches that are piped.
- *Riparian impervious surfaces*: Proportion of the area within 100 ft of the stream centerline that is covered by impervious surfaces. This metric is retained for reaches that are piped because it can help inform daylighting opportunities. For example, a piped reach that is covered by 5% impervious surfaces would potentially be much easier to daylight than a piped reach covered by 70% impervious surfaces.
- *Reach length*: Total length of each stream reach, derived from GIS stream stationing.

B.3 Summary of Results

The Greater Kelsey Creek Watershed includes more than one-third of the open streams present in the City of Bellevue (**Map B-1**). As part of the Open Streams Condition Assessment (OSCA), Sturtevant, Richards, Sunset, Goff, Valley, and Sears Creek subbasins were surveyed in the spring to fall of 2019, and the mainstem of Kelsey Creek was primarily surveyed in the summer of 2020, although Reach 2 was surveyed the preceding fall. Mercer Slough was not surveyed during the OSCA project as it is not wadeable. The West Tributary of Kelsey Creek (West Tributary) was surveyed in 2016 under a different protocol (Tetra Tech 2016). **Map B-2** and **Table B-3** present the surveyed streams within the Greater Kelsey Creek Watershed and the survey level used for each. Stream reaches surveyed under a Level 3 assessment level are included in the table for completeness, but the data for those reaches are not presented in this report. Hereafter, the phrase “surveyed reaches” will apply to stream reaches assessed under a Level 1 or Level 2 protocol.



Map B-1. The nine subbasins of the Greater Kelsey Creek Watershed.



Map B-2. Map showing the survey protocol level used for streams in the Greater Kelsey Creek Watershed.

Table B-3. List of inventoried Bellevue streams, including Bellevue Stream Segment number and Water Resource Inventory Area (WRIA) number, organized from downstream to upstream.

Stream Name	WRIA #	Bellevue Stream Reach	Bellevue Segment ID	Assessment Level
Sturtevant Creek	08.0260	Reach 1	75_01	3
		Reach 2	75_02	1
		Reach 4	75_04	1
		Reach 5	75_05	1
Kelsey Creek	08.0259	Reach 2	76_02	1
		Reach 4	76_04	3
		Reach 5	76_05	1
		Reach 6	76_06	1
		Reach 7	76_07	1
		Reach 8	76_08	1
		Reach 9	76_09	1
		Reach 10	76_10	3
		Reach 11	76_11	3
		Reach 13	76_13	3
		Reach 14	76_14	3
Wilburton Tributary	-	Reach 1	76_03_11	3
		Reach 2	76_03_12	3
Unnamed Tributary	08.0265N	Reach 1	76_07_21	3
		Reach 2	76_07_22	3
		Reach 3	76_07_23	3
		Reach 4	76_07_24	3
		Reach 5	76_07_25	3
Unnamed Tributary	-	Reach 1	76_11_11	3
Richards Creek	08.0261	Reach 1	77_01	1
		Reach 2	77_02	3
		Reach 3	77_03	1
		Reach 4	77_04	3
		Reach 5	77_05	1, 3
		Reach 6	77_06	3
		Reach 8	77_08	1
Unnamed Tributary	-	Reach 1	77_02_11	3
		Reach 2	77_02_12	3
		Reach 3	77_02_13	3
Unnamed Tributary	-	Reach 1	77_03_11	3
		Reach 1	77_03_21	3
East Creek	-	Reach 1	78_01	1
		Reach 2	78_02	2
		Reach 3	78_03	3
		Reach 4	78_04	3

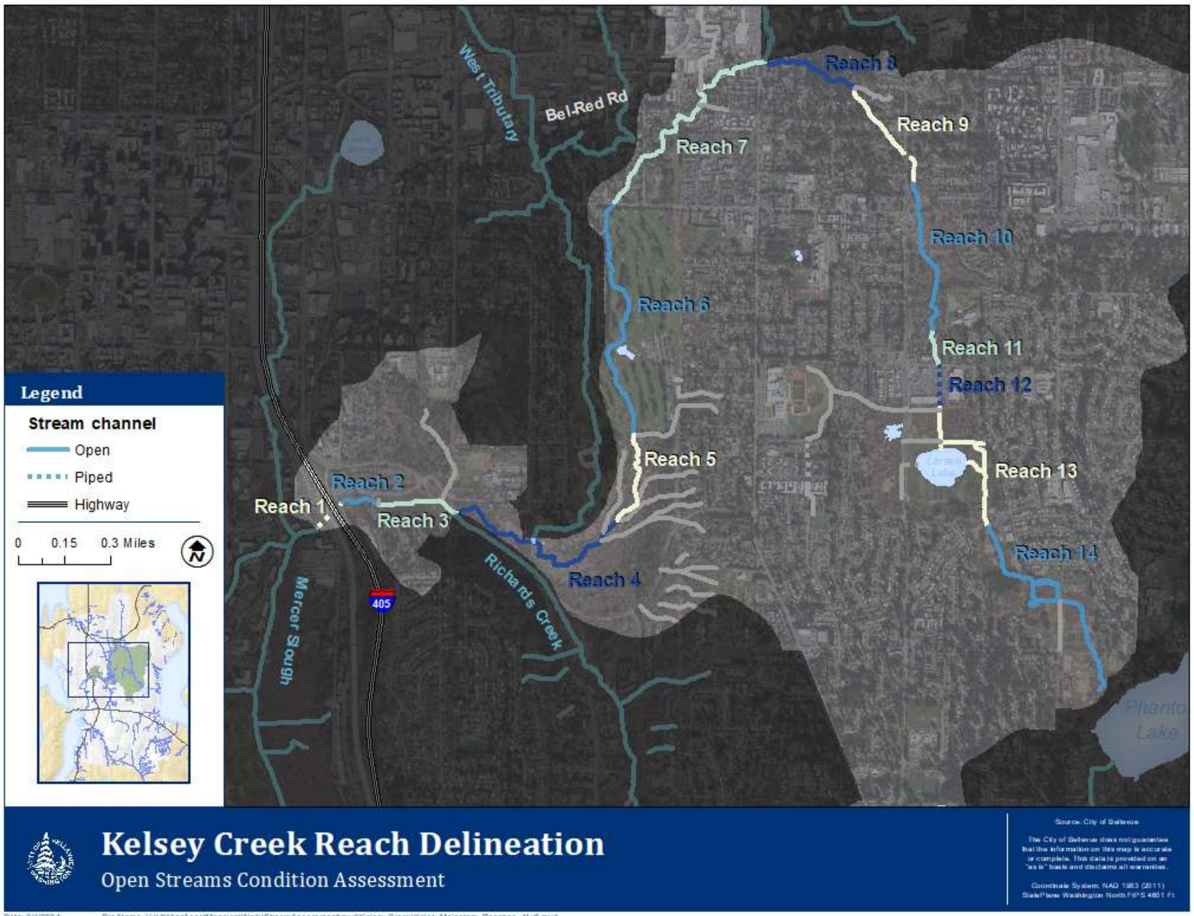
East Creek Tributary 0263A	08.0263A	Reach 1	78_02_11	3
Unnamed Tributary	-	Reach 1	78_02_11_11	3
Unnamed Tributary	-	Reach 1	78_03_11	3
Unnamed Tributary	-	Reach 1	78_03_11_11	3
Unnamed Tributary	-	Reach 1	78_04_11	3
Sunset Creek	08.0262	Reach 1	79_01	1
		Reach 3	79_03	1
		Reach 5	79_05	1
		Reach 7	79_07	1
		Reach 8	79_08	1
		Reach 10	79_10	1
		Reach 11	79_11	1,3
		Reach 12	79_12	3
West Tributary	08.0264	Reach 0	80_00	*
		Reach 1	80_01	*
		Reach 2	80_02	*
		Reach 3	80_03	*
		Reach 4	80_04	*
		Reach 6	80_06	*
		Reach 8	80_08	*
Tributary 0264A	08.0264A	Reach 1	80_03_1	*
Goff Creek	-	Reach 1	81_01	3
		Reach 2	81_02	1
		Reach 4	81_04	1
		Reach 6	81_06	1
		Reach 7	81_07	1
		Reach 8	81_08	1
Valley Creek	08.0266	Reach 1	82_01	3
		Reach 2	82_02	3
		Reach 4	82_04	3
		Reach 5	82_05	3
		Reach 6	82_06	1
		Reach 7	82_07	1
		Reach 9	82_09	1
Sears Creek	-	Reach 1	83_01	1
		Reach 3	83_03	1
		Reach 5	83_05	1

* The West Tributary and Tributary 0264A were surveyed under a different protocol (Tetra Tech 2016).

B.3.1 KELSEY CREEK SUBBASIN

Located in the middle of the City, Kelsey Creek flows through numerous neighborhoods, including Lake Hills, Crossroads, Bel-Red, Wilburton, Woodridge, and West Bellevue. In the sense of location and importance to Bellevue communities, Kelsey Creek is truly the heart of the City. The subbasin encompasses 2,891 acres or 13.5% of the City. Land use is highly varied but residential property is most common. Parks and open space account for 15.5% of the subbasin. Elevation ranges from 20 to 449 ft. Overall, there is 10.7 miles of open channel in the subbasin and 57.7 miles of storm drainage pipes (Bellevue 2017).

Historically the headwaters of Kelsey Creek were found in the Phantom Lake area, flowing north through a broad wetland complex to Larsen Lake (**Map B-3**). As development occurred in Bellevue, the outlet of Phantom Lake was redirected towards Lake Sammamish, and much of the upper reaches of Kelsey Creek and its associated wetlands were ditched and modified to accommodate homesteads, farming, and roads. Today, the modified wetlands and ditches south of Larsen Lake act as the present-day headwaters. Kelsey Creek meanders north to a piped conveyance (Reach 12) and wetlands (Reaches 10 and 11) until the road crossing near 148th Avenue NE. The mainstem of Kelsey then flows through mixed commercial and residential properties (Reaches 7-9) until it reaches the Glendale Country Club and Kelsey Creek Park and Open Space (Reaches 5-6) and Kelsey Creek Wetlands (Reach 4). The stream becomes more slough-like (Reaches 2 and 3) before passing under I-405 (Reach 1) and becoming Mercer Slough at a concrete fish ladder that was rebuilt in 2003 to improve fish passage.



Map B-3. Mainstem reaches of Kelsey Creek.

B.3.1.1 Channel Morphology and Riparian Corridor

The Kelsey Creek stream corridor generally consists of a portion of relatively higher gradient pool-riffle and plane-bed channels (Reaches 5 through 9) sandwiched between two large wetland reaches, Reach 4 and 10 (**Table B-4**). However, Mercer Slough transitions into Kelsey Creek at a fish ladder located just east of the I-405 culvert, and the channel is primarily slough-like until it crosses under Lake Hills Connector and enters the wetlands at Kelsey Creek Park (Reach 4). The upper portion of the Kelsey Creek mainstem is highly modified into stormwater detention wetlands, ditched wetland channels, piped conveyance (under the Kelsey Creek Center Shopping Mall parking lot) and agricultural fields that surround Larsen Lake. The overall stream gradient is 0.8%, which is lower than average for streams in the Greater Kelsey Creek Watershed.

Despite varied land use, the Kelsey Creek stream corridor has retained a fairly healthy riparian zone. The riparian canopy cover is moderately good for an urban stream, and the proportion of impervious surfaces within the 100 ft riparian buffer is generally quite low (Table B-4). Native riparian vegetation abounds in the wetland reaches, although reed canary grass is also highly abundant. The middle portion of the Kelsey Creek mainstem (Reach 7-9) is dominated by residential and some commercial development, and riparian vegetation is correspondingly fragmented, although the channel generally retains canopy cover. Invasive knotweed is prevalent along the Kelsey Creek corridor from Reach 5 to

Reach 8 and occasionally forms dense monoclonal stands. Other invasive plant species, including Himalayan blackberry and English ivy, are sporadically prevalent.

Apart from Mercer Slough, the mainstem of Kelsey Creek is the broadest stream in the City of Bellevue. Despite intermittent channel confinement and alterations, the stream generally widens and deepens as you procced downstream (**Figure B-1** and **Figure B-2**). Across all surveyed reaches, the median wetted and bankfull widths are 14.2 ft and 17.0 ft, respectively, and the median representative thalweg depth is 0.9 ft.

Table B-4. Kelsey Creek mainstem reach attributes.

Reach Segment ID	**Reach 1** 76_01	**Reach 2** 76_02	**Reach 3** 76_03	**Reach 4** 76_04	**Reach 5** 76_05	**Reach 6** 76_06	**Reach 7** 76_07
River Mile Boundaries	0.00 – 0.12	0.12 – 0.25	0.25 – 0.53	0.53 – 1.32	1.32 – 1.67	1.67 – 2.55	2.55 – 3.40
Sediment Dynamics	Forced transport	Response	Response	Response	Response	Response	Response
Channel Type	Piped conveyance	Plane-bed	Plane-bed	Wetland	Pool-riffle	Pool-riffle/ Plane-bed	Pool-riffle
Stream Gradient (%)	0.2	2.1	0.6	0.3	0.8	1.4	1.4
Riparian Canopy Cover (%)	-	50	67	6	66	31	54
Riparian Impervious Surface Cover (%)	54	17	7	2	4	9	29
Reach Length (ft)	650	650	1050	4150	1,875	4,625	4,500
Reach Segment ID	**Reach 8** 76_08	**Reach 9** 76_09	**Reach 10** 76_10	**Reach 11** 76_11	**Reach 12** 76_12	**Reach 13** 76_13	**Reach 14** 76_14
River Mile Boundaries	3.40 – 3.76	3.76 – 4.15	4.15 – 4.69	4.69 – 4.81	4.81 – 4.95	4.95 – 5.47	5.47 – 6.26
Sediment Dynamics	Response	Response	Response	Response	Forced transport	-	-
Channel Type	Plane-bed	Plane-bed	Wetland	Ditched wetland	Piped conveyance	Ditched wetland	Ditched wetland
Stream Gradient (%)	1.7	1.8	0.2	0.3	0.1	0.2	0.1
Riparian Canopy Cover (%)	57	63	38	53	-	28	29
Riparian Impervious Surface Cover (%)	24	17	8	24	88	10	6
Reach Length (ft)	1,900	2,050	2,850	650	725	2,775	4,150

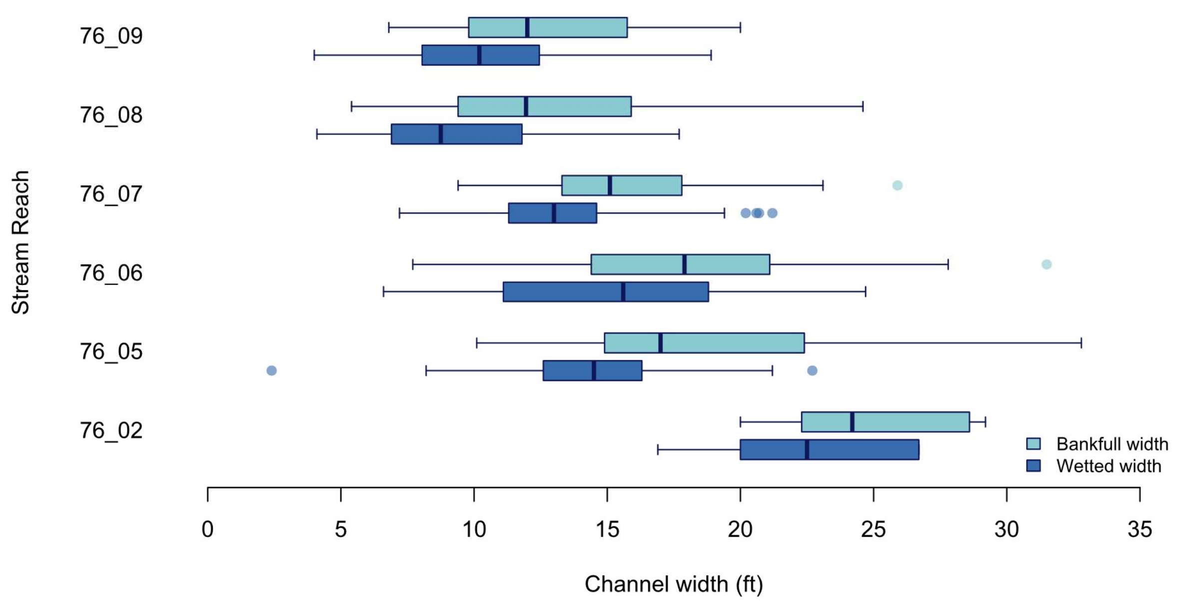


Figure B-1. Boxplot of the wetted and bankfull channel widths for the Kelsey Creek mainstem reaches.

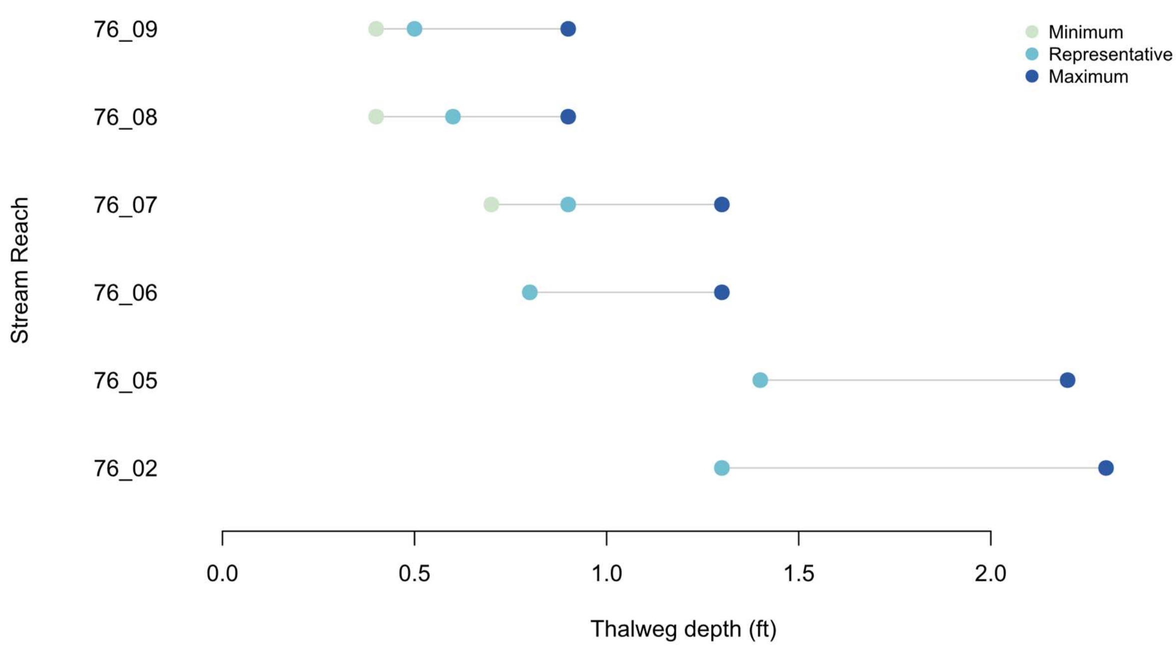


Figure B-2. Dumbbell plot of wetted stream depths for the mainstem reaches of Kelsey Creek. Points represent the median value for the minimum, representative, and maximum depth for each reach. Minimum depths were not recorded for Reaches 2, 5, and 6.

B.3.1.2 Habitat Unit Composition and Off-Channel Habitat

The Kelsey Creek mainstem exhibits a true riffle-pool channel type. Riffle habitat comprises 58% of the stream by area and 63% by length (**Figure B-3** and **Figure B-4)**. Pools are the second-most dominant habitat type comprising 35% of the stream by area and 31% by length. This is the greatest percent pools of any subbasin in the City of Bellevue. Glide habitat makes up the remaining 7% of the stream area (5% by length).

Pool habitat is relatively abundant in the mainstem of Kelsey Creek. The ratio of riffle habitat area to pool habitat area is 1.7, which is the second best observed in the City of Bellevue and approaches the ideal ratio of 1 which has been found to maximize the productivity of juvenile salmonids (Naman *et al.* 2008). Overall, the Kelsey Creek mainstem has a pool frequency of 40 pools per mile or approximately 7.8 bankfull channel widths per pool. Although this falls short of the ideal pool frequency of 50 pools per mile for similarly sized, "properly functioning" streams (NOAA 1996), it is the highest pool frequency observed in any fish-bearing stream in the City of Bellevue. Pools in the Kelsey mainstem are somewhat clustered due to weirs and other channel modifications leading to a relatively low median distance between pools of 48 ft.

Pools in Kelsey Creek are generally deeper than pools found throughout the City of Bellevue and consequently provide better fish habitat. Deep pools provide velocity and thermal refugia for migrating adult salmonids as well as rearing juveniles. In the mainstem of Kelsey Creek, 14% of pools have a maximum depth greater than 3 ft and 5% have a residual depth greater than 3 ft (**Figure B-5**). Although pool depth, in keeping with overall channel depth, decreases upstream, pools with a residual depth greater than 3 ft are present through Reach 7. The history and presence of beaver throughout the subbasin may contribute to the pool frequency and depth observed during the OSCA surveys. Beavers are known to inhabit the lower mainstem reaches through Reach 6 and upper Reaches 10-14.

Off-channel habitat in Kelsey Creek is limited and predominantly restricted to wetland Reaches 4 and 10. These wetland reaches provide numerous braided channels and edge habitat providing quality aquatic habitat. In the primary stream reaches, only one short side channel habitat unit is present in Reach 5, and it was partially dry at the time of the survey in late June of 2020. Reach 5 (in Kelsey Creek Park) provides a connected floodplain and allows natural channel migration, evidence of which was observed during the surveys. Off-channel habitat is limited throughout the upstream reaches of the Kelsey Creek mainstem, as they are confined by residential and commercial development that consequently restricts natural channel processes. Wetland Reaches 4, 10, and 11 provide stormwater retention capacity and significant water quality benefits. In particular, Reach 4 provides quality rearing habitat for juvenile salmonids and other fishes.

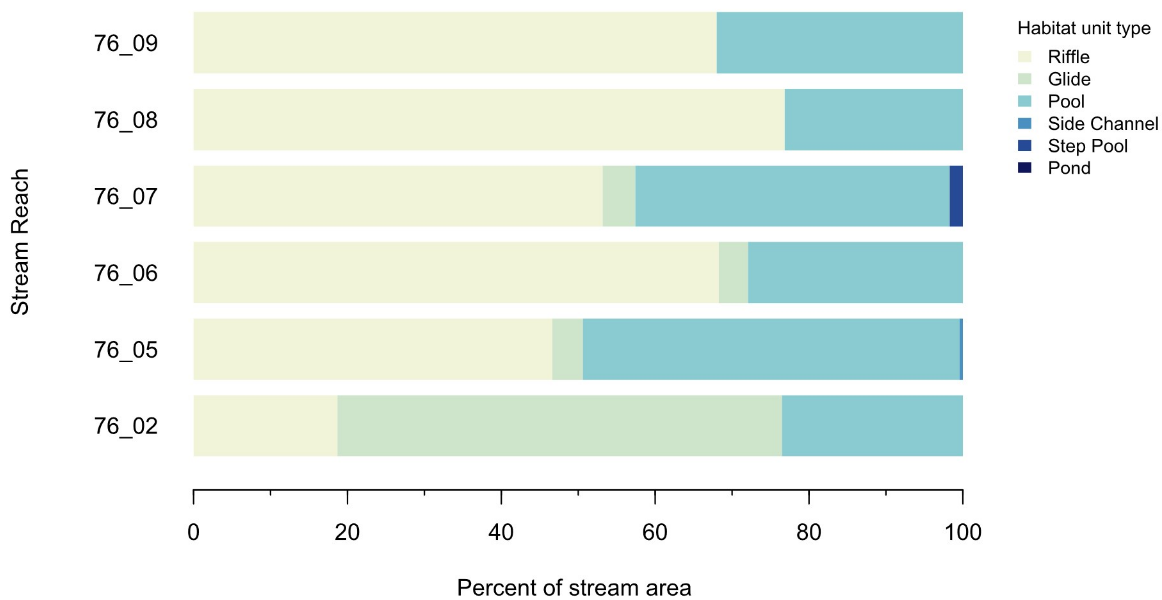


Figure B-3. Habitat unit composition (by percent area) of the Kelsey Creek mainstem reaches.

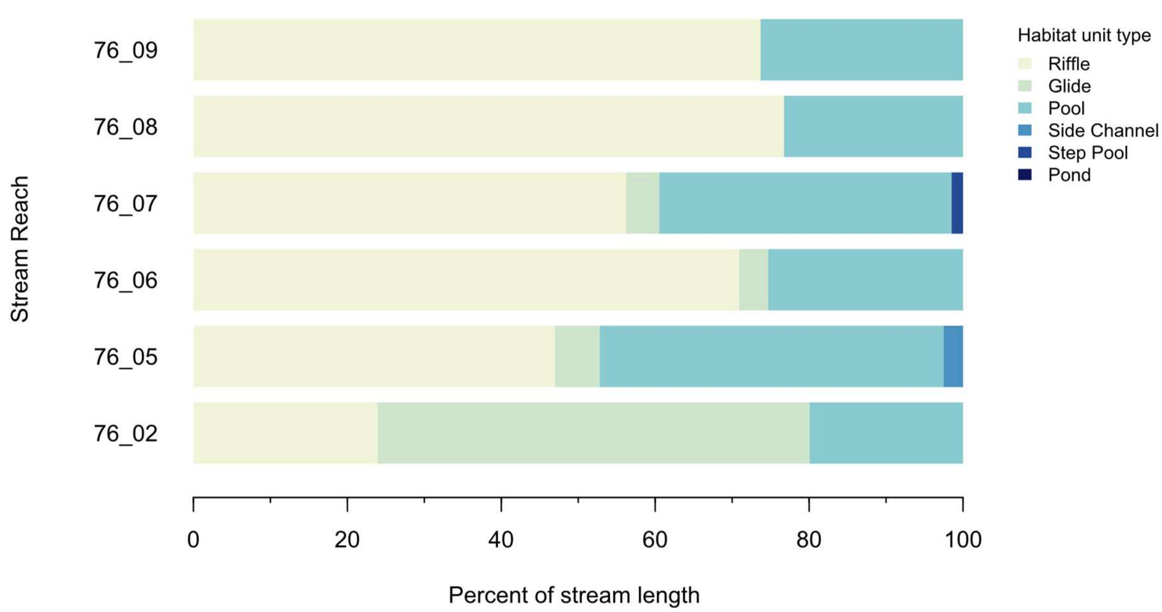


Figure B-4. Habitat unit composition (by percent length) of the Kelsey Creek mainstem reaches.

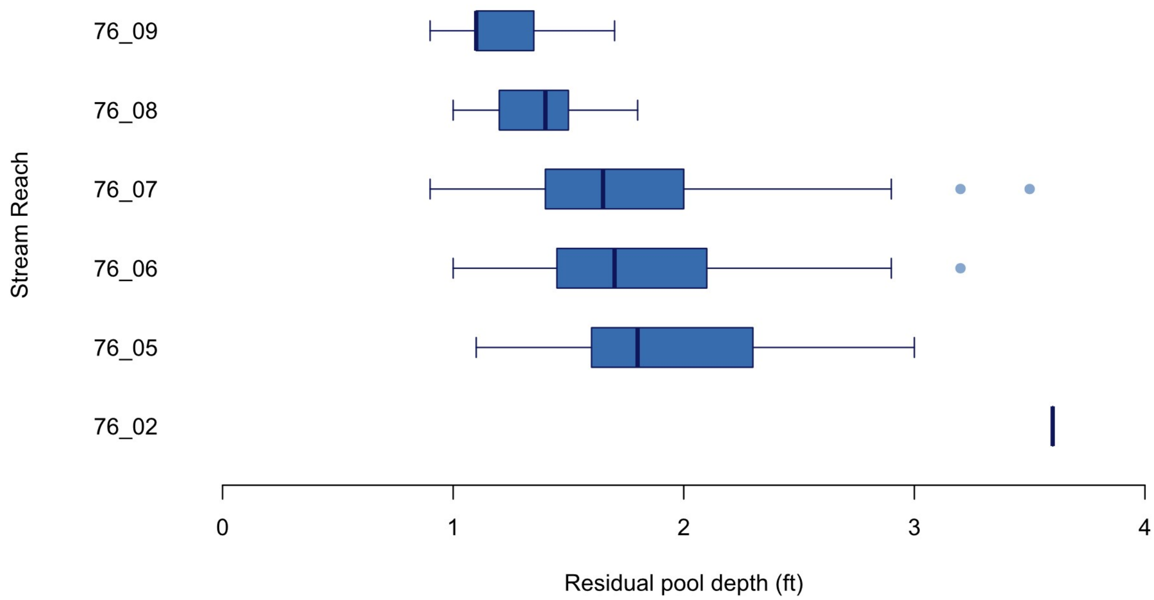


Figure B-5. Boxplot of residual pool depths observed in the mainstem reaches of Kelsey Creek.

B.3.1.3 Large Woody Material

The mainstem of Kelsey Creek has rather low levels of large woody material (LWM; **Figure B-6**). The overall wood density for surveyed reaches is 154 pieces per mile (10 pieces per 100 m). This wood density is far below the levels expected in similarly sized, un-impaired streams (Fox and Bolton 2007) but is slightly above average for subbasins in the Greater Kelsey Creek Watershed. In general, Kelsey Creek has a moderate riparian canopy, so there is the potential for natural recruitment of LWM. However, education and outreach to streamside property owners about the benefits of leaving fallen trees may be necessary, and natural recruitment alone will be insufficient to restore LWM density to levels necessary for subbasin recovery.

Beavers also play a notable role in LWM recruitment throughout the Kelsey Creek mainstem. Small woody material contributes to dams observed in Reaches 2-5 and 10-14. Beaver activity that contributes to overbank flooding and expansion of the existing wetlands may impact the surrounding trees and may even cause tree mortality. These trees should be retained when safety allows for general habitat benefits and LWM recruitment potential.

Numerous projects have contributed LWM to the Kelsey Creek corridor (**Figure B-7**). Overall, 19% of the observed LWM has been placed. Reach 6 (along the Glendale Country Club Golf Course) has particularly benefited from stream enhancement projects with 71% of the observed LWM being placed.

LWM is likely influential in forming and maintaining pool habitat in Kelsey Creek. LWM frequency is equivalent in riffle and glide habitat (21% of all wood is found in each habitat type), yet it is much greater in pool habitat. Overall, 41% of all LWM in Kelsey Creek occurs in pool habitat. Furthermore, Kelsey Creek has the highest proportion (70%) of LWM that is actively engaging the wetted channel out of all subbasins in the Greater Kelsey Creek Watershed. This is likely due, at least in part, to the channel's size.

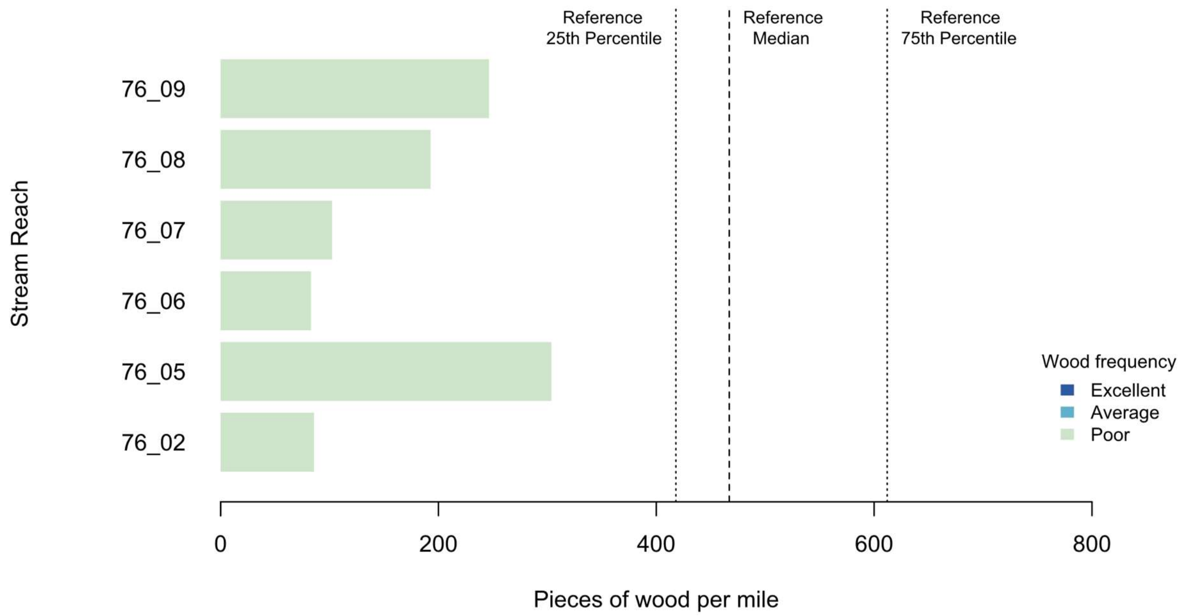


Figure B-6. Large woody material frequency in the mainstem of Kelsey Creek compared to reference levels (Fox and Bolton 2007).

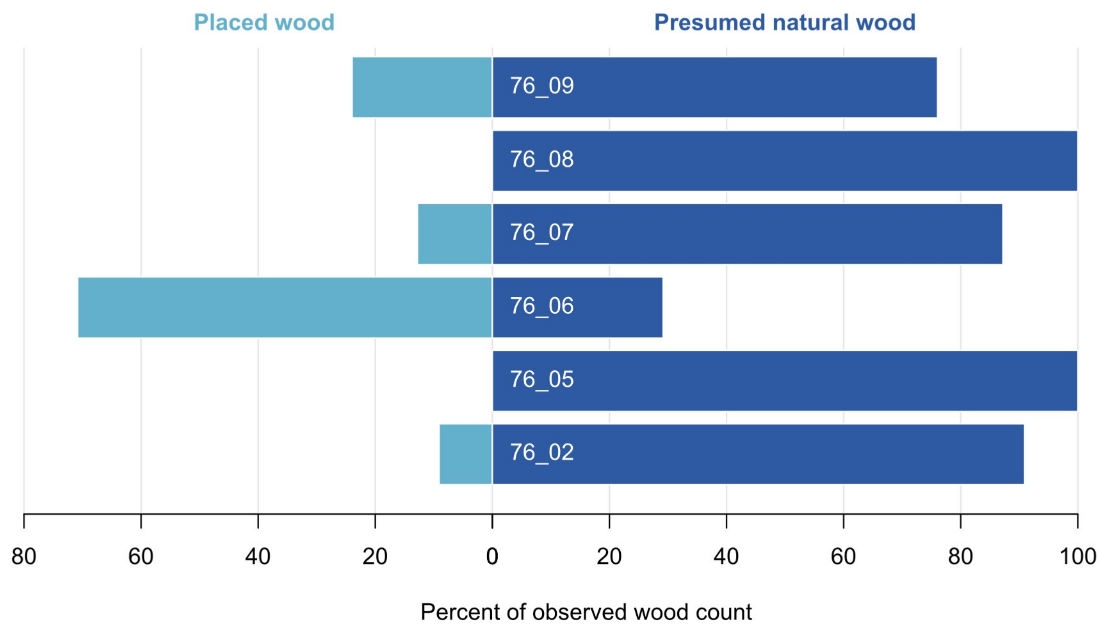


Figure B-7. Diverging bar graph showing the proportion of wood observed in each stream reach of the mainstem of Kelsey Creek that is of natural origin or was placed.

B.3.1.4 Streambed Substrate

Substrate composition for riffle habitats in the mainstem of Kelsey Creek (**Figure B-8**) is predominantly gravels and cobbles throughout the stream corridor, consistent with sizes suitable for fish spawning and rearing habitat. Fines consistently account for just under a quarter of the substrate composition in riffle habitat, which is higher than ideal for salmonid spawning but is lower than that found in all other subbasins in the Greater Kelsey Creek Watershed. Exposed hardpan glacial till accounts for 10% of the substrate in fast water (riffle and glide) habitat in Reach 2 and is sporadically observed in Reaches 5 and 9. Qualitative habitat observations from the late 2000s document significant streambed scour and exposed hardpan throughout Reach 5, yet these appear to have filled in and become less significant by the time of the OSCA survey in 2020. Gravels are continuing to migrate downstream through Reach 5 and into the upper portion of the wetland Reach 4, potentially increasing spawning habitat.

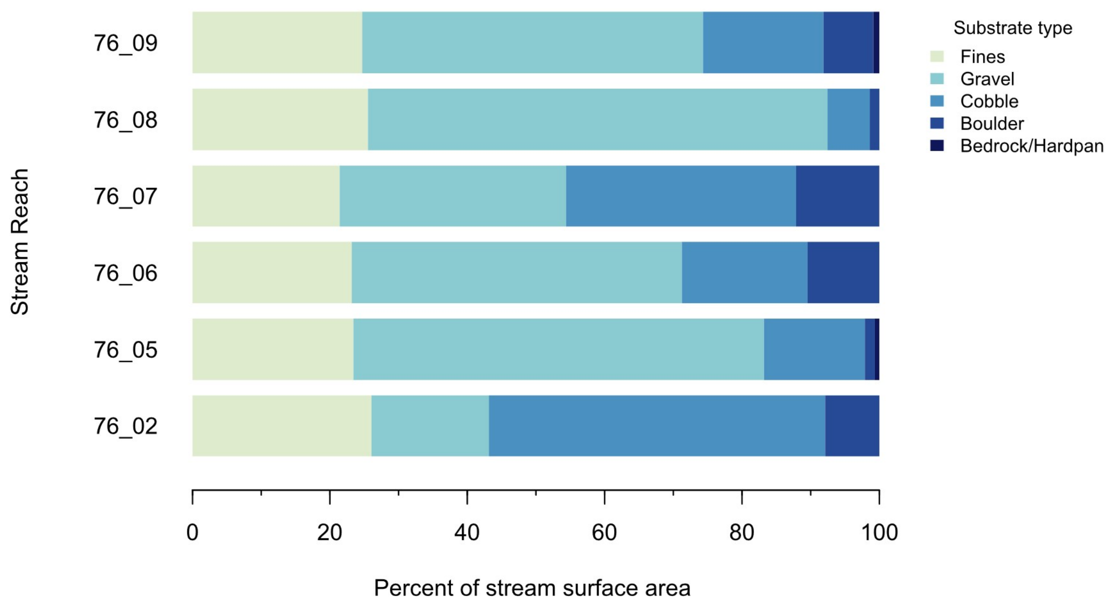


Figure B-8. Substrate composition of riffle habitat in the Kelsey Creek mainstem reaches, determined by visual estimation.

B.3.1.5 Streambank Conditions

Streambank armoring is relatively frequent along the mainstem of Kelsey Creek (**Figure B-9**). Overall, 28% of the streambank in surveyed reaches is armored, which is approximately average for subbasins in the Greater Kelsey Creek Watershed but greater than average for subbasins within the City of Bellevue. The degree of streambank armoring varies considerably among reaches. Reach 5, which passes through the Kelsey Creek Park, has the least armoring with only 1% of its streambanks armored. Reach 7 has the most extensive streambank armoring with 50% of its streambanks armored as it passes through residential, multi-family, and office parcels. Throughout the mainstem of Kelsey Creek, streambank armoring is generally patchy and short in extent as it is often associated with individual parcels; most individual instances of armoring are less than 50 ft in length, although some streambank armoring in Reach 7 extends for 200 to 500 ft. Most of the streambank armoring in Kelsey Creek is traditional or “hard” armoring, predominantly large angular rock. Bioengineered armoring only accounts for 2% of the total stream length or 7% of all armoring.

Streambank erosion and undercutting in the Kelsey Creek mainstem is slightly higher than average for the Greater Kelsey Watershed. A total of 15% of the surveyed streambanks are experiencing erosion (**Figure B-10**) and 9% of the streambanks are undercut (**Figure B-11**). By comparison, for the entire Greater Kelsey Creek Watershed, 11% of the streambanks are eroding and 7% are undercut. Reach 2, which is large and more closely resembles Mercer Slough than the rest of Kelsey Creek, has the least erosion with only 4% of its streambanks experiencing erosion. Reach 7, which is Kelsey Creek’s most urban-impacted reach, has the most frequent erosion with 20% of is streambanks showing evidence of erosion.

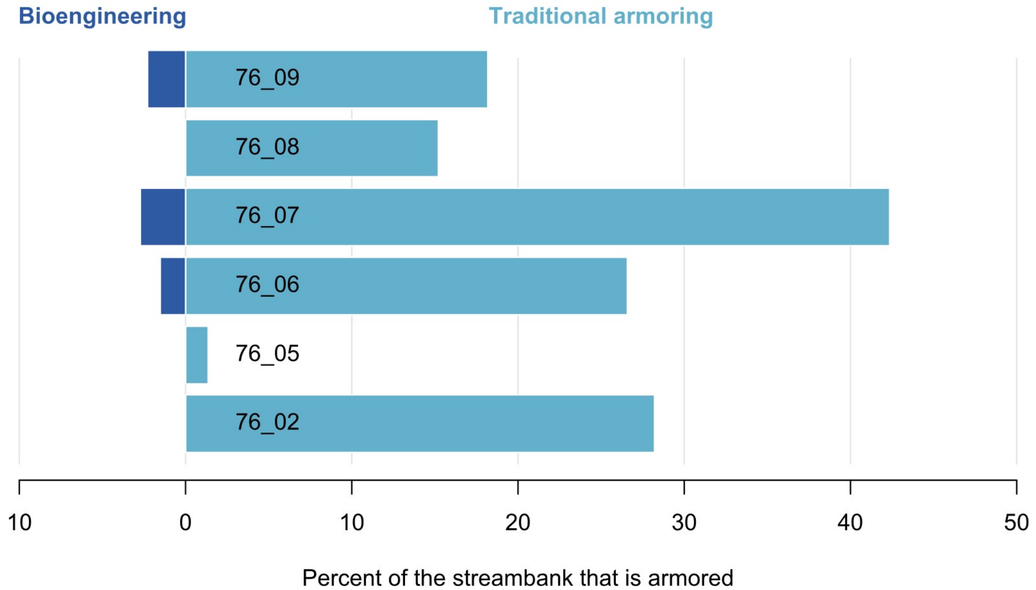


Figure B-9. Diverging bar graph showing the proportion of the streambank that is armored using traditional materials (right) and bioengineering (left) for the mainstem reaches of Kelsey Creek.

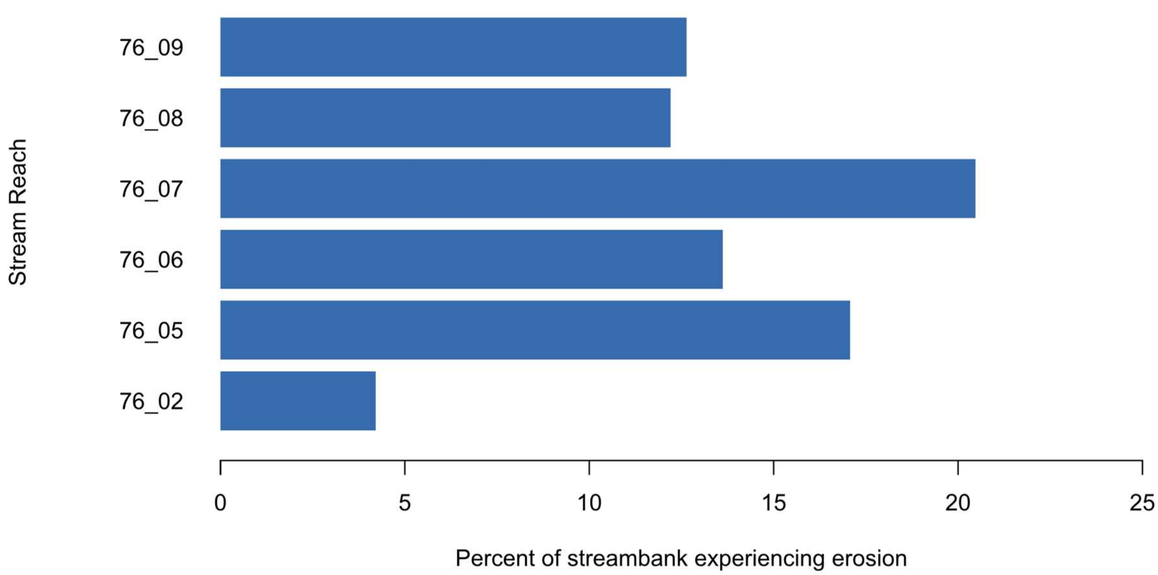


Figure B-10. Percent of each Kelsey Creek mainstem reach that is experiencing erosion.

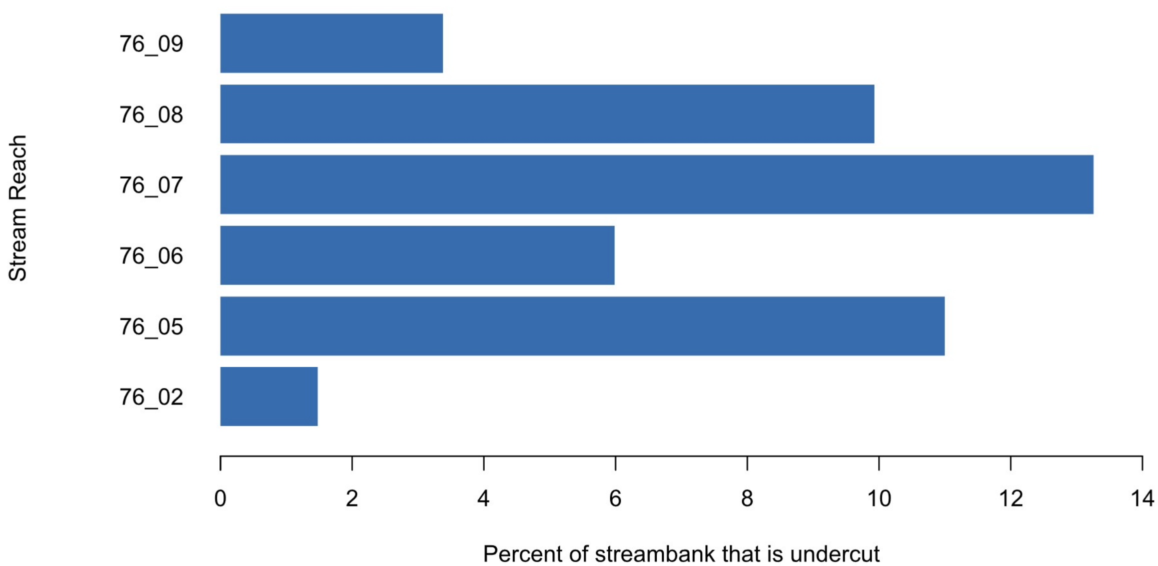


Figure B-11. Percent of each Kelsey Creek mainstem reach with undercut streambanks.

B.3.1.6 Fish Habitat and Passage Barriers

Kelsey Creek provides some of the best fish habitat found in the City of Bellevue. Fish were observed during OSCA surveys through Reach 9. However, fish abundance and diversity are greatest in Reaches 5 and 6 where trout, sculpin, and lamprey are frequently observed. Additionally, Kelsey Creek has one of the most well-known and abundant adfluvial Cutthroat Trout populations documented in the greater Lake Washington watershed, and Peamouth Minnows return to lower Kelsey Creek each spring to spawn. Ample pool habitat likely contributes to these successful fish populations. During OSCA surveys, fish were observed in nearly half (45%) of all pool habitat units.

The mainstem of Kelsey Creek has historically supported spawning Sockeye, Chinook, and Coho salmon. Salmon spawning habitat extends towards the end of Reach 9 near 148th Avenue NE. The number of returning spawners has dwindled dramatically in the last 15 years (WDFW 2020). The cause of this decline is certainly multifaceted, but fish passage barriers in Mercer Slough and Kelsey Creek likely play a key role. Additionally, water quality is a primary concern. In 2013 and 2014, surplus Coho Salmon adults returning to the Issaquah hatchery were transported and released into Kelsey Creek, but this effort was abandoned following very high rates of pre-spawn mortality presumably related to toxicity from stormwater runoff.

There are several physical obstructions in the mainstem of Kelsey Creek that may impede fish migration. WDFW has documented three partial and one complete fish passage barrier (WDFW 2021). The partial barriers include the City-owned culvert under 121st Avenue SE, a series of City-owned weirs on the Glendale Country Club property, and a private culvert upstream from 140th Avenue NE. The complete barrier is the City-owned culvert under the westbound lanes of Lake Hills Connector which poses a summer low flow barrier. Barrier correction is in the planning stages for most of these structures. See Appendix D of this report for a complete inventory of formally documented fish passage barriers in the watershed.

In addition to the formally documented barriers, there are other undocumented barriers and potential impediments to fish passage, including weirs and habitat degradation associated with regional infrastructure (i.e. Olympic Pipeline and power line corridors). Throughout the surveyed stream reaches, there are a total of 51 weirs (averaging 17 weirs per mile) with jump heights ranging from 0 to 1.5 ft. These weirs are predominantly man-made and privately owned, but there are some natural weirs present. Additionally, beavers are active in the subbasin, and their dams may impede fish passage during low flow periods. This is primarily a concern in Reaches 4 and 5 where migratory salmonids are regularly observed.

B.3.1.7 Opportunities

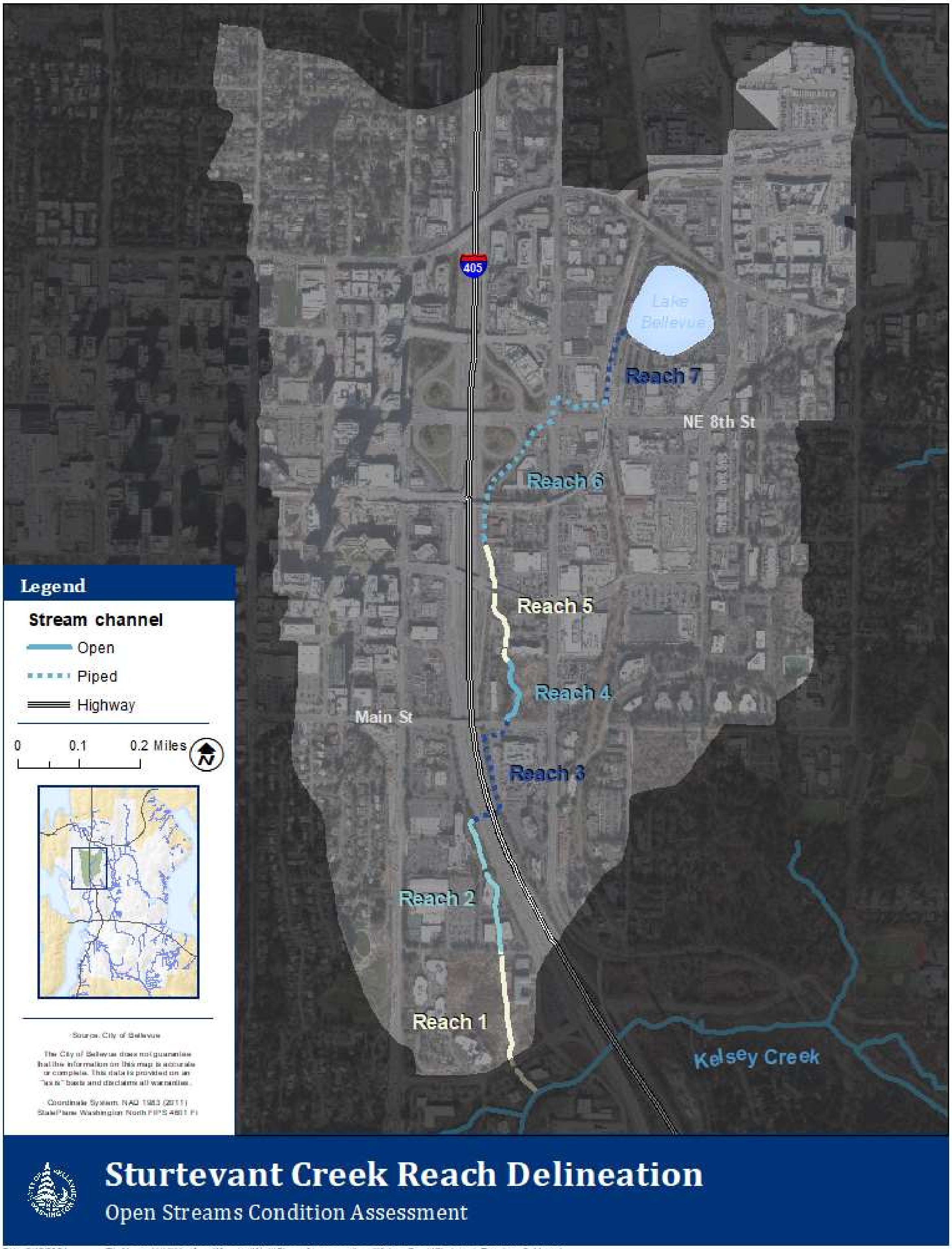
In addition to correcting the fish passage barriers described above, there are several opportunities to protect and improve stream habitat and water quality in Kelsey Creek. City-owned parcels surrounding stream Reach 5 and wetland Reaches 4, 10, and 13 should continue to be managed to allow natural stream processes such as overbank flooding, channel migration, and the natural recruitment of LWM. The City may wish to explore opportunities to restore wetland habitat in the present-day headwaters south of Larsen Lake through land acquisition and restoration to benefit aquatic habitat and water quality, in addition to reducing chronic flooding of nearby roads and infrastructure. Beaver should be allowed to inhabit these restoration areas to promote beneficial habitat and water quality functions that their presence may contribute.

Since much of Kelsey Creek passes through privately owned property, the City can best support stream health through stormwater control and treatment measures and programs that foster good stewardship in both the residential and business communities. Where feasible, the stream would greatly benefit from the addition of LWM and from having streambank armoring removed or replaced with “soft” armoring or bioengineering. Furthermore, invasive knotweed is prevalent throughout Reaches 5 to 8 and may be a catalyst in streambank erosion. Control measures are recommended to manage this rapidly spreading noxious weed, which is already forming dense monoculture stands along portions of the Kelsey Creek streambank. Aquatic invasive species management (for prevention and control of New Zealand Mud Snails and zebra mussels) and enhancement of the riparian corridor and wetlands are encouraged throughout the subbasin.

B.3.2 STURTEVANT CREEK SUBBASIN

Located in northwest Bellevue, Sturtevant Creek primarily flows through the Downtown/Bel-Red, Wilburton, and West Bellevue neighborhoods. The 772-acre subbasin, which encompasses much of the downtown area, is dominated by commercial and office land use and public right of way, most notably I-405 **(Map B-4**). Like many of the other subbasins in the Greater Kelsey Creek Watershed, the Sturtevant Creek Subbasin is relatively low-lying, ranging in elevation from 19 to 246 ft. The subbasin has only 0.8 miles of open channel but 22.6 miles of storm drainage pipes (Bellevue 2017).

The headwater seeps and springs that historically fed Sturtevant Creek were located in the spring district upstream of Lake Bellevue (previously referred to as Sturtevant Lake). Today, all of the headwater streams and wetlands have been piped into Lake Bellevue or storm drains that outfall towards the neighboring West Tributary subbasin. Sturtevant Creek east of I-405 is highly fragmented and constrained as it switches back and forth between piped conveyance and open channel that flow through commercial and small business properties. Two areas east of I-405 have been recently enhanced as mitigation for the Sound Transit light rail (Reach 7 was recently daylighted) and for WSDOT mitigation (a portion of Reach 5 was enhanced). Both Reach 1 and 4 are large, privately-owned wetland parcels. Wetland and constrained slow water glides dominate lower Sturtevant Creek west of I-405. This area between I-405 and Mercer Slough is intersected by numerous office buildings and fragmented by small road and driveway crossings.



Map B-4. Sturtevant Creek stream reaches. Note: Reach 7 was piped at the time of the surveys but has since been daylighted.

B.3.2.1 Channel Morphology and Riparian Corridor

Sturtevant Creek is the most highly urbanized subbasin in the Greater Kelsey Creek Watershed with limited riparian canopy cover and abundant impervious surface area within the 100 ft riparian buffer (**Table B-5**). Overall, the stream gradient is 1.6%, which is approximately average for streams in the Greater Kelsey Creek Watershed. Between its headwaters near Lake Bellevue and its confluence with Mercer Slough, 55% of the stream channel was piped at the time of the survey. Since that time, the final approximately 700 ft stretch of stream leading into Lake Bellevue (Reach 7) has been daylighted as part of Sound Transit's mitigation work for the light rail expansion. In general, the stream has very little riparian buffer, with the exception of wetland Reaches 1 and 4, and much of the subbasin is covered by impervious surfaces. Because the subbasin has had more than 40% impervious surfaces for greater than 20 years, stormwater flow controls are not required (Ecology 2005). Consequently, Sturtevant Creek is subject to very flashy streamflow which has resulted in channel incision. This is highly evident in Reach 4, which was formerly a wetland that included an extensive beaver dam complex, but now the stream channel is severely incised at the upstream end and is becoming increasingly disconnected from the associated wetlands and floodplain.

The loss or removal of resident beavers has contributed to the disconnection of the stream from its floodplain in Reach 4. During surveys in October of 2019, it was evident that beavers had formerly been very active in this portion of stream and wetland but were no longer present. Beaver dams help maintain floodplain connection by impounding and raising water levels, storing sediment, and attenuating erosive streamflow (Nash *et al.* 2021). Allowing beavers to return to this wetland could be a cost-effective, process-based restoration option to reconnect the stream with its floodplain and provide much needed surface water storage capacity for this urban stream. Additional water quality benefits of wetlands and floodplains include nutrient and sediment storage, temperature reduction, and groundwater recharge.

Across all surveyed reaches, the median wetted and bankfull channel widths are 8.7 ft and 9.3 ft, respectively (**Figure B-12**). The channel is confined by entrenchment and channel modifications such as streambank armoring, resulting in a bankfull to wetted width ratio of 1.1, making it the most confined stream channel in the City of Bellevue. Although channel widths diminish was you proceed upstream, the wetted thalweg depths remain relatively consistent (**Figure B-13**). Across all surveyed reaches, the median representative depth is 0.7 ft and the median maximum depth is 1.1 ft.

Table B-5. Reach attributes for Sturtevant Creek.

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Reach Segment ID	75_01	75_02	75_03	75_04	75_05	75_06	75_07
River Mile Boundaries	0.00 – 0.26	0.26 – 0.48	0.48 – 0.69	0.69 – 0.80	0.80 – 0.98	0.98 – 1.36	1.36 – 1.50
Sediment Dynamics	Response	Response	Forced transport	Response/ Source	Response	Forced transport	Forced transport
Channel Type	Wetland	Forced plane-bed*	Piped conveyance	Pool-riffle/ Wetland	Plane-bed	Piped conveyance	Piped conveyance†
Stream Gradient (%)	0.7	0.8	1.6	0.5	2.7	2.8	0.3
Riparian Canopy Cover (%)	16	29	-	28	25	-	-
Riparian Impervious Surface Cover (%)	15	55	77	6	65	80	73
Reach Length (ft)	1,350	1,200	1,075	575	1,000	2,000	700

* In its natural state, this reach would likely exhibit a pool-riffle channel type. However, entrenchment and channel confinement have forced it to assume a plane-bed morphology.
† This reach was piped at the time of the OSCA surveys but has since been daylighted.

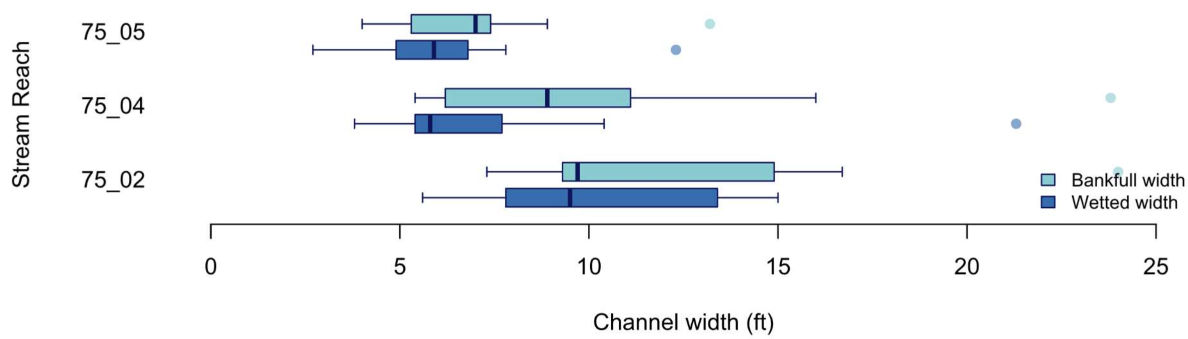


Figure B-12. Boxplot of the wetted and bankfull channel widths for stream reaches in Sturtevant Creek.

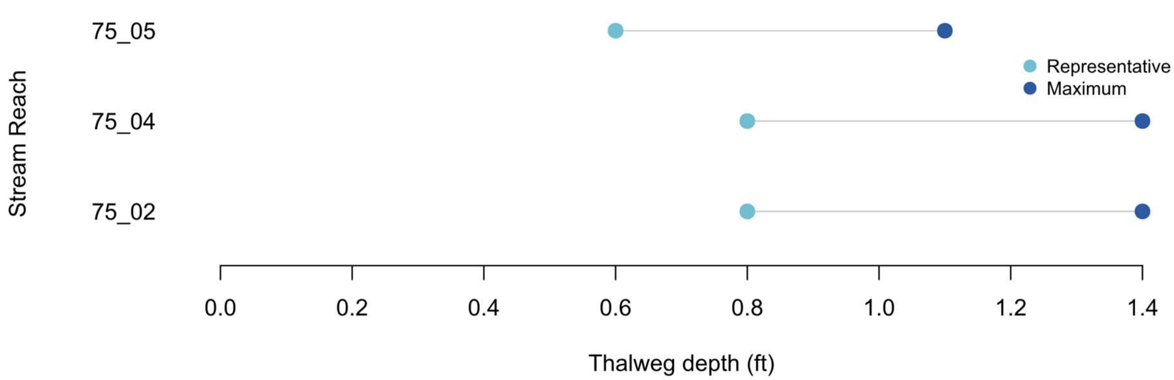


Figure B-13. Dumbbell plot of wetted stream depths in Sturtevant Creek. Points represent the median representative and maximum depth in each stream reach.

B.3.2.2 Habitat Unit Composition and Off-Channel Habitat

The surveyed reaches of Sturtevant Creek are primarily composed of riffle habitat, which comprises 48% of the habitat by area and 59% by length (**Figure B-14** and **Figure B-15**). As frequently observed in streams impacted by urbanization, it has a relatively high proportion of glide habitat. Glide habitat accounts for 28% of the stream area and 21% of the stream length, which is a greater proportion than that found in all but one other subbasin in the Greater Kelsey Creek Watershed. Somewhat surprisingly, Sturtevant Creek has a relatively high abundance of pool habitat, accounting for approximately a quarter of the total habitat area.

Sturtevant Creek has moderately good pool habitat given its highly urbanized nature. It has an overall riffle to pool ratio of 2, which is the third best in the Greater Kelsey Creek Watershed. Likewise, Sturtevant Creek has a pool frequency of 26 pools per mile (22 channel widths per pool), which is second only to the mainstem of Kelsey Creek, though still far below the target level of approximately 100 pools per mile for similarly sized, "properly functioning" streams (NOAA 1996). Unfortunately, pools are not evenly distributed throughout the stream corridor, but are instead highly clustered in Reach 4 while being sparse in Reaches 2 and 5, leading to a median distance between pools of 120 ft. In general, the pools tend to be shallower than is ideal for fish habitat. Only two pools have a depth greater than 3 ft and the median residual pool depth is 1.2 ft (**Figure B-16**).

Off-channel habitat in Sturtevant Creek is restricted to wetland Reaches 1 and 4. The upstream half of Reach 4 is entrenched and disconnected from any potential off-channel habitat, but the downstream portion of the reach remains connected to the floodplain and shows more traditional wetland characteristics. Several braided channels and small pools are present here and are associated with old beaver dams.

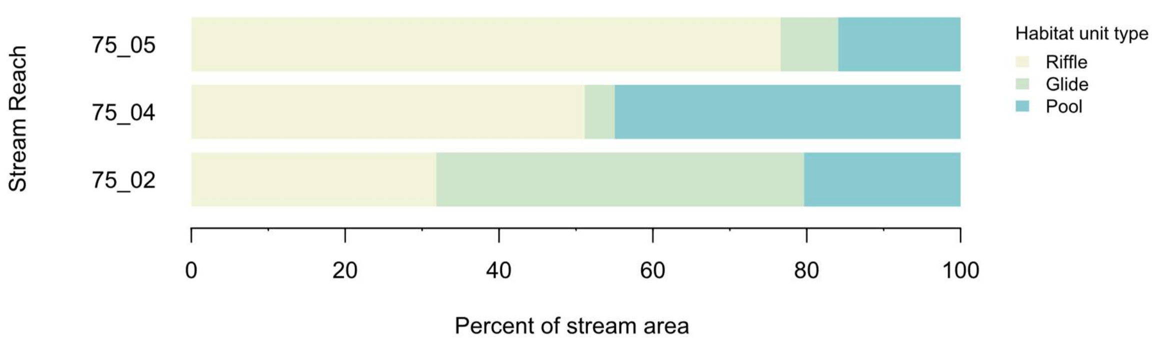


Figure B-14. Habitat unit composition (by percent area) in Sturtevant Creek.

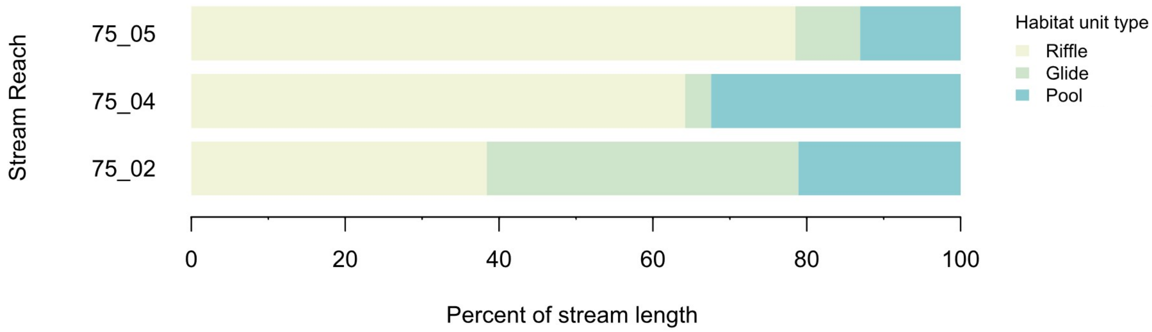


Figure B-15. Habitat unit composition (by percent length) in Sturtevant Creek.

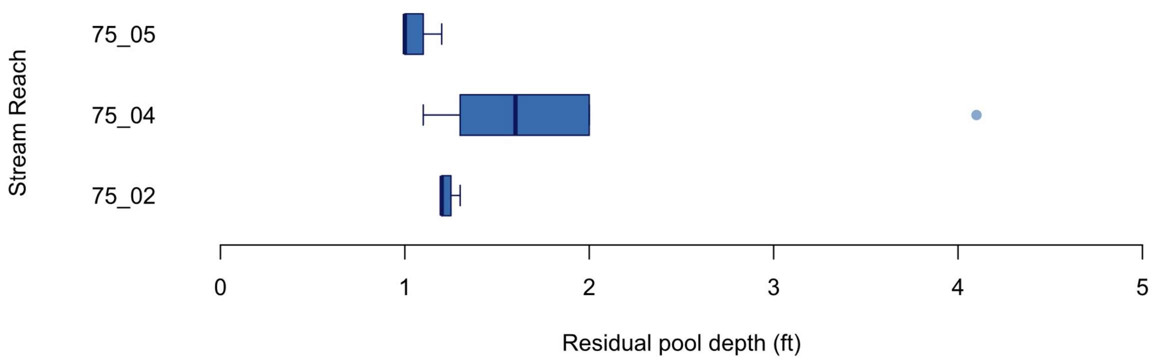


Figure B-16. Boxplot of residual pool depths in stream reaches of Sturtevant Creek.

B.3.2.3 Large Woody Material

Large woody material (LWM) is largely absent from Sturtevant Creek. The average wood density across all surveyed reaches is 63 pieces per mile (4 pieces per 100 m), which is the second lowest LWM level observed in the Greater Kelsey Creek Watershed and is far below reference levels (**Figure B-17**). Only one piece of wood was observed in all of Reach 2. Stream restoration activities in Reach 5 have enhanced the rather meager LWM levels by contributing a high proportion of placed wood (**Figure B-18**). Opportunities for natural recruitment of LWM are minimal in Sturtevant Creek.

Figure B-17. Large woody material frequency in Sturtevant Creek compared to reference levels (Fox and Bolton 2007).

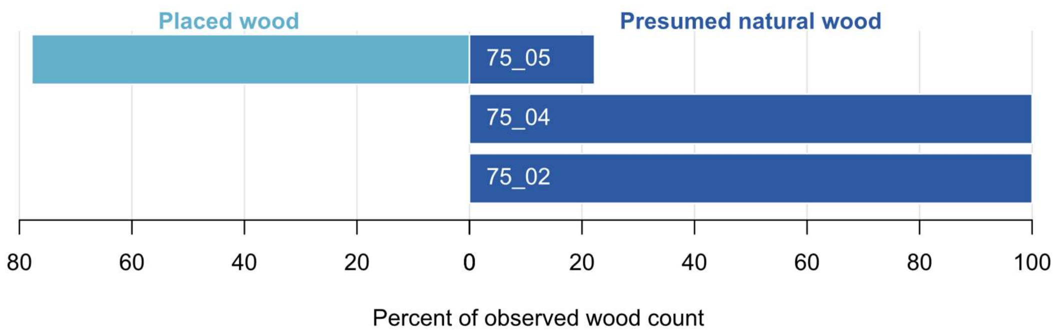


Figure B-18. Diverging bar graph showing the proportion of wood observed in each stream reach of Sturtevant Creek that is of natural origin or was placed.

B.3.2.4 Streambed Substrate

Streambed substrate composition in Sturtevant Creek riffle habitat is predominantly (40%) gravel. Fines and cobbles are approximately equivalent and make most of the remaining substrate composition (**Figure B-19**). Although the percent fines in riffle habitat is slightly higher than ideal (28%), the substrate composition is still adequate for spawning salmonids. Substrate in glide habitats is generally less coarse, with fines comprising 49% of the substrate. Some of the "cobbles" present in Reach 4 are actually chunks of hardpan clay that have mobilized into the channel and are functioning as coarse substrate.

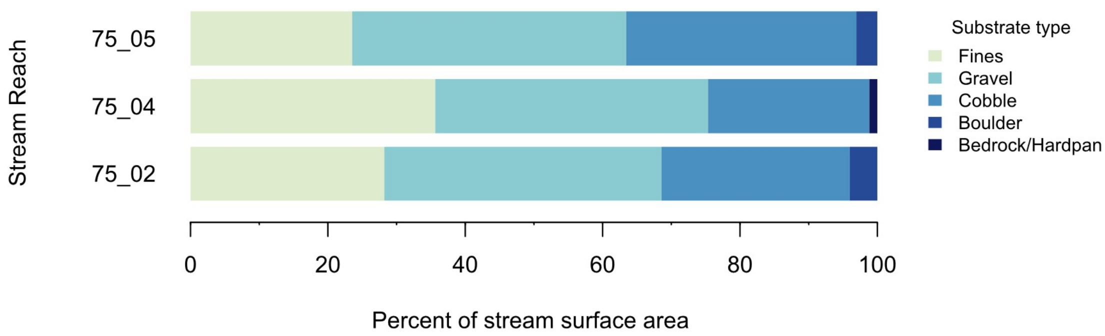


Figure B-19. Substrate composition of riffle habitat in Sturtevant Creek, determined by visual estimation.

B.3.2.5 Streambank Conditions

Streambank armoring is prevalent in Sturtevant Creek. Across all surveyed reaches, 32% of the streambanks are armored, making it the third-most armored stream in the Greater Kelsey Creek Watershed. The extent of streambank armoring varies with land use; there is no armoring in the partial wetland of Reach 4 while nearly half of the highly urbanized Reach 5 is armored (**Figure B-20**). Most of this streambank armoring is composed of large angular rock and is usually less than 5 ft high.

Sturtevant Creek is quite entrenched and has the greatest extent of streambank erosion of all streams in the Greater Kelsey Creek Watershed. Nearly a quarter (24%) of the surveyed channel shows evidence of streambank erosion. Patterns of streambank erosion vary by stream reach (**Figure B-21** and **Figure B-22**). Reach 5 has very little erosion while erosion in Reach 2 is predominantly low scour with undercut banks at the waterline likely resultant from the flashy streamflow of this urban subbasin. Reach 4 is characterized by strong channel incision ranging in height from 3 to 6 ft. Individual instances of erosion are greater in length in Sturtevant Creek than in the rest of the Greater Kelsey Creek Watershed. The median erosion length is 24 ft, but some instances of erosion extend for more than 300 ft.

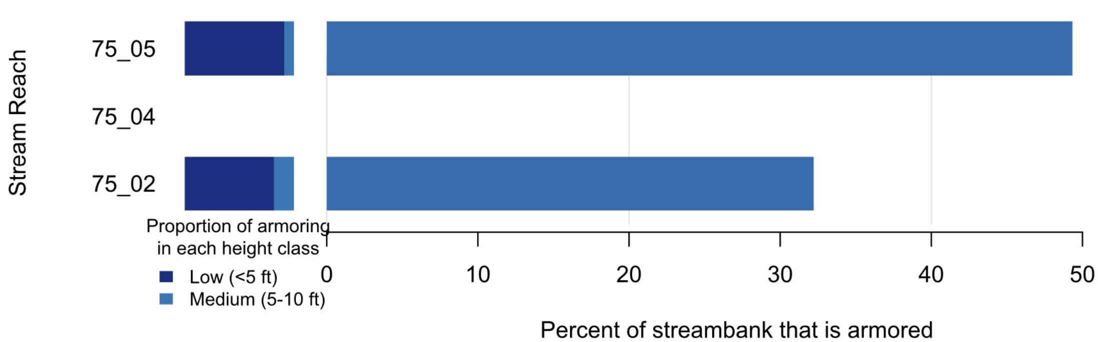


Figure B-20. Bar graphs showing the percent of each Sturtevant Creek reach that is armored as well as the proportion of armoring in each armoring height class.

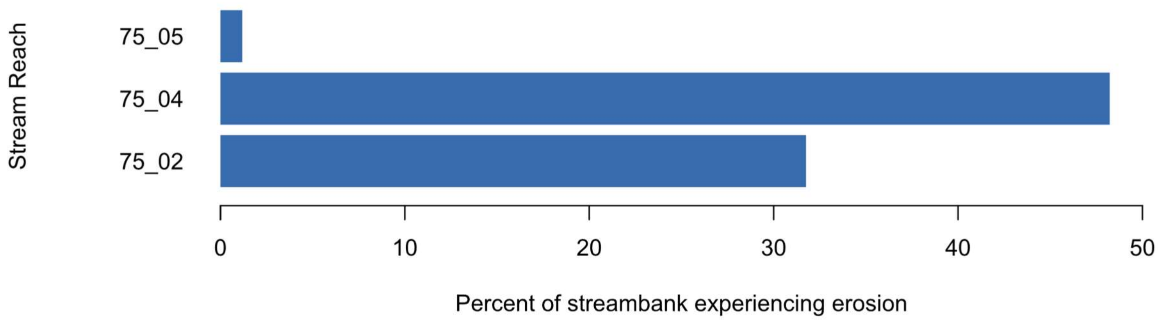


Figure B-21. Percent of each stream reach in Sturtevant Creek that is experiencing erosion.

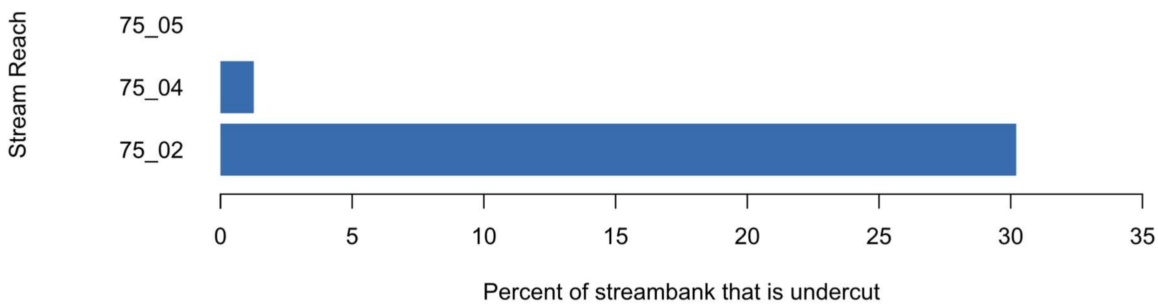


Figure B-22. Percent of each stream reach in Sturtevant Creek that has undercut streambanks.

B.3.2.6 Fish Habitat and Passage Barriers

Although Sturtevant Creek historically supported many fish species, including spawning Coho Salmon (Williams *et al.* 1975), fish are now rather sparse. During the 2019 OSCA surveys, trout were observed only in the lower portion of Reach 2. The only other fish observed was a goldfish (*Carassius auratus*) found in Reach 4. Good spawning gravels are present throughout the surveyed reaches and the pool habitat, particularly in Reach 4, could support resident fish. The notable lack of fish in these areas may indicate that water quality and flashy streamflow pose the biggest challenge to resident fishes. A 2010 report documenting fish use of streams in the City of Bellevue, mentions that Lake Bellevue supports a population of non-native goldfish (Bellevue 2010). It is possible that other warmwater (bass or sunfish) or exotic fish species may have been introduced to this highly urban lake, yet no formal fish studies have occurred. Fish introduced to Lake Bellevue may be washed downstream to portions of Sturtevant Creek during large storm events.

There are several physical barriers to fish movement and migration in Sturtevant Creek. Fish passage between I-405 and Lake Bellevue is highly fragmented. WDFW (2021) has identified three partial barriers and one complete barrier along the mainstem channel. The downstream-most partial barrier is the I-405 culvert which is followed by a piped stream conveyance (Reach 3) that extends for two-tenths of a mile. The City owns the next partial barrier at Main Street. The complete fish passage barrier is located at the break between Reaches 4 and 5 and consists of an approximately 4-ft hydraulic drop at a culvert outlet. Upstream from here, there is a partial barrier at the City-owned culvert under NE 2nd Place, which is downstream of a short section of stream restored by WSDOT. An undocumented fish passage barrier consisting of numerous privately owned sections of piped conveyance extends for three-tenths of a mile from just south of the NE 6th Street and the Sound Transit light rail crossing of I-405 to the new Lake Bellevue outlet channel restoration. See Appendix D of this report for a complete inventory of formally documented fish passage barriers in the watershed.

B.3.2.7 Opportunities

Opportunities for sustaining ecosystem function and stream health in Sturtevant Creek should be primarily focused on stormwater impacts, particularly streamflow and pollutant/nutrient loading which are the primary drivers shaping the deficiencies in physical habitat. Upland stormwater detention, flow control, and stormwater runoff treatment would greatly benefit this stream. Numerous oil spills have been documented along the I-405 off ramps and regularly require instream cleanup measures, specifically in Reaches 1 and 2.

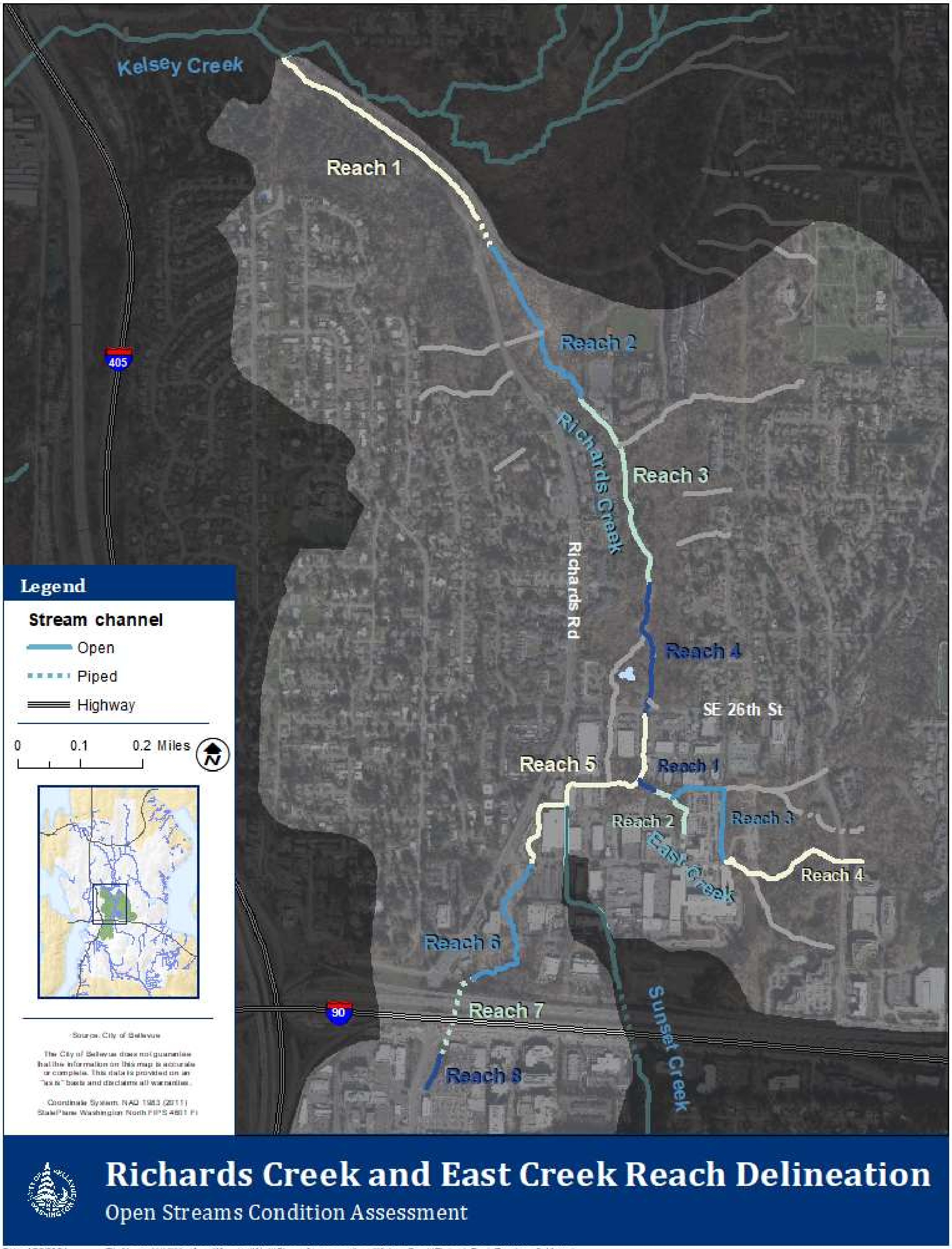
The addition of LWM would help dampen streamflow velocities and increase habitat complexity. Because the upper one-third of the channel is piped and the stream experiences highly flashy and erosive streamflow, sediment dynamics are altered, leaving the channel sediment-starved and incising. In addition to attenuating streamflow, the addition of LWM would also help retain and sort sediment. Instream fish habitat enhancement, including riparian buffer restoration and LWM placement, should be focused in Reach 2 until fish passage can be restored upstream (or east) of I-405.

Halting channel incision should be a priority, particularly in Reach 4 where the stream is becoming disconnected from its floodplain. As mentioned previously, allowing beavers to return to this reach could be an effective way of using process-based restoration to regain surface water storage capacity and off-channel habitat. Because channel incision is responsible for creating the complete fish passage barrier at the upstream end of Reach 4, it is recommended that actions to reduce channel incision are prioritized over upstream barrier corrections. All fish passage barrier corrections and instream habitat improvements should be sequenced appropriately in the downstream to upstream direction.

B.3.3 Richards Creek Subbasin (including East Creek)

Richards Creek is located in south Bellevue and primarily flows through the Woodridge neighborhood (**Map B-5**). The Richards Creek Subbasin encompasses 1,380 acres of mixed residential and commercial land use and contains 4.6 miles of open stream channel and 31.3 miles of storm drainage pipes (Bellevue 2017). Elevation in the subbasin ranges from 23 ft to 436 ft.

Historically, Richards Creek headwaters in seeps and wetlands south of I-90 in the Factoria neighborhood, yet most of the headwaters have been filled or piped with the exception of one relict channel located just north of Newport High School along SE 42nd Street. The Richards Creek Subbasin is urban and receives untreated runoff from I-90 and many of the commercial properties that constrain Reaches 3-8. Wetlands dominate Reaches 2, 4, and 6, and beavers are common throughout the subbasin. The confluence of a significant tributary, Sunset Creek, is located in Reach 5, squeezed between commercial buildings. A second tributary, East Creek, also flows into what is now referred to as Richards Creek Reach 5. Until 2010, East Creek was longer and paralleled the mainstem of Richards Creek, until streamflow from Richards Creek avulsed, now flowing in the historic East Creek channel. This left an abandoned Richards Creek channel and reduced the drainage area of the East Creek Subbasin to a localized area in the vicinity of Bellevue College and the Eastgate Park and Ride.



Map B-5. Richards and East Creek stream reaches.

B.3.3.1 Channel Morphology and Riparian Corridor

The Richards Creek Subbasin is the lowest gradient stream system in the City of Bellevue and is dominated by a plane-bed channel type (**Table B-6** and **Table B-7**). The average channel gradient is 0.5%. Wetlands compose more than one-third of Richards Creek by length and are interspersed between primary channel reaches with varying degrees of urban impact. Across all surveyed reaches in the Richards Creek Subbasin, the 100 ft riparian buffer contains 52% urban tree canopy cover and 29% impervious surface cover, which is average for subbasins in the Greater Kelsey Creek Watershed. Urban development has most strongly impacted the subbasin in East Creek Reach 5 of Richards Creek (**Map B-5**).

The riparian vegetation is highly varied in the Richards Creek Subbasin. Understory vegetation is often quite dense and includes native plants such as dogwood and salmonberry as well as invasive plants including Himalayan blackberry and reed canary grass. Policeman's helmet and jewel weed are particularly dense in Richards Creek, especially in Reach 4 around the abandoned channel. Likewise, knotweed is present in low to medium density from the abandoned channel to the confluence with Sunset Creek.

Richards Creek is second in width only to the mainstem of Kelsey Creek and maintains a greater depth when compared to all other streams in the City of Bellevue, except possibly Mercer Slough. The median wetted width for the subbasin is 12.3 ft and the median bankfull width is 14.4 ft, but East Creek is noticeably smaller than Richards Creek (**Figure B-23** and **Figure B-24**). Although the Richards Creek channel narrows as you proceed upstream, the wetted depth remains consistent with a median representative depth of 0.8 ft and median maximum depth of 1.7 ft.

Table B-6. Reach attributes for Richards Creek.

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8
Reach Segment ID	77_01	77_02	77_03	77_04	77_05	77_06	77_07	77_08
River Mile Boundaries	0.00 – 0.47	0.47 – 0.78	0.78 – 1.11	1.11 – 1.34	1.34 – 1.74	1.74 – 2.02	2.02 – 2.16	2.16 – 2.23
Sediment Dynamics	Response	Response	Response	Response	Response	Response	Forced transport	Response
Channel Type	Forced dune-ripple*	Wetland	Forced pool-riffle†	Wetland	Forced pool-riffle†	Wetland	Piped conveyance	Plane-bed
Stream Gradient (%)	0.3	0.7	0.1	0.3	0.7	0.7	0.3	1.0
Riparian Canopy Cover (%)	57	14	71	55	31	35	-	10
Riparian Impervious Surface Cover (%)	23	6	10	5	56	18	56	55
Reach Length (ft)	2,475	1,625	1,775	1,175	2,155	1,450	725	375

* This reach would likely be a part of the wetland complex at Kelsey Creek Park. However, due to land use alterations, it is confined between the east- and westbound lanes of Lake Hills Connector.

† Beaver activity is responsible for creating pool habitat.

Table B-7. Reach attributes for East Creek.

	Reach 1	Reach 2	Reach 3	Reach 4
Reach Segment ID	78_01	78_02	78_03	78_04
River Mile Boundaries	0.00 – 0.06	0.06 – 0.19*	0.09 – 0.27	0.27 – 0.53
Reach Morphology	Response	Response	Response	Source
Channel Type	Plane-bed	Plane-bed	Plane-bed	Unknown
Stream Gradient (%)	0.9	1.3	2.0	12.8
Riparian Canopy Cover (%)	73	71	40	62
Riparian Impervious Surface Cover (%)	20	29	50	10
Reach Length (ft)	300	700	925	1,400

* River miles are not consecutive between Reaches 2 and 3 due to the highly modified nature of this channel. See **Map B-5**.

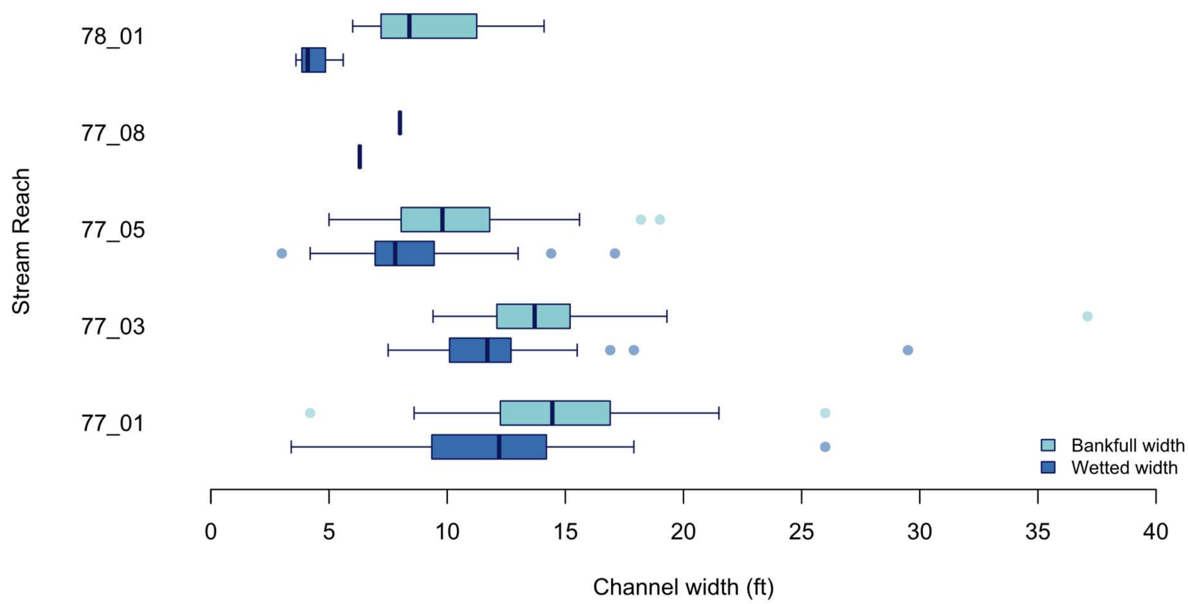


Figure B-23. Boxplot of the wetted and bankfull channel widths for the Richards Creek Subbasin. Richards Creek stream reaches have the prefix 77 and East Creek stream reaches have the prefix 78.

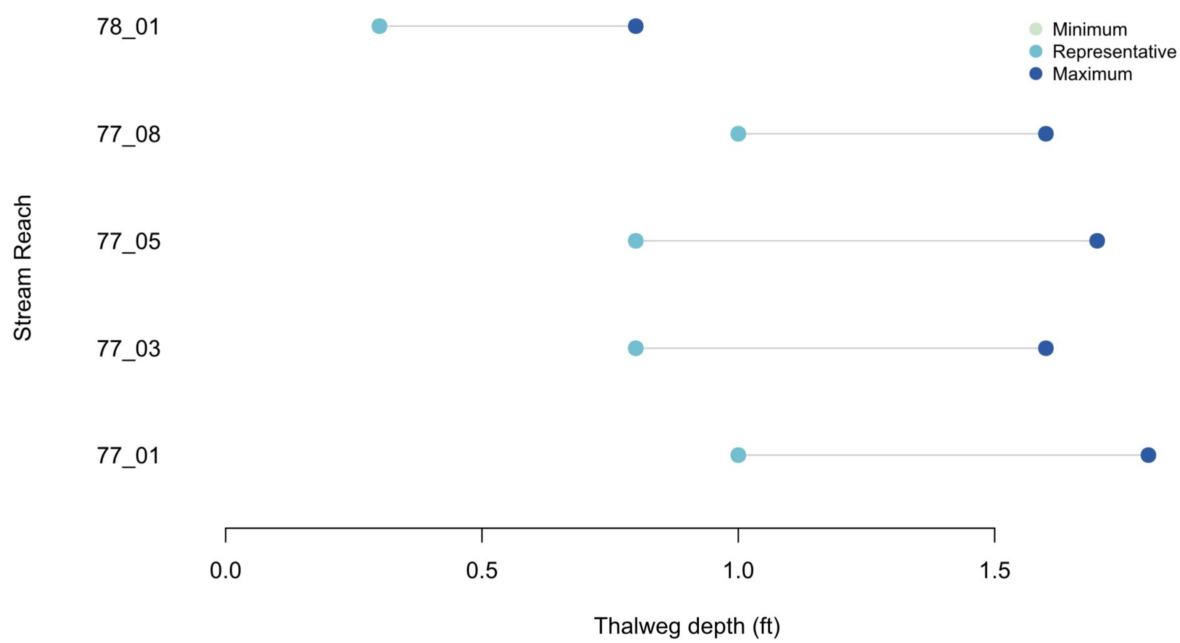


Figure B-24. Dumbbell plot of wetted stream depths in the Richards Creek Subbasin. Points represent the median representative and maximum depth in each stream reach. Richards Creek stream reaches have the prefix 77 and East Creek stream reaches have the prefix 78.

B.3.3.2 Habitat Unit Composition and Off-Channel Habitat

Unique among the subbasins of the Greater Kelsey Creek Watershed, the Richards Creek Subbasin is dominated by glide habitat. Although East Creek is exclusively composed of riffle habitat, glide habitat in Richards Creek accounts for 58% of the stream by area and 53% by length for surveyed reaches (**Figure B-25** and **Figure B-26**). Riffle habitat and pool habitat are approximately equal in Richards Creek, accounting for 22% and 21% of the stream length or 18% and 22% of the stream area, respectively.

Although only one pool was observed in East Creek, Richards Creek is the only stream in the Greater Kelsey Creek Watershed to have a greater area of pool habitat than riffle habitat for surveyed reaches. This results in a riffle to pool ratio of 0.9 which is beneficial to the productivity of juvenile salmonids (Naman *et al.* 2008). Overall, Richards Creek has a pool frequency of 20 pools per mile (1 pool per 100 m) or approximately 18.3 channel widths per pool, which falls far short of the ideal 70 pools per mile for similarly sized, “properly functioning” streams (NOAA 1996). The median residual pool depth in Richards Creek is 1.8 ft (**Figure B-27**), which is greater than that found in all other subbasins in the Greater Kelsey Creek Watershed, and 15% of all pools have a maximum depth greater than 3 ft.

Beavers are instrumental in creating and maintaining pool habitat in Richards Creek. Nearly 40% of all pools recorded during OSCA surveys were associated with beaver dams. Beaver activity was observed in Reaches 1 through 5 and is facilitating instream habitat diversity.

Traditional off-channel habitat in the primary channels of the Richards Creek Subbasin is limited to only a few short side channel habitat types found in Reaches 1 and 5. However, wetland Reaches 2, 4, and 6 have become beaver playgrounds and provide numerous braided channels, undercut banks, floodplain connection, and habitat complexity. Qualitative observations over the past fifteen years suggest that wetland habitat throughout the subbasin has increased, improving instream flood storage and sediment storage capacity.

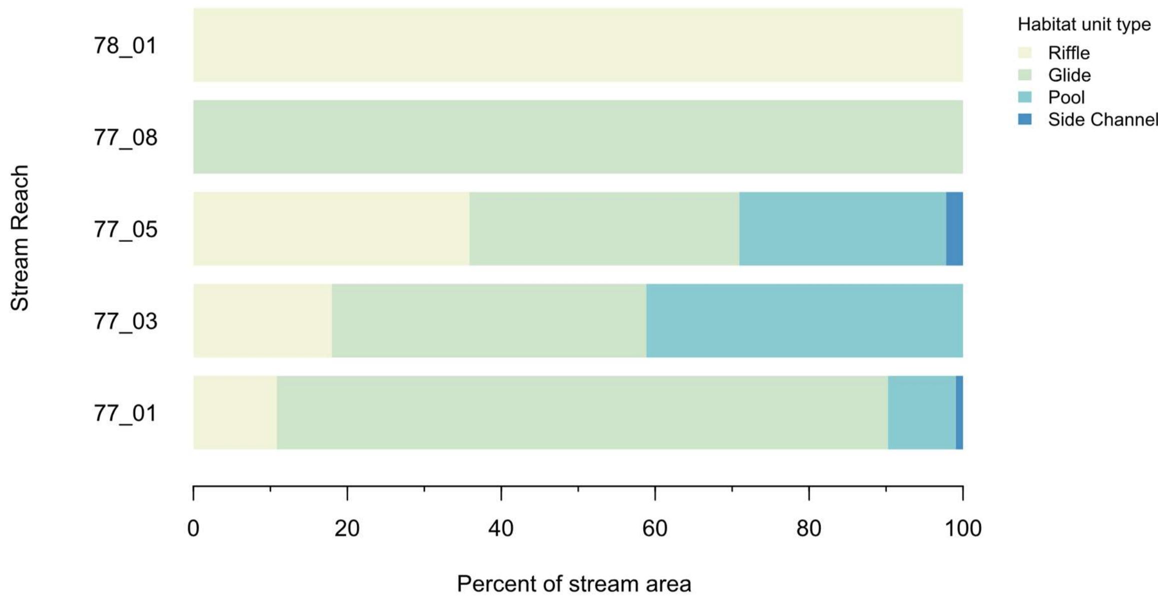


Figure B-25. Habitat unit composition (by percent area) of the Richards Creek Subbasin stream reaches. Richards Creek stream reaches have the prefix 77 and East Creek stream reaches have the prefix 78.

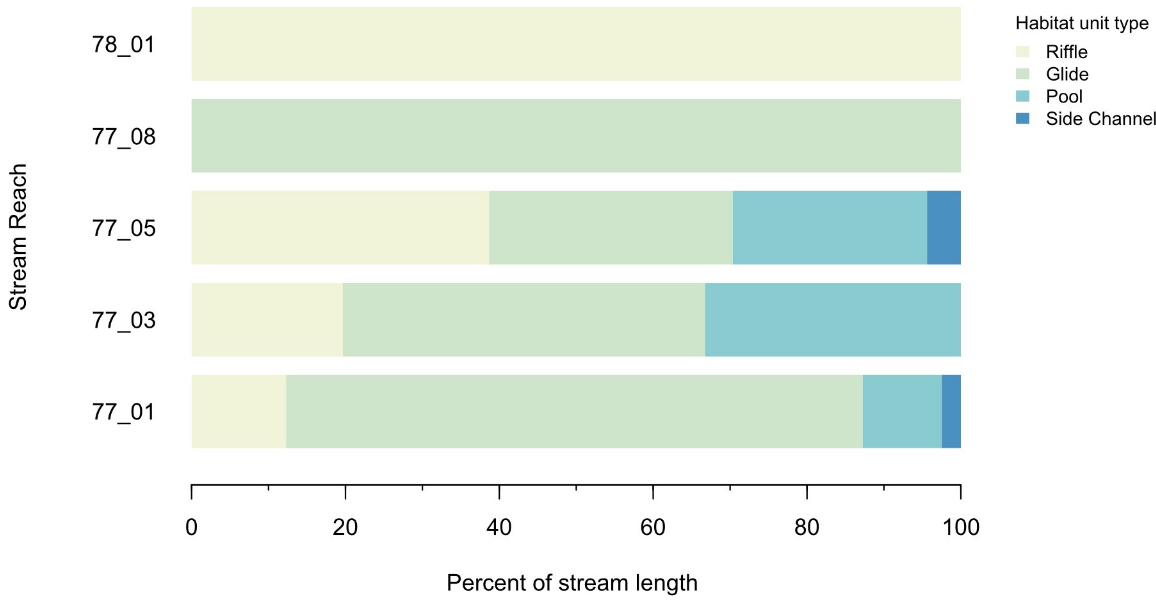


Figure B-26. Habitat unit composition (by percent length) of the Richards Creek Subbasin stream reaches. Richards Creek stream reaches have the prefix 77 and East Creek stream reaches have the prefix 78.

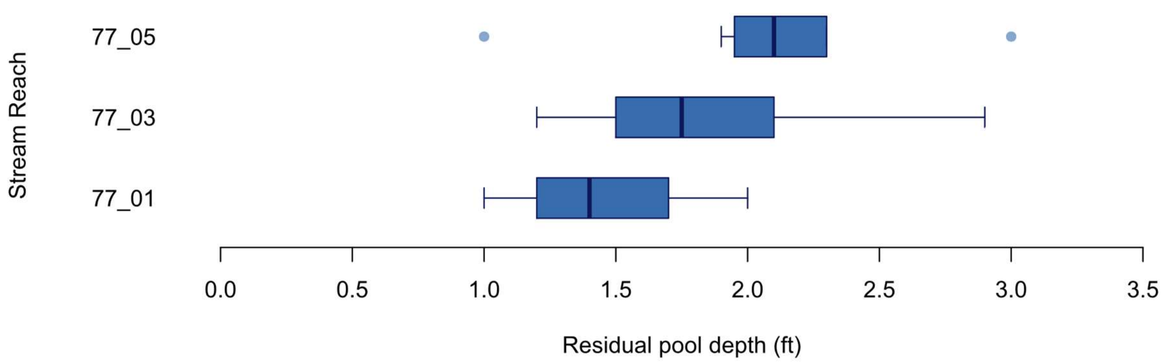


Figure B-27. Boxplot of residual pool depths observed in the Richards Creek Subbasin.

B.3.3.3 Large Woody Material

Large woody material (LWM) is lacking in the Richards Creek Subbasin, but restoration efforts have augmented natural LWM levels. The average wood frequency across all surveyed reaches is 220 pieces per mile (14 pieces per 100 m), which is far below reference levels (**Figure B-28**). Restoration activities in Reach 5 include wood placed for both habitat and bank stabilization. Placed wood accounts for 34% of all LWM observed in Reach 5. Although narrow, a decent riparian canopy cover in Reaches 1, 3, and 4 provides an opportunity for the natural recruitment of LWM. However, in the more highly urbanized

Reaches 5 and 8, there is very little natural LWM recruitment potential. In Reaches 1 through 5, beavers have facilitated the natural recruitment of LWM by felling trees and incorporating trees and large branches into dams, which trap and sort debris and sediment.

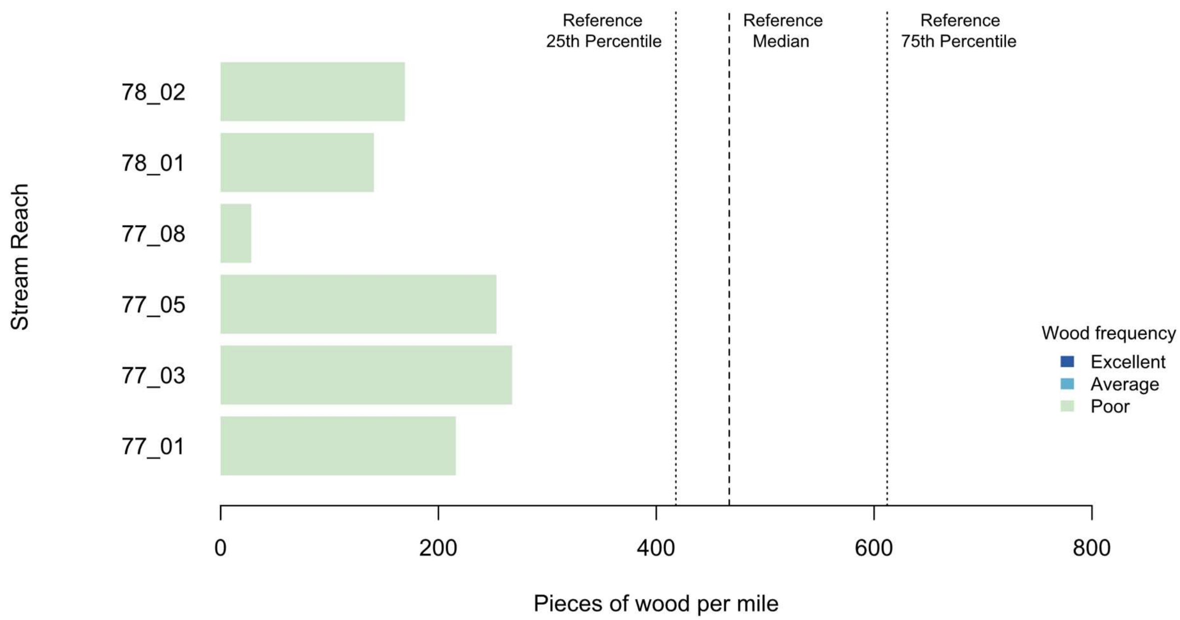


Figure B-28. Large woody material frequency in stream reaches of the Richards Creek Subbasin compared to reference levels (Fox and Bolton 2007). Richards Creek stream reaches have the prefix 77 and East Creek stream reaches have the prefix 78.

B.3.3.4 Streambed Substrate

The Richards Creek Subbasin has the highest proportion of fines found in the Greater Kelsey Creek Watershed. Fines account for 78% of the streambed substrate in all fast water habitat units and 58% in riffle habitat. Although substrate composition in riffle habitat varies among stream reaches (**Figure B-29**), no reach has less than 40% fines. This proportion of fines is generally too high for the successful spawning and incubation of Pacific salmon (NOAA 1996).

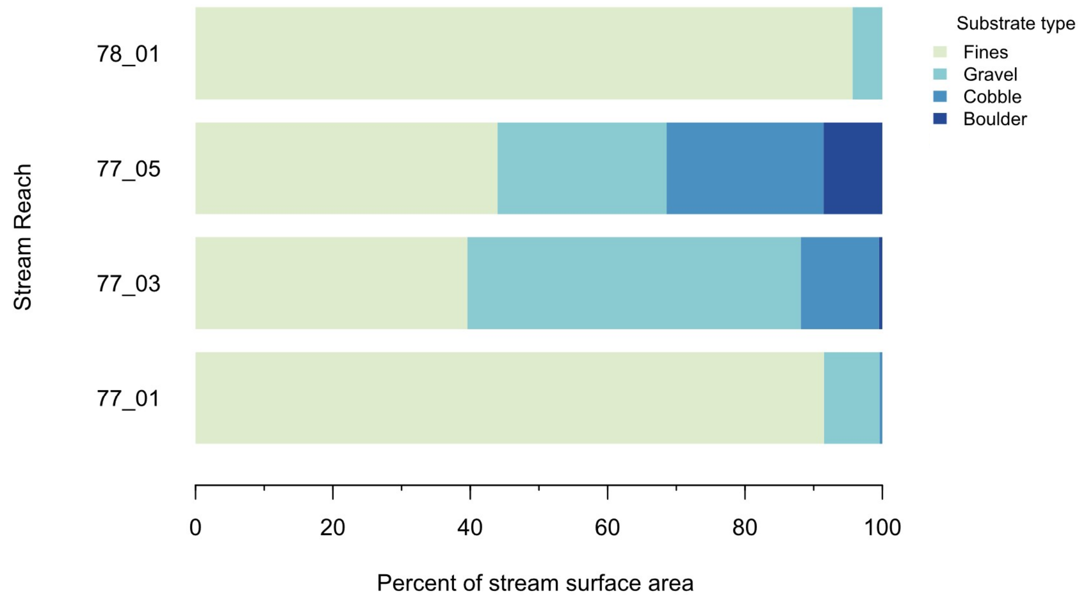


Figure B-29. Substrate composition of riffle habitat in the Richards Creek Subbasin, determined by visual estimation. Richards Creek stream reaches have the prefix 77 and East Creek stream reaches have the prefix 78.

B.3.3.5 Streambank Conditions

The Richards Creek Subbasin has the second lowest frequency of streambank armoring in the Greater Kelsey Creek Watershed. Across all surveyed reaches, 8% of the streambanks are armored. However, the extent of streambank armoring varies greatly by stream reach (**Figure B-30**). There is little to no armoring in East Creek or Richards Creek Reach 1, while Richards Creek Reach 8 is armored on both banks for the entire extent of the reach. Large angular boulders are the primary armoring material used in the Richards Creek Subbasin. However, stream improvement projects in Richards Creek Reach 5 have installed rootwads and rounded boulders as “soft” streambank armoring. This bioengineering accounts for 78% of all armoring present in Reach 5.

Streambank erosion in the Richards Creek Subbasin is approximately average for the Greater Kelsey Creek Watershed. Overall, 13% of the surveyed streambanks are experiencing erosion and 7% are undercut, with most erosion located in Richards Creek Reach 3 and East Creek Reach 1 (**Figure B-31** andFigure B-32). Most of this erosion is low (less than 5 ft) in height and there are several areas where toe scour has created stable undercut banks which provide good habitat and refuge for fish and other aquatic species. The median length of individual instances of streambank erosion is 30 ft, which is the highest observed in the Greater Kelsey Creek Watershed, and there are several instances where erosion stretches for 100 ft or more.

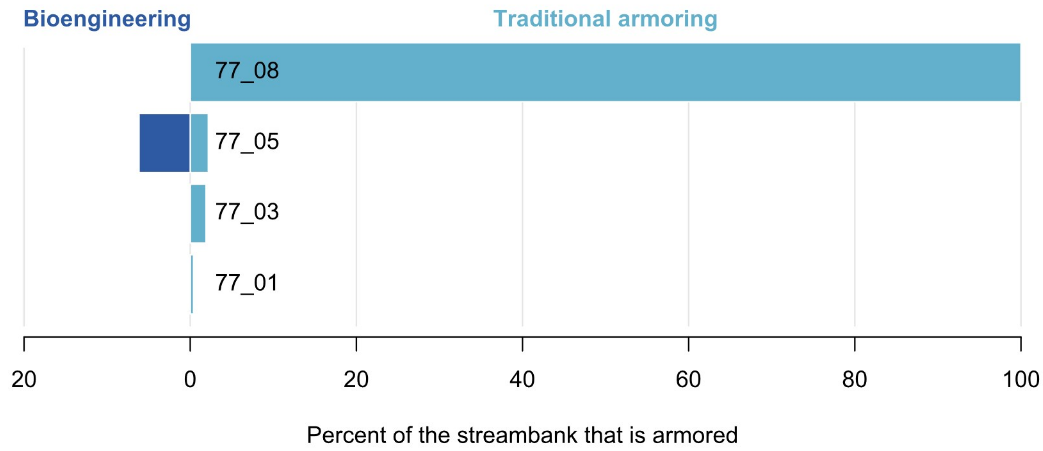


Figure B-30. Diverging bar graph showing the proportion of the streambank in the Richards Creek Subbasin that is armored using traditional materials (right) and bioengineering (left). Reaches without streambank armoring are omitted from the figure except for East Creek Reach 2 which has traditional armoring along 1% of its streambank.

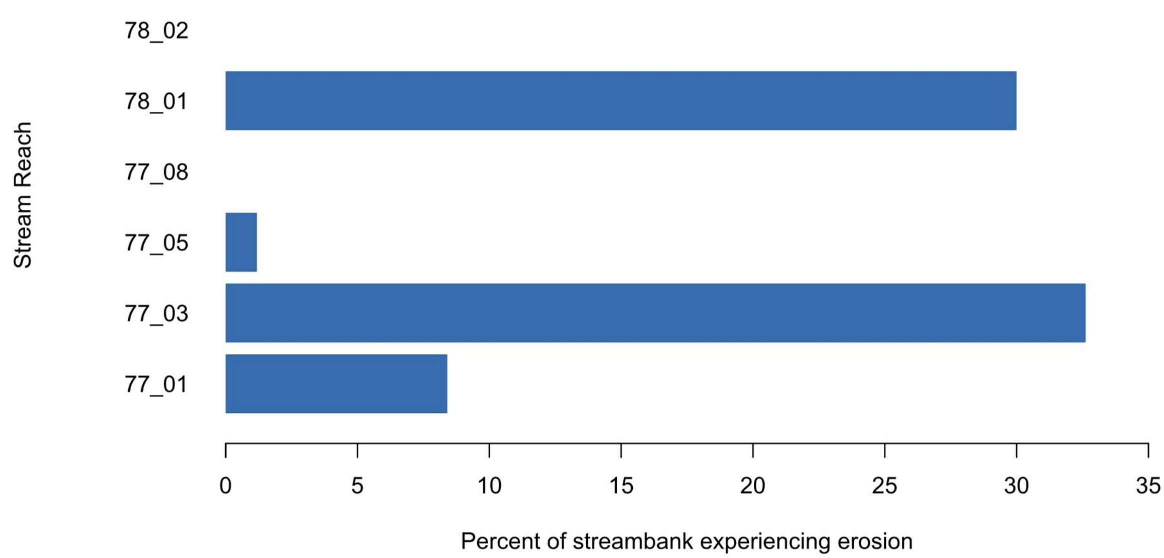


Figure B-31. Percent of each stream reach in the Richards Creek Subbasin that is experiencing erosion. Richards Creek stream reaches have the prefix 77 and East Creek stream reaches have the prefix 78.

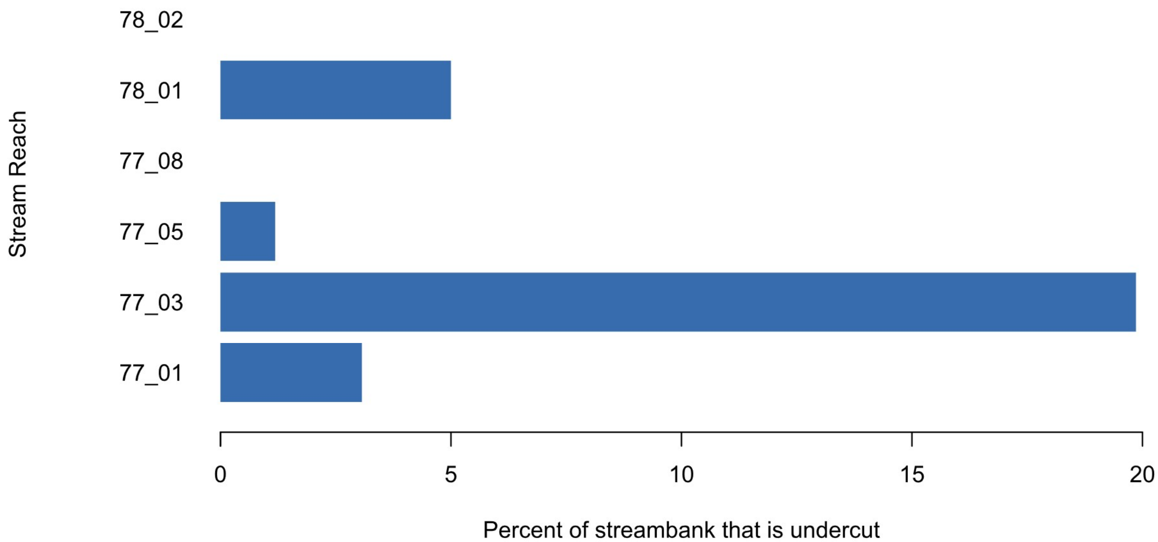


Figure B-32. Percent of each stream reach in the Richards Creek Subbasin that has undercut banks. Richards Creek stream reaches have the prefix 77 and East Creek stream reaches have the prefix 78.

B.3.3.6 Fish Habitat and Passage Barriers

Richards Creek currently supports a healthy resident trout population. During OSCA surveys in 2019, fish presumed to be Cutthroat Trout ranging in size from 2 to 8 inches were frequently observed throughout all of Richards Creek downstream of I-90. Additionally, a pair of lamprey were observed spawning in Richards Creek Reach 3. Fish were even observed in East Creek where habitat was enhanced by a beaver pond. Unfortunately, the high proportion of fine sediment in the streambed substrate makes most of Richards Creek unsuitable for spawning salmon. However, the deeper water, good ratio of riffle to pool habitat, and abundant wetlands make this reach excellent rearing habitat for salmonids. Unfortunately, invasive mud snails are also highly abundant in Richards Creek downstream of I-90 and impaired water quality is a great concern.

There are a few known barriers to fish passage in the Richards Creek; East Creek has not been assessed for barriers. WDFW (2021) has documented two partial barriers and one complete barrier. See Appendix D of this report for a complete inventory of formally documented fish passage barriers. The complete barrier is City-owned and is the piped stream conveyance upstream of Reach 8 at Factoria Boulevard. There is only a short portion of ditched channel open upstream of this pipe. Additionally, there are numerous beaver dams that could impede fish movement. However, at the time of the OSCA surveys, only one dam had created a hydraulic drop of greater than 1 ft and many were partially breached.

B.3.3.7 Opportunities

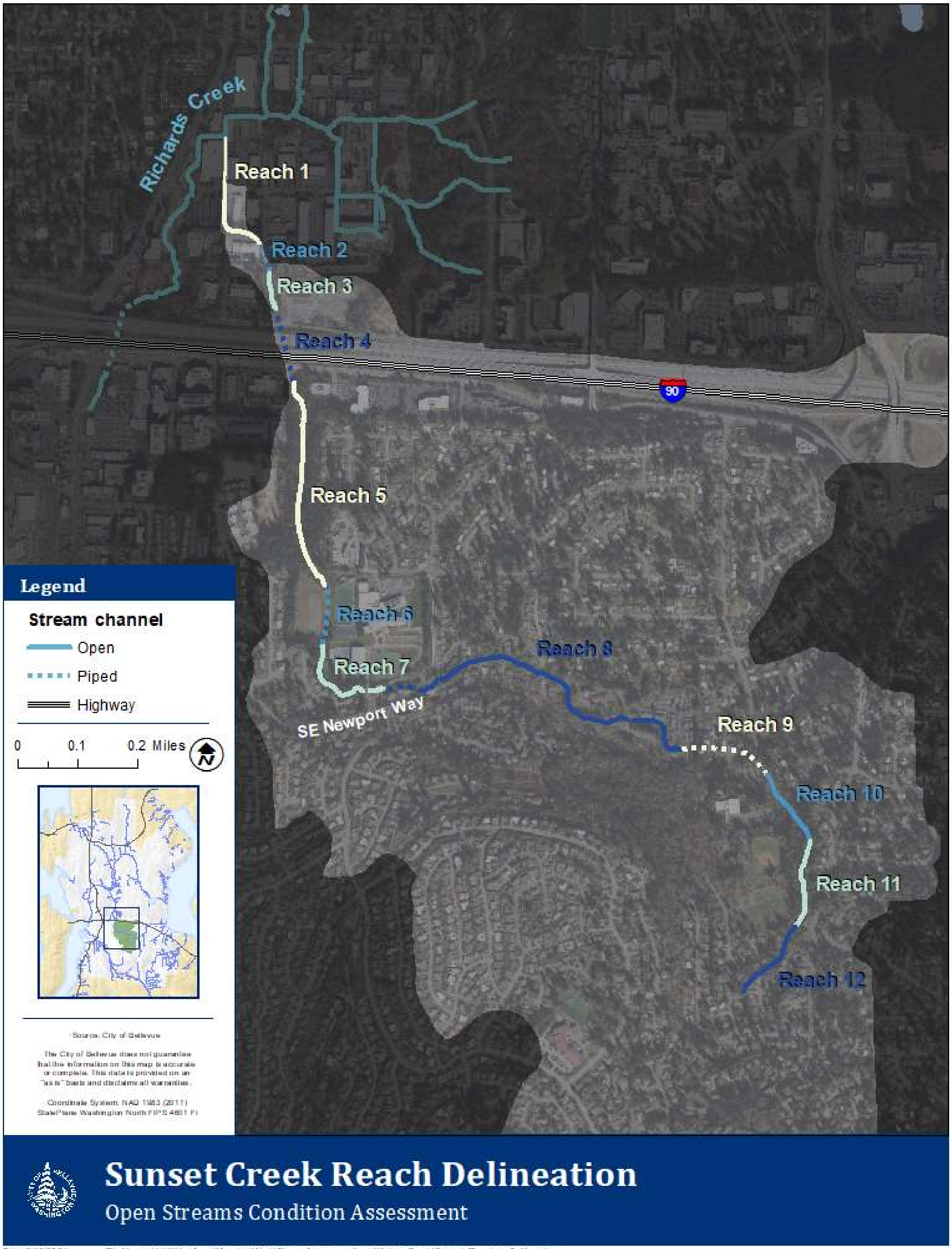
Current City policies and private property ownership limits the City's ability to pursue stream enhancement along much of the stream corridor in Reaches 3 through 6. Therefore, using this current approach, the City's focus for improving and protecting existing habitat should prioritize water quality improvement, protecting and enhancing the stream buffer and riparian corridor, and invasive species control (including vegetation and aquatic invasive species). Across the Richards and East Creek subbasins, opportunities to buffer the impacts of urban runoff and degraded water quality must be pursued to reduce impacts of flashy storm events, warm water, turbidity, etc. Solutions should focus on flow control, fine sediment catchment (upland and instream options may need to be explored), and process-based solutions where feasible (i.e., wetland enhancement).

Opportunities to improve physical habitat conditions may require new policies and programs for land acquisition and instream restoration efforts on both public and private property. These efforts may include barrier correction, LWM installation, and an invasive species control and management plan.

B.3.4 Sunset Creek Subbasin

Sunset Creek is a significant tributary to Richards Creek. Located in south Bellevue, it flows through the Eastgate/Factoria and Woodridge neighborhoods. The Sunset Creek Subbasin comprises 854 acres of mostly residential properties. However, public right of way, most notably I-90, accounts for over a quarter of the subbasin. Although much of the Greater Kelsey Creek Watershed is low-lying, elevation in the Sunset Creek Subbasin ranges from 64 ft to 1,010 ft. Overall, the subbasin contains 1.8 miles of open stream channel and 21.9 miles of storm drainage pipes (Bellevue 2017).

Present-day headwaters of Sunset Creek are found in drainage ditches throughout the Somerset Neighborhood. This extensive stormwater network outfalls into a steep-walled ravine for four tenths of a mile (Reaches 10-12) before meandering through numerous residential and multi-family parcels (**Map B-6**). Near the Tyee Middle School, Sunset Creek enters a second steep-walled ravine until it flows under I-90. This area, known as the Sunset Ravine, has a history of slope failure and mass wasting and has been a source of downstream sedimentation problems that have caused flooding in lower Sunset and Richards Creeks. The lower three reaches of Sunset Creek are entrenched and confined as they parallel Richards Creek in a highly urban commercial district near Eastgate.



Map B-6. Sunset Creek stream reaches.

B.3.4.1 Channel Morphology and Riparian Corridor

Sunset Creek is the highest gradient stream in the Greater Kelsey Creek Watershed and is dominated by the plane-bed channel type (**Table B-8**). In the upper-most reaches, the channel in places has been scoured down to hardpan glacial till creating cascades. The upper-most portion of open channel is at an elevation of approximately 580 ft, which is more than 200 ft greater than any other stream in the watershed. The average stream gradient is 4.3% and some reaches have a gradient exceeding 8%. In addition to influencing the stream gradient, the elevation of upper Sunset Creek also influences the hydrology of the system as precipitation in the City of Bellevue is positively correlated to elevation.

Sunset Creek generally has an intact and healthy riparian corridor for an urban stream (**Map B-6**). With the exception of Reach 1 which is highly impacted by commercial development, Sunset Creek has good to excellent riparian canopy cover and a generally low proportion of impervious surfaces within the 100 ft riparian buffer (**Table B-8**). The canopy generally consists of bigleaf maple and western red cedar with a healthy understory of native plants. However, invasive species such as Himalayan blackberry are intermittently abundant and English ivy is quite dense in places and occasionally chokes the channel.

Sunset Creek has the narrowest and shallowest channel of all primary streams in the Greater Kelsey Creek Watershed. Across all surveyed reaches, the median wetted and bankfull widths are 4.6 ft and 7.1 ft, respectively. The wetted width generally decreases as you proceed upstream, but the bankfull width remains slightly more constant throughout the stream corridor (**Figure B-33**). With an average bankfull width to wetted width ratio of 1.5, Sunset Creek is the least confined channel in the Greater Kelsey Creek Watershed. It is also the shallowest channel in the watershed with a median representative depth of 0.2 ft and median maximum depth of 0.5 ft (**Figure B-34**).

Table B-8. Reach attributes for Sunset Creek.

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Reach Segment ID	79_01	79_02	79_03	79_04	79_05	79_06
River Mile Boundaries	0.00 – 0.22	0.22 – 0.27	0.27 – 0.33	0.33 – 0.45	0.45 – 0.82	0.82 – 0.93
Sediment Dynamics	Response	Forced transport	Source/ Transport	Forced transport	Source/ Response	Transport
Channel Type	Plane-bed	Piped conveyance	Cascade	Piped conveyance	Plane-bed	Piped conveyance
Stream Gradient (%)	2.4	3.4	6.1	5.2	5.2	5.3
Riparian Canopy Cover (%)	25	-	85	-	83	-
Riparian Impervious Surface Cover (%)	69	71	1	51	1	1
Reach Length (ft)	1,150	300	300	650	1,950	550

	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11	Reach 12
Reach Segment ID	79_07	79_08	79_09	79_10	79_11	79_12
River Mile Boundaries	0.93 – 1.11	1.11 – 1.71	1.71 – 1.88	1.88 – 2.01	2.01 – 2.16	2.16 – 2.31
Sediment Dynamics	Forced transport	Response	Forced transport	Response	Transport	Source/ Transport
Channel Type	Plane-bed	Plane-bed	Piped conveyance	Plane-bed	Cascade/ Bedrock	Colluvial/ Cascade
Stream Gradient (%)	3.3	1.2	6.2	8.2	8.6	6.1
Riparian Canopy Cover (%)	53	49	-	87	86	67
Riparian Impervious Surface Cover (%)	33	33	46	6	< 1	24
Reach Length (ft)	950	3,175	875	700	800	800

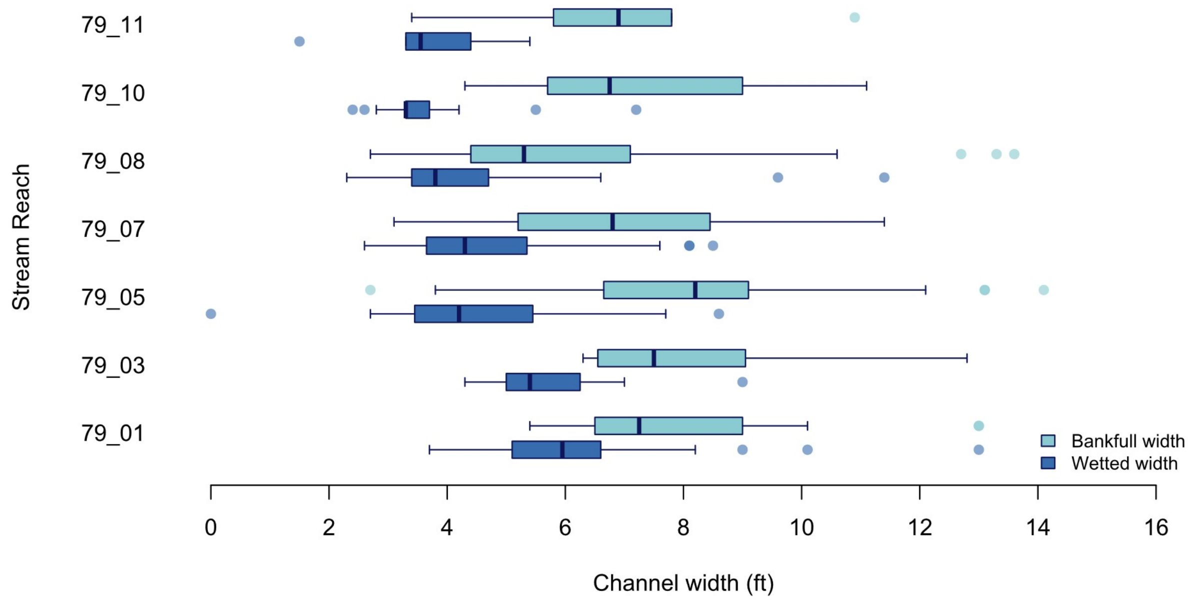


Figure B-33. Boxplot of the wetted and bankfull channel widths for stream reaches in Sunset Creek.

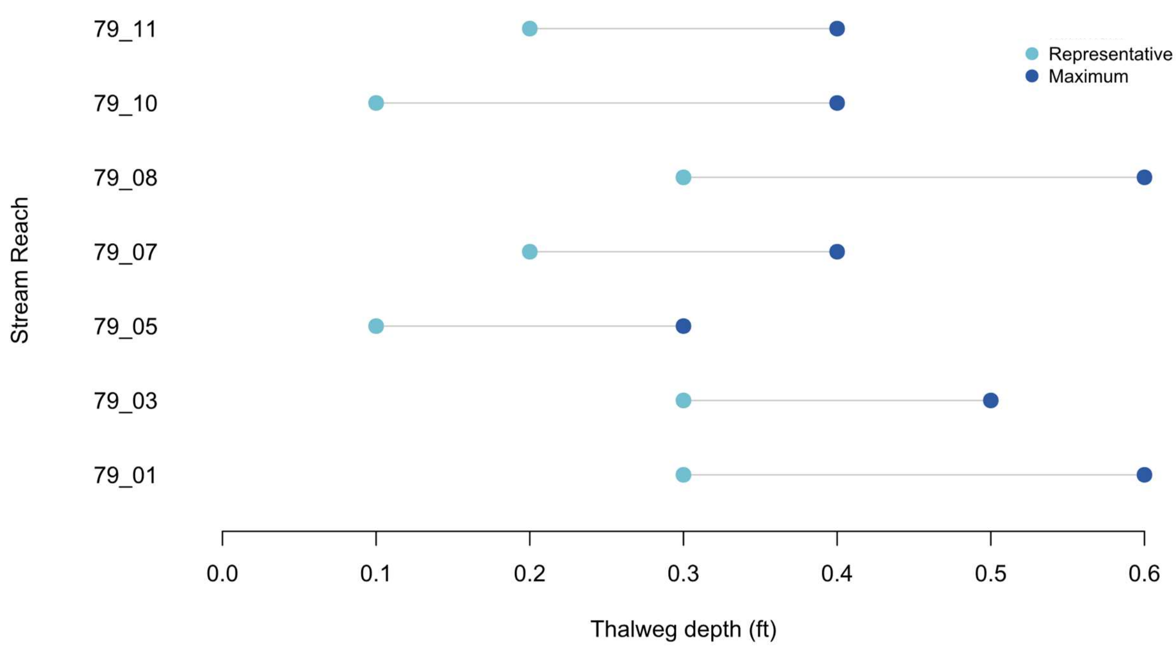


Figure B-34. Dumbbell plot of wetted stream depths in Sunset Creek. Points represent the median representative and maximum depths for each stream reach.

B.3.4.2 Habitat Unit Composition and Off-Channel Habitat

Sunset Creek is dominated by riffle habitat, which comprises 68% of the stream area and 72% of the stream length (**Figure B-35** and **Figure B-36**). Glide habitat is the second-most common habitat type, comprising 22% of the stream area and 20% of the stream length. Pool habitat is somewhat lacking in Sunset Creek. Across all surveyed reaches, pool habitat accounts for 10% of the stream area and 7% of the stream length. However, pool habitat is more prevalent downstream of I-90 than in the rest of the subbasin. Habitat units in Sunset Creek range in length from 5 ft to 183 ft with a median of 34 ft, which is the shortest length observed in the Greater Kelsey Creek Watershed.

The quality and frequency of pool habitat in Sunset Creek is below ideal standards for fish habitat. Juvenile salmon productivity is highest when there is roughly an equal area of riffle habitat and pool habitat. However, across all surveyed reaches in Sunset Creek, there is seven times more riffle habitat than pool habitat. This is the second worst riffle to pool ratio in the Greater Kelsey Creek Watershed. Even downstream of I-90 where pools are more abundant, riffles outsize pools by three to one. Overall, Sunset Creek has a pool frequency of 23 pools per mile (1 pool per 100 m) or 32.8 channel widths per pool, which falls far short of the ideal pool frequency of approximately 140 pools per mile expected in healthy, “properly functioning” streams of similar size (NOAA 1996). The median residual pool depth is 1.0 ft (**Figure B-37**), which is the shallowest found in the Greater Kelsey Creek Watershed. Only one pool has a residual depth greater than 2 ft, and it results from the I-90 culvert outfall. Approximately one-third of all pools in Sunset Creek result from artificial impacts, primarily weirs and culvert or stormwater outfalls.

Off-channel habitat is virtually absent in the Sunset Creek Subbasin. Only three short side channel habitat units are present, two of which were dry at the time of the surveys. Unlike all other subbasins in the Greater Kelsey Creek Watershed, Sunset Creek has no associated wetlands.

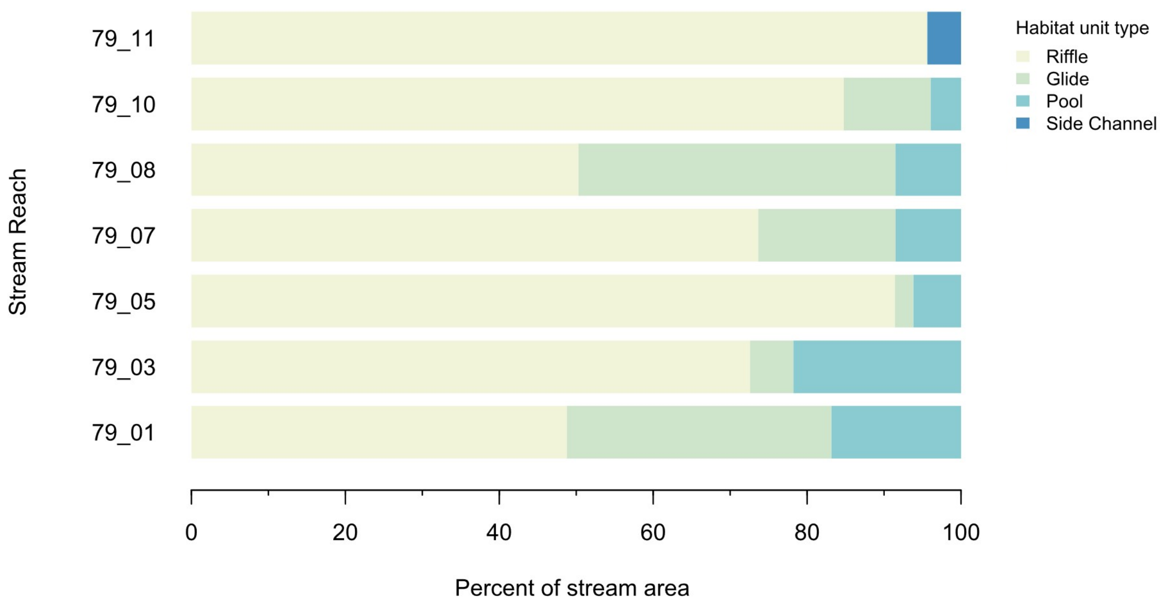


Figure B-35. Habitat unit composition (by percent area) in Sunset Creek.

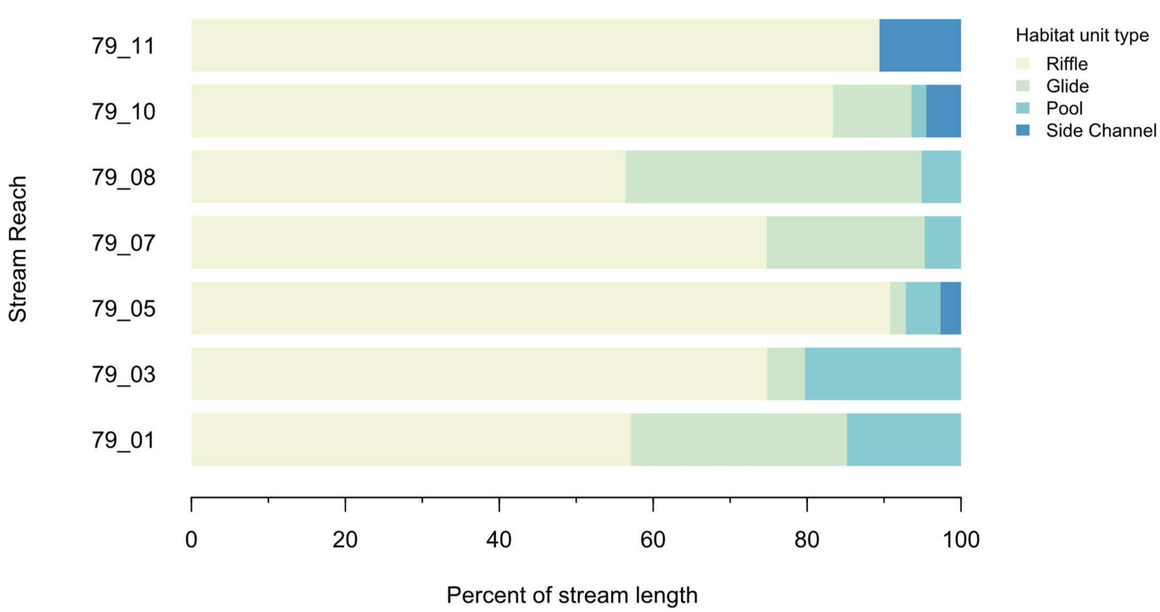


Figure B-36. Habitat unit composition (by percent length) in Sunset Creek.

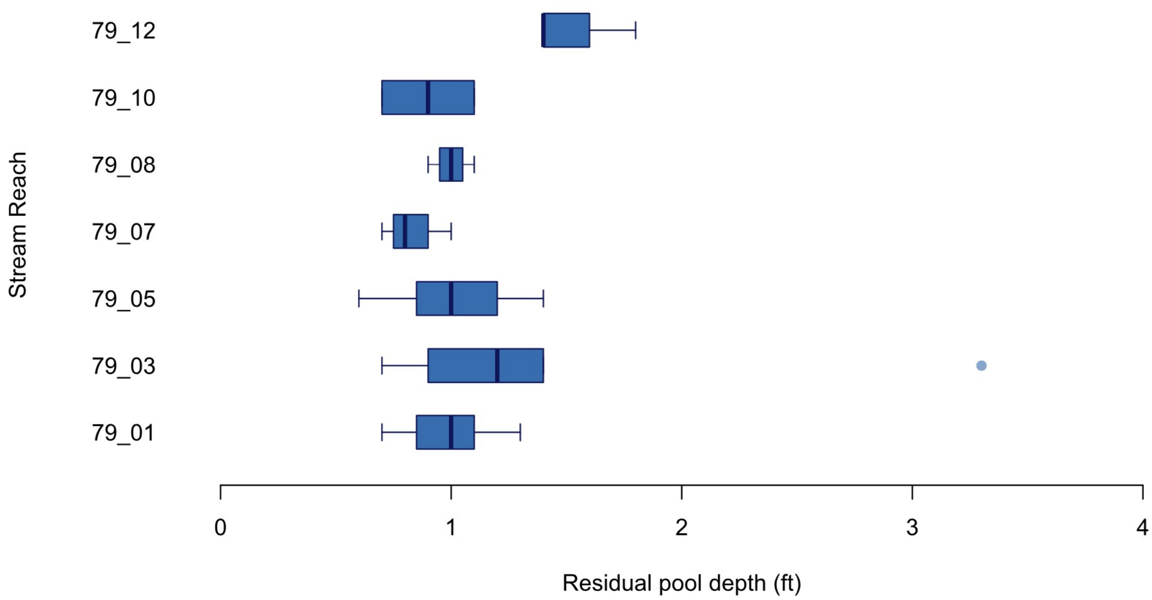


Figure B-37. Boxplot of residual pool depths in stream reaches of Sunset Creek.

B.3.4.3 Large Woody Material

As in the rest of the Greater Kelsey Creek Watershed, large woody material (LWM) is limited in the Sunset Creek Subbasin. The average wood density across all surveyed reaches in Sunset Creek is 156 pieces per mile (10 pieces per 100 m), which is far below reference levels (**Figure B-38**) but is the second highest LWM density observed in the Greater Kelsey Creek Watershed. Restoration activities in Reach 1 have enhanced natural LWM levels with placed wood, which accounts for 56% of all wood observed in that reach and 11% of all wood in the subbasin. Although LWM frequency is low, the potential for natural recruitment is fairly high due to the good riparian canopy cover present in the subbasin (**Table B-8**).

LWM is likely influential in creating and maintaining pool habitat in Sunset Creek. Although pools account for only 10% of the stream area, 37% of all LWM is found in pool habitat. This indicates that habitat quality and complexity could be improved by increasing the abundance of LWM through restoration activities and educational outreach to property owners about the importance of allowing the natural recruitment of LWM.

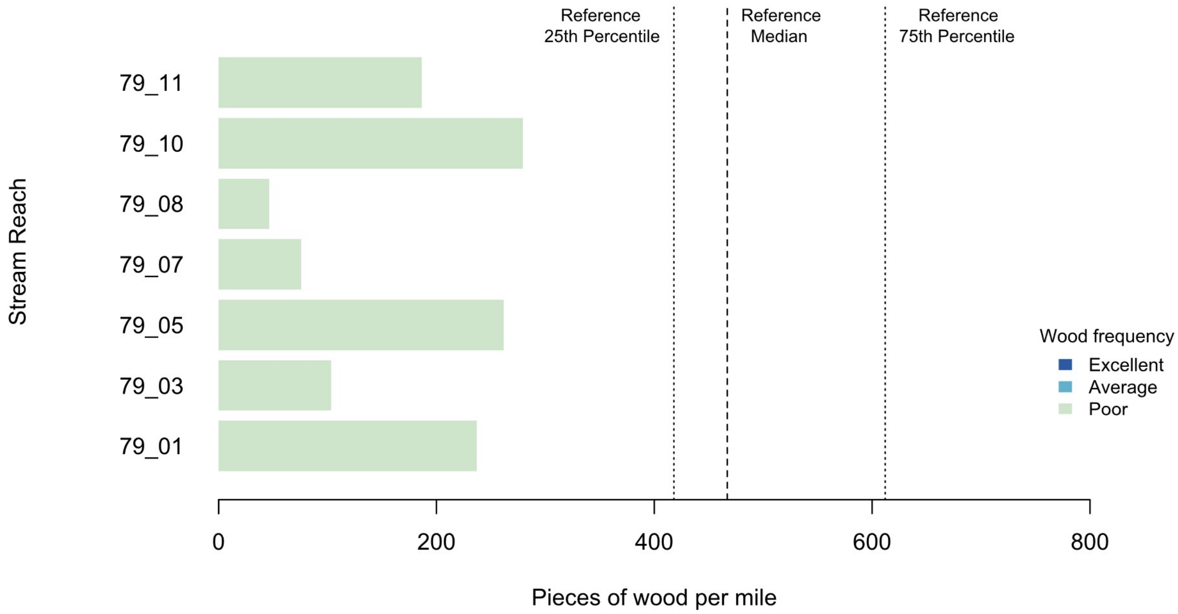


Figure B-38. Large woody material frequency in Sunset Creek compared to reference levels (Fox and Bolton 2007).

B.3.4.4 Streambed Substrate

Streambed substrate in fast water habitat of Sunset Creek primarily consists of gravel (35%), fines (30%), and cobble (26%). Sunset Creek has a lower-than-average proportion of fines in riffle habitat (25%) compared to other subbasins in the Greater Kelsey Creek Watershed and the substrate composition is suitable for spawning salmonids, particularly in the downstream Reaches 1, 3, and 5 (**Figure B-39**). There are several areas where the channel bed has scoured down to glacial till hardpan. This is particularly noticeable in Reach 11 where exposed hardpan accounts for 30% of the streambed substrate.

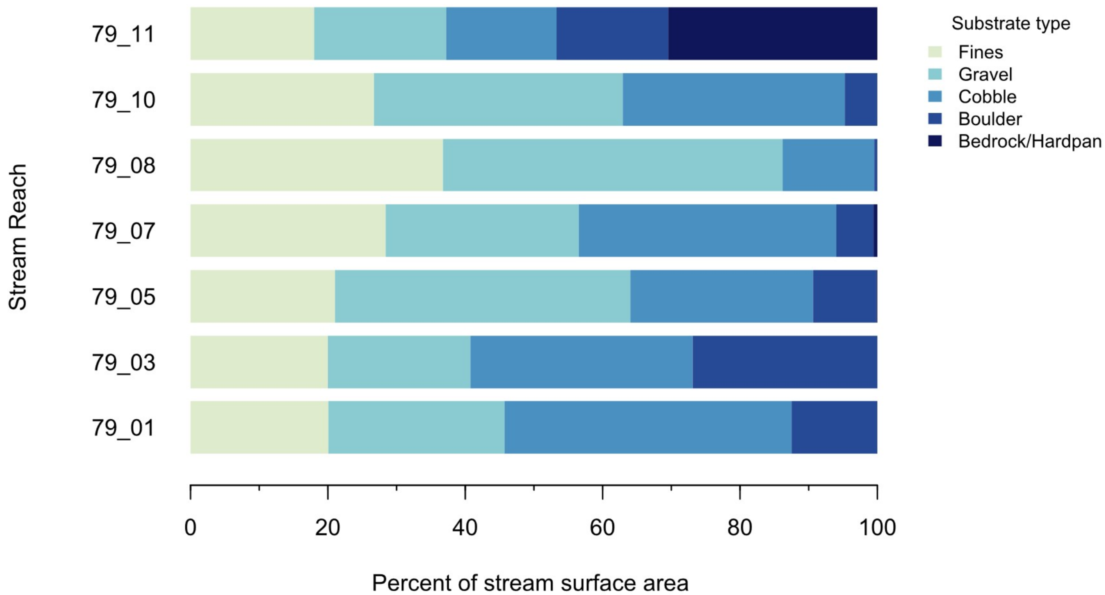


Figure B-39. Substrate composition of riffle habitat in Sunset Creek, determined by visual estimation.

B.3.4.5 Streambank Conditions

Streambank armoring in Sunset Creek is slightly lower than average for the Greater Kelsey Creek Watershed. Across all surveyed reaches, 11% of the streambank is armored with the majority of armoring found in Reaches 1 and 7 (**Figure B-40**). In general, individual instances of armoring tend to be short in extent, but some extend for 100 to 200 ft. Although most of the armoring is low in height (<5 ft), a larger proportion is 5 to 10 ft high compared to other subbasins in the watershed. Like other subbasins in the watershed, armoring in Sunset Creek is predominantly large angular rock. However, somewhat unique to this basin is the moderately high proportion (30%) of concrete armoring in the form of both solid walls as well as stacked concrete chunks. Bioengineering is only found in Reach 1 where it accounts for 44% of all armoring present in that reach. Across all reaches, nearly 20% of all armoring is failing, which is about average for subbasins in the Greater Kelsey Creek Watershed.

Sunset Creek is experiencing less streambank erosion than most other streams in the Greater Kelsey Creek Watershed. Across all surveyed reaches, 8% of the streambank shows evidence of erosion and 6% of the streambank is undercut (**Figure B-41** and **Figure B-42**). More than half of all erosion, especially in Reach 8, is low toe scour with stable but undercut banks which provides good habitat for fish and other aquatic animals. Reach 5, the Sunset Ravine, includes three instances of erosion greater than 10 ft in height that are associated with significant mass wasting and active hillslope failure.

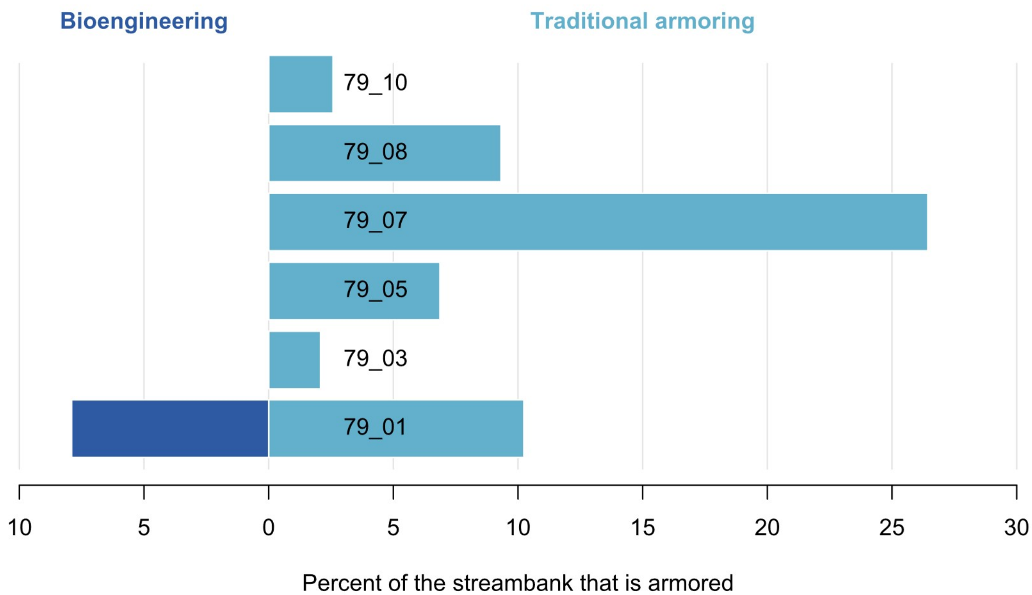


Figure B-40. Diverging bar graph showing the proportion of the streambank in Sunset Creek that is armored using traditional materials (right) and bioengineering (left).

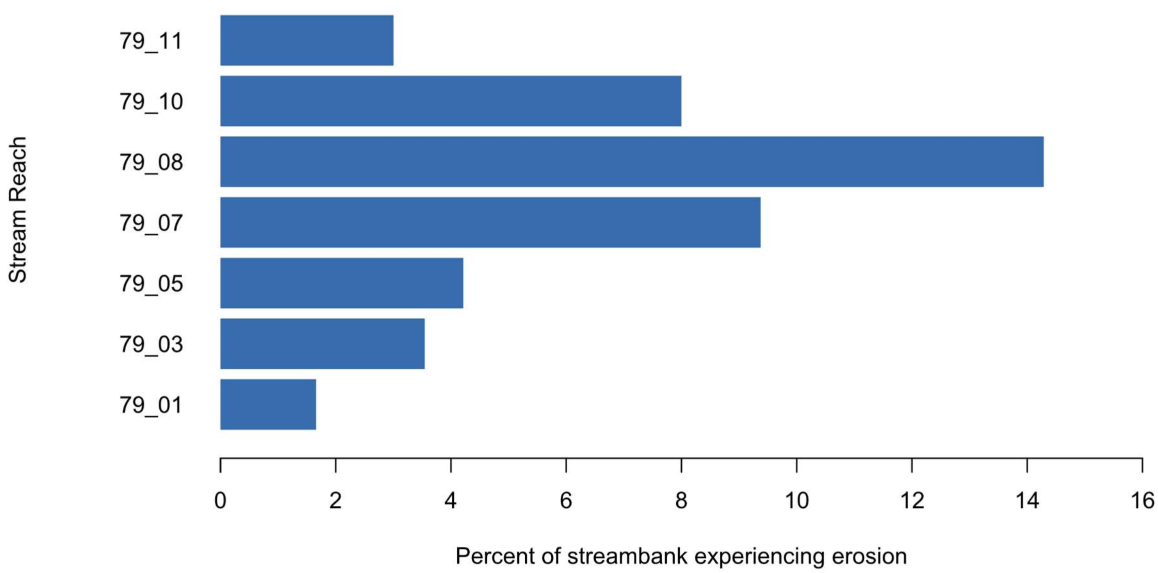


Figure B-41. Percent of each stream reach in Sunset Creek that is experiencing erosion.

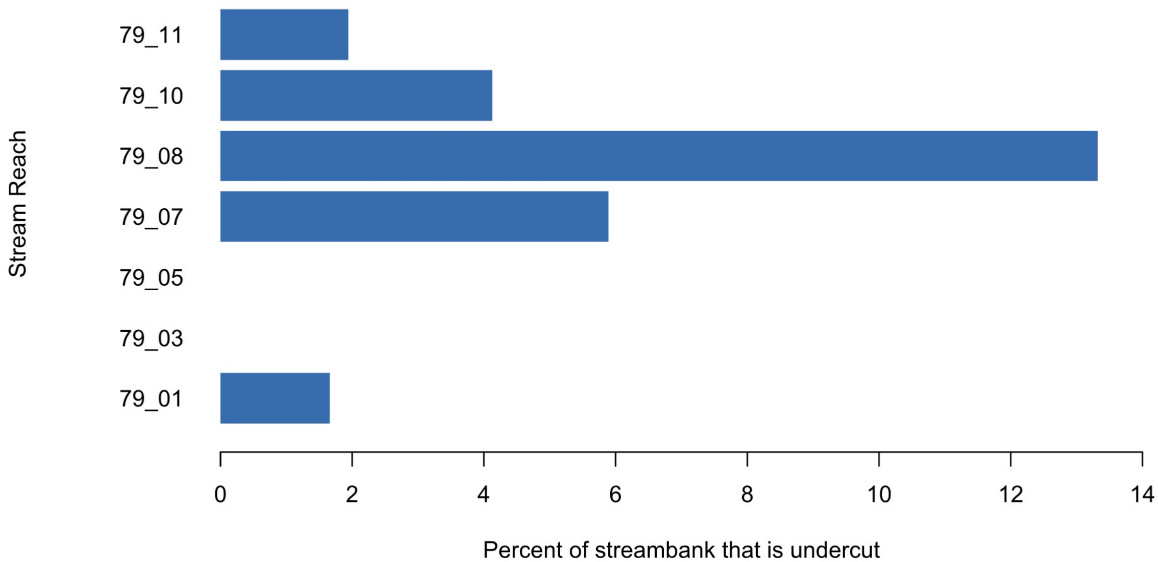


Figure B-42. Percent of each stream reach in Sunset Creek that has undercut streambanks.

B.3.4.6 Fish Habitat and Passage Barriers

Although Sunset Creek historically hosted Chinook Salmon, Coho Salmon, Sockeye Salmon, steelhead and resident trout (Bellevue 2010), fish use of this stream is now fairly limited. During the OSCA surveys, fish (presumably Cutthroat Trout) were frequently observed only in Reaches 1 and 3. The only fish observed upstream of I-90 was a goldfish in Reach 8. Additionally, invasive New Zealand Mud Snails were present, sometimes in very high densities, throughout the entire stream and were even observed at the stormwater outfall structure at the upstream end of Reach 12.

With a healthy riparian buffer and canopy cover upstream of I-90 and relatively low proportion of fines in the streambed substrate, Sunset Creek has the potential to provide quality fish habitat. However, there are several notable challenges. The stream is currently lacking in pool habitat as well as the LWM necessary to create and maintain pools in this higher gradient stream. Additionally, the channel is quite shallow. Adult trout and Coho Salmon generally require a minimum depth of 0.4 and 0.6 ft, respectively (Thompson 1972). However, riffle habitat in Sunset Creek has a median representative depth of only 0.1 to 0.2 ft and a median maximum depth ranging from 0.3 to 0.5 ft. At present, this is likely insufficient to sustain fish populations. Low water levels may be the result of a high-flow bypass located at the downstream end of Reach 8 that has been known to cause portions of the downstream reaches, especially Reach 5, to dry up during summer low flow periods.

Additionally, there are numerous barriers to fish movement and migration. WDFW (2021) has documented one partial barrier and six complete barriers in addition to one natural waterfall forming a complete barrier in Reach 12. See Appendix D of this report for a complete inventory of formally documented fish passage barriers in the watershed. One of the complete barriers, the I-90 culvert, is currently in final design and scheduled to be replaced by the Washington Department of Transportation with several bridges and a roughened channel. This will reconnect upper Sunset Creek with lower Sunset and Richards Creeks where there is an abundance of slow water and wetland habitat that is ideal for the rearing of juvenile trout and Coho Salmon. If habitat could be improved in Reaches 5 through 8, these reaches could provide an associated spawning habitat. However, it would first be necessary to conduct a study on the impacts of the high-flow bypass in Reach 5 and the projected change in hydrology if it were removed. Additionally, Reaches 5 and 6 are higher gradient (just over 5%). This is at the low end of the threshold of 5-7% generally considered to be the maximum stream gradient tolerated by adult Coho Salmon. Quality pools would be necessary resting habitat for migrating adult salmon.

B.3.4.7 Opportunities

With the upcoming I-90 culvert removal and channel enhancement, there are unique and prescient opportunities to protect and restore stream health in Sunset Creek. As previously mentioned, one such opportunity is a study evaluating the current function and continued need of the high-flow bypass that diverts flow from the downstream end of Reach 8 to the downstream end of the Sunset Ravine (Reach 5). Additional opportunities include correcting the numerous fish passage barriers, daylighting Reach 6, and enhancing habitat and aiding pool formation by placing LWM with particular emphasis on Reaches 5 through 8.

Another opportunity includes improving riparian conditions throughout the stream corridor. Because much of Sunset Creek is on privately-owned parcels, educational outreach and incentive programs are recommended to reduce the impact of invasive vegetation and maintain and improve native riparian cover, especially in the reaches downstream of I-90. Sunset Creek also has the highest incidence of litter and dumping observed in the Greater Kelsey Creek Watershed. Household items, tires, large chunks of concrete, and metal shopping carts are among the items found in the stream and should be removed to enhance stream health. Although encampments are not as prevalent in lower Sunset Creek as they are in Valley and Sears Creeks, there is evidence of human activities around the stream and accordingly Sunset Creek should be including in the relevant City programs.

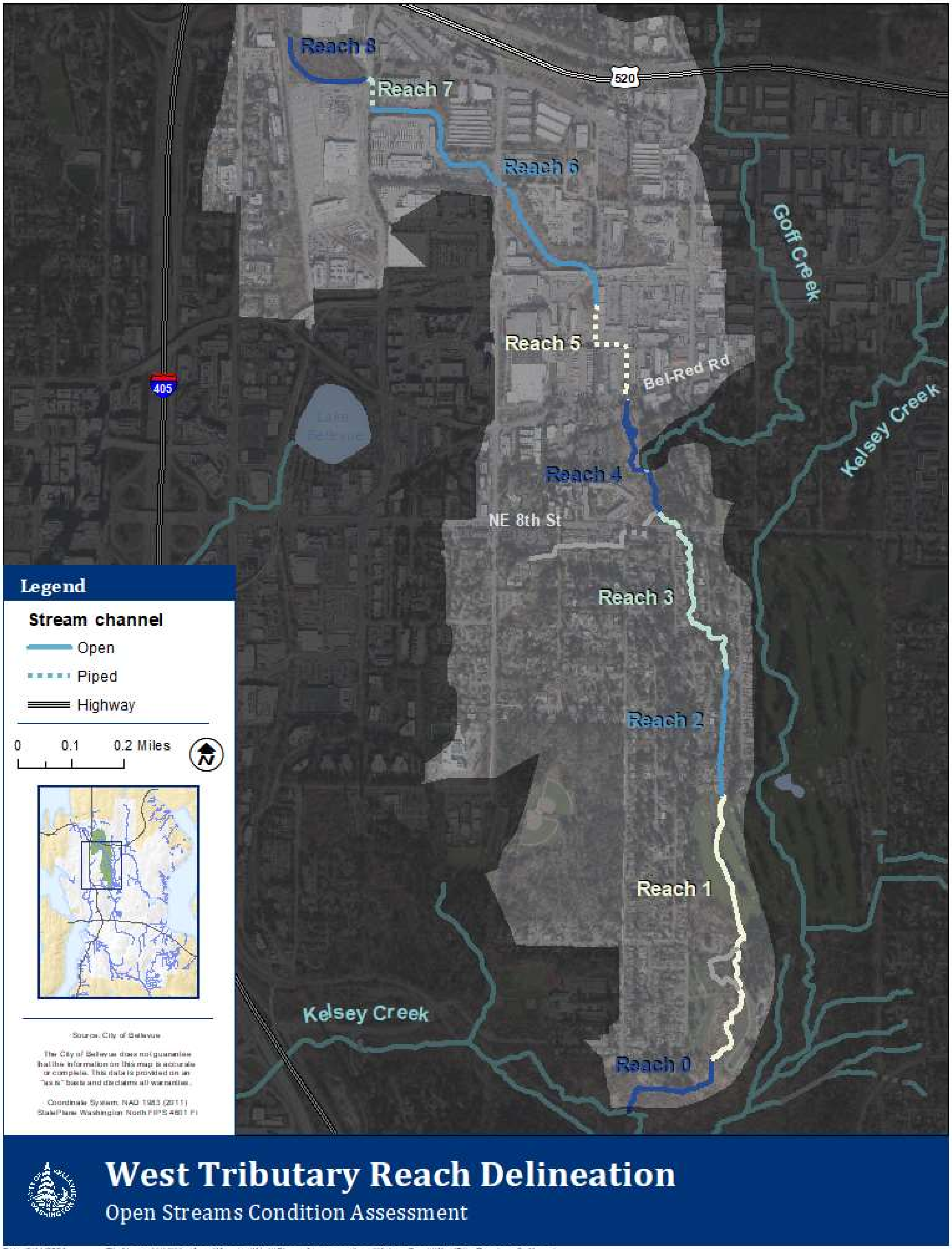
Because Sunset Creek is high-gradient and feeds into low-gradient Richards Creek, it is highly probable that erosion in Sunset Creek is the source for much of the fine sediment accumulating in Richards Creek. The Sunset Ravine, in particular, has a history of slope failure and mass wasting. Projects aimed at improving channel complexity and bank stabilization in this area could help reduce sedimentation and flooding that frequently occurs in lower Sunset and Richards Creeks.

B.3.5 West Tributary Subbasin

West Tributary is a noteworthy tributary to the mainstem of Kelsey Creek located in the Northwest Bellevue, Downtown/Bel-Red and Wilburton neighborhoods. The West Tributary Subbasin encompasses 963 acres of mixed land use primarily consisting of residential, commercial, and industrial properties. The subbasin ranges in elevation from 27 ft to 496 ft and contains 3.4 miles of open stream channel and 18.0 miles of storm drainage pipes.

The present-day headwaters of West Tributary are found in the Reach 8 wetland complex that hosts an extensive beaver pond network (**Map B-7**). The upper portion of West Tributary alternates between wetland and piped conveyance north of Bel-Red Road (Reaches 4-8) in what is primarily a commercial district often referred to throughout the City as the Spring District. The confluence of Goff Creek, a tributary to West Tributary, is located in Reach 4 in the Goff Creek Regional Detention Facility. Slightly downstream a small tributary, Tributary 0264A, confluences near the Lower West Tributary Regional Detention Facility in Reach 4 and primarily functions as a drainage corridor from commercial and residential properties and may only receive seasonal streamflow. Salmonid spawning is primarily limited to Reaches 1 through 3 which flow along privately-owned parcels that parallel the mainstem of Kelsey Creek from NE 8th Street downstream to the extensive wetlands at Kelsey Creek Park. This extensive wetland complex includes West Tributary Reach 0 and the confluence of these two branches of Kelsey Creek.

It should be noted that West Tributary and Tributary 0264A were surveyed in 2016 under a different protocol than the OSCA surveys presented in this appendix. Here, we provide a summary of results from that survey for comparison with the other Bellevue streams. For complete results and a description of the methods used in West Tributary, see the final project report (Tetra Tech 2016). It should also be noted that in this appendix, we refer to the downstream-most reach of West Tributary as Reach 0 (80_00). However, the Tetra Tech report refers to it as 76_04 (which is, in fact, Kelsey Creek Reach 4). It was renamed in this appendix to avoid confusion. Additionally, the 2016 West Tributary survey protocol included wetland reaches, yet those data are excluded here so that they are more comparable to the other subbasins in this appendix.



Map B-7. West Tributary stream reaches.

B.3.5.1 Channel Morphology and Riparian Corridor

West Tributary generally varies from a typical small order stream with varying urban impact to large, marsh-dominated areas with no defined stream channel interspersed with piped stream conveyances. When not piped or in a wetland, the channel generally takes on a plane-bed morphology of limited complexity (**Table B-9**).

Riparian vegetation and shading conditions are highly variable in quality, and non-native invasive species are present and dominant in most reaches. Wetland reaches primarily consist of only small trees, shrubs and herbaceous vegetation. Therefore, these areas may be impacting stream temperature and could benefit from larger trees such as wetland tolerant conifers and cottonwood.

The primary stream channels of West Tributary (Reaches 1-3) are similar in dimensions and confinement to Sturtevant Creek and slightly larger than average for the Greater Kelsey Creek Watershed. The average wetted and bankfull widths are 8.5 ft and 9.4 ft, respectively, and the average depth is 0.7 ft. With a bankfull to wetted width ratio of 1.1, West Tributary ties with Sturtevant Creek as the most confined primary channel in the watershed.

Table B-9. West Tributary reach attributes.

	Reach 0	**Reach 1**	**Reach 2**	**Reach 3**	**Reach 4**
Reach Segment ID	80_00	80_01	80_02	80_03	80_04
River Mile Boundaries	0.00 – 0.26	0.26 – 0.83	0.83 – 1.07	1.07 – 1.49	1.49 – 1.76
Sediment Dynamics	Response	Response	Response	Response	Response
Channel Type	Wetland	Plane-bed/ Pool-riffle	Plane-bed	Plane-bed	Wetland
Stream Gradient (%)	0.5	0.5	2.8	0.9	0.8
Riparian Canopy Cover (%)	21	33	39	47	44
Riparian Impervious Surface Cover (%)	1	9	40	31	8
Reach Length (ft)	1,350	3,050	1,250	2,200	1,420
	Reach 5	**Reach 6**	**Reach 7**	**Reach 8**	
Reach Segment ID	80_05	80_06	80_07	80_08	
River Mile Boundaries	1.76 – 1.99	1.99 – 2.66	2.66 – 2.72	2.72 – 2.92	
Sediment Dynamics	Forced transport	Response/ Source	Forced transport	-	
Channel Type	Piped conveyance	Wetland	Piped conveyance	Wetland	
Stream Gradient (%)	0.7	0.5	0.1	0.4	
Riparian Canopy Cover (%)	-	26	-	25	
Riparian Impervious Surface Cover (%)	92	31	62	29	
Reach Length (ft)	1,260	3,520	330	1,040	

B.3.5.2 Habitat Unit Composition and Off-Channel Habitat

The primary stream channel of West Tributary (Reaches 1-3) is dominated by riffle habitat (**Figure B-43** and **Figure B-44**). Riffles account for 65% of the stream area. Glide habitat is the second-most abundant habitat type accounting for 34% of the stream area, although Tributary 0264A predominantly consists of glide habitat. Pool habitat is lacking in the West Tributary primary channel. Only 2% of the habitat area is comprised of pools, and that is predominantly restricted to Reach 2. The abundant wetland habitat found in Reaches 0, 4, 6, and 8 provides deep pools and complex side- and off-channel habitat. Beavers are active in these wetlands and greatly contribute to the habitat complexity.

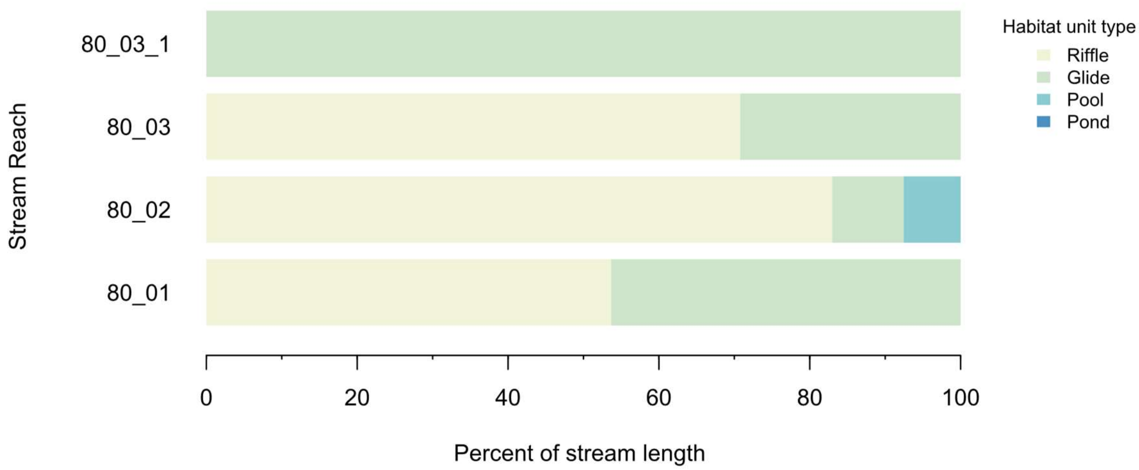


Figure B-43. Habitat unit composition (by percent area) of West Tributary stream reaches and the unnamed tributary (80_03_1).

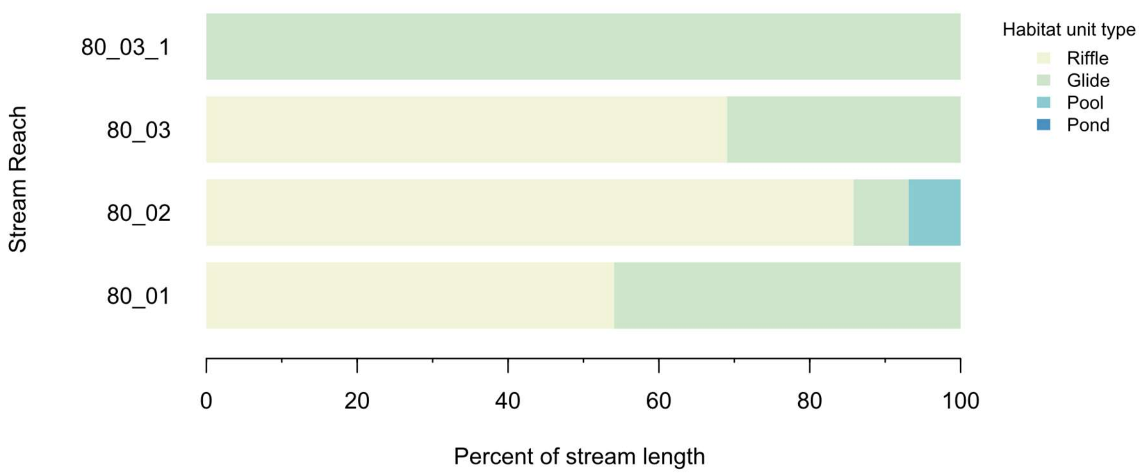


Figure B-44. Habitat unit composition (by percent length) of West Tributary stream reaches and the unnamed tributary (80_03_1).

B.3.5.3 Large Woody Material

West Tributary has one of the lowest densities of large woody material (LWM) seen in the City of Bellevue. Across all primary stream reaches, the wood density is approximately 30 pieces per mile. This is comparable to wood levels observed in Sears Creek, which has the least LWM of any subbasin in the City of Bellevue. Reaches 2 and 3 have virtually no LWM, and although Reach 1 has the highest levels of LWM in the subbasin, it still falls far below reference levels (**Figure B-45**). Much of the LWM recruitment in West Tributary is associated with beaver activity. Accordingly, the wetland reaches generally have a greater abundance of LWM compared to the primary stream reaches presented here.

Figure B-45. Large woody material frequency in the mainstem reaches of West Tributary compared to reference levels (Fox and Bolton 2007).

B.3.5.4 Streambed Substrate

West Tributary's streambed substrate in riffle habitat is dominated by gravels (49%) and fines (31%) intermixed with cobbles (14%) and sporadic boulders (6%). Riprap from streambank armoring has mobilized into the stream channel and accounts for some of the larger substrate. The proportion of fines varies by stream reach (**Figure B-46**) and is highest at the lowest reaches where it is generally too high for the successful spawning and incubation of Pacific salmon.

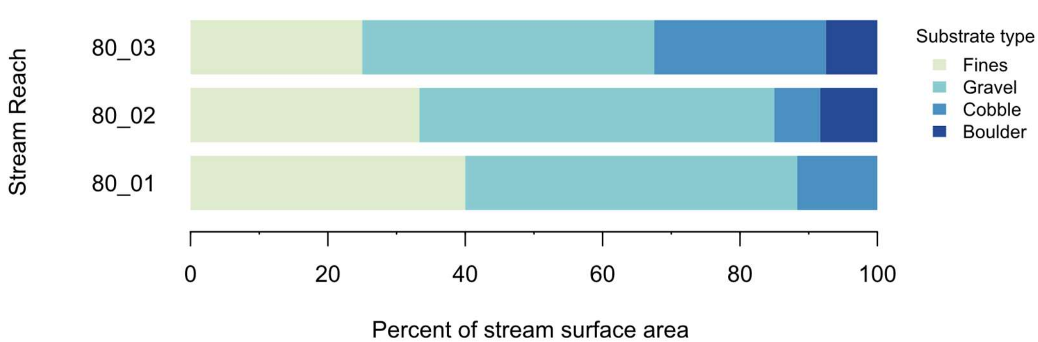


Figure B-46. Substrate composition of riffle habitat in West Tributary stream reaches, determined by visual estimation. Reaches not presented here did not have riffle habitat or were not surveyed.

B.3.5.5 Streambank Conditions

Regional stormwater detention facilities and numerous beaver dams found in West Tributary reduce flashy storm flows and velocities, thereby reducing bank instability compared to other subbasins of the Greater Kelsey Creek Watershed. Tetra Tech's 2016 Habitat Assessment found bank instability to be most common in Reach 1 where a combination of limited riparian vegetation, high groundwater table, and stream dynamics contribute to bank slumping.

Streambank armoring is abundant, particularly on private property in residential areas of Reaches 2 and 3. Undercut banks and toe scour is rare in the confined stream Reaches 1 and 2, due to bank protection. Tetra Tech (2016) reported that the water level increases vertically along the armored streambank but does not show evidence of toe scour. Channel incision was likely common after residential development occurred but appears to have stabilized with the installed traditional bank hardening materials (primarily riprap) along the streambank and failed material along the streambed.

B.3.5.6 Fish Habitat and Passage Barriers

Fish rearing habitat is available in most reaches, although during low flow conditions, water depths are relatively shallow and there is a lack of riparian cover in most reaches. Beaver ponds and wetlands found throughout Reaches 0, 4, 6 and 8 provide high quality rearing habitat for juvenile salmonids, lamprey, and other native fish species while also providing good winter refugia from flashy urban streamflow. West Tributary has limited spawning habitat, which is primarily restricted to Reaches 1-3 downstream of NE 8th Street, yet riffles with suitably-sized spawning gravels are often overlaid with fine sediment that could limit survival of eggs if spawning occurs. Coho Salmon have been documented spawning in these areas, and resident and adfluvial Cutthroat Trout regularly utilize habitat through Reach 4 (Bellevue 2020). In 2005, Peamouth Minnow were observed spawning in West Tributary Reach 1 at Kelsey Creek Park (Bellevue 2010).

There are three documented partial fish passage barriers within West Tributary. All are City-owned and include NE 8th Street, Lower West Tributary Regional Detention Facility, and Goff Regional Detention Facility (WDFW 2021). See Appendix D of this report for a complete inventory of formally documented fish passage barriers in the watershed. Several other undocumented barriers or impediments to fish passage are located throughout the subbasin, including a long culvert at Bel-Red Road that likely prevents fish passage to the upper reaches. Resident fish surveys in the early 2000s found no fish populations in wetland Reaches 6 or 8, but it is possible for this habitat to sustain fish and other aquatic life should downstream barriers be corrected. Water quality is a concern for fish and overall stream health in West Tributary, especially around Reach 6. Beaver dams throughout the subbasin may create seasonal or temporary impediments to fish passage but were not considered to be barriers at the time of Tetra Tech's 2016 habitat assessment.

B.3.5.7 Opportunities

There are many opportunities to protect, improve, and sustain heathy aquatic habitat throughout West Tributary. Invasive species control and native riparian enhancement should be a priority across the subbasin. Wetlands found in Reaches 0, 4, 6 and 8 offer numerous benefits including: flood control, sediment and nutrient storage, ground water recharge, and habitat and refuge for fish and wildlife species. These wetlands lack tall shade trees (conifers or cottonwoods) and do host numerous invasive plant species (particularly reed canary grass) which need to be controlled and maintained. Allowing more desirable native trees and shrubs to become established would help reduce stream temperature, maintain water storage capacity, and act as a source for LWM recruitment. Experimental techniques to control non-native reed canary grass and/or the use of elevated planting mounds are potential options for restoration in the wetland reaches.

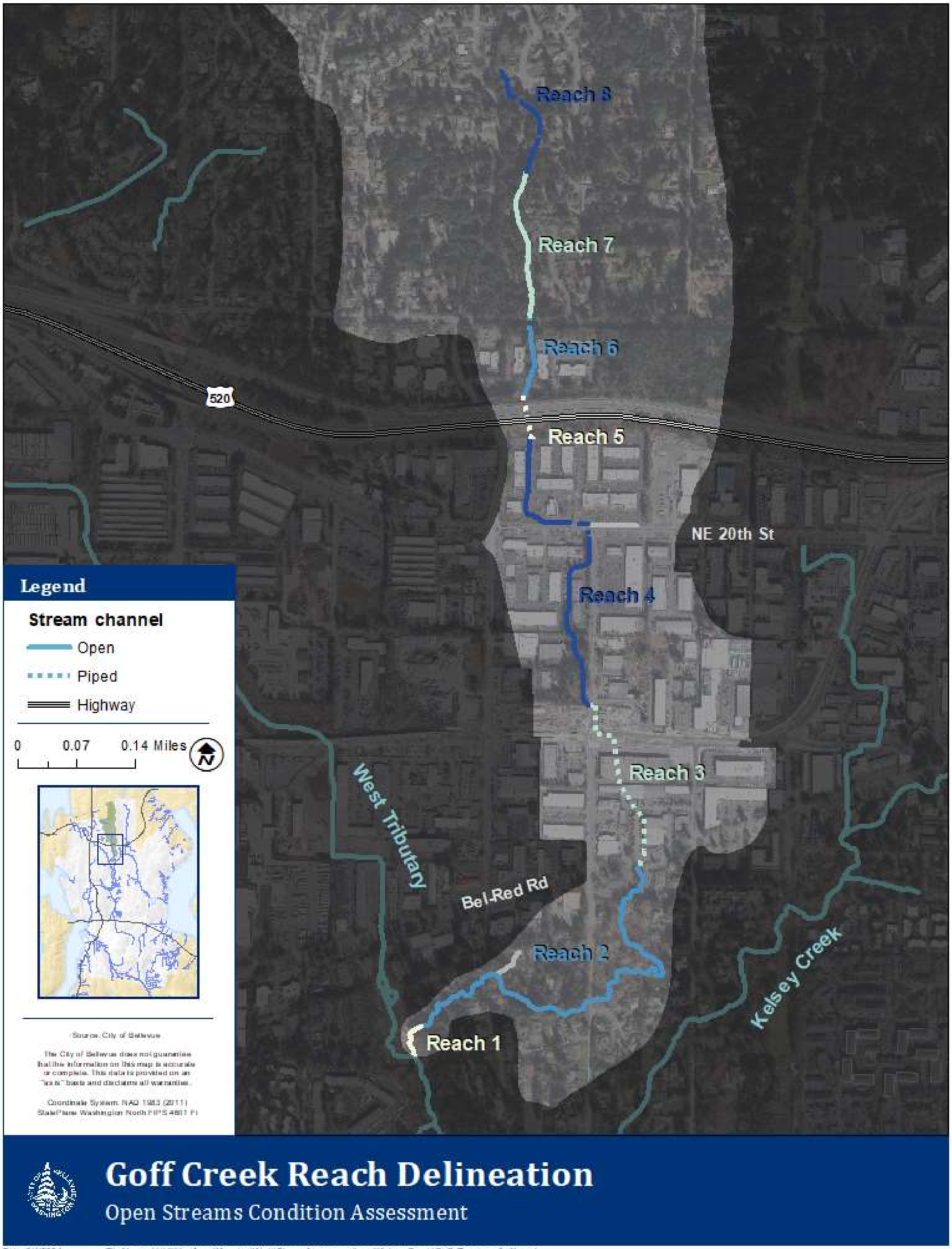
Reaches 2 and 3 are primarily private residential and golf course properties that could benefit from limiting further encroachment from development and restoring the riparian corridor by removing bank protection and/or replacing it with “soft” armoring and planting native trees and shrubs to establish edge habitat and stream cover.

Correction of documented fish barriers and undocumented impediments to fish passage should be prioritized downstream of the confluence with Goff Creek in Reaches 1, 2 and 3. All fish passage barrier corrections should be sequenced appropriately in the downstream to upstream direction.

B.3.6 Goff Creek Subbasin

Goff Creek, a tributary of West Tributary, is located in North Bellevue in the Bridle Trails, Bel-Red and Wilburton neighborhoods (**Map B-8**). The subbasin encompasses 700 acres with elevations ranging from 111 ft to 541 ft. Within the City of Bellevue, land use is predominantly residential although public right of way accounts for over a third of the subbasin area. Although there is very little open space in the subbasin within the City limits, the upper portion of the subbasin passes into Bridle Trails State Park and accounts for more than a quarter of the subbasin area. Within Bellevue, the subbasin has 2.5 miles of open stream channel and 9.4 miles of storm drainage pipes (Bellevue 2017).

The headwaters to Goff Creek originate in unincorporated King County and Bridle Trails State Park and are conveyed into storm drains prior to flowing into an open stream channel in private residential backyards just north of NE 28th Place. The upper reaches of Goff Creek primarily flow through a densely forested ravine that passes behind private residential parcels until land use changes, similarly to Valley Creek, to a highly urban and heavily commercial land use area both upstream and downstream of State Route 520. Reach 4 of Goff Creek is especially entrenched and constrained by the surrounding commercial district north of Bel-Red Road and has some of the lowest riparian cover observed across the City (only 23% riparian tree canopy cover). The lower two stream reaches offer good instream habitat and riparian cover even though they are impacted by invasive vegetation and fragmentation along private residential parcels. The confluence of Goff Creek and West Tributary is located in the extensive wetland complex that makes up the Goff Creek and Lower West Tributary Regional Detention Facilities.



Map B-8. Goff Creek stream reaches.

B.3.6.1 Channel Morphology and Riparian Corridor

Stream and riparian characteristics vary considerably among the Goff Creek stream reaches (**Map B-8** and **Table B-10**). Reach 1 has an undefined channel as it is part of the Goff Creek Regional Detention Pond located at the confluence of Goff Creek and West Tributary. Reaches 2, 7, and 8 pass through residential properties and have moderately good riparian canopy cover and a fairly low proportion of impervious surfaces in the 100 ft riparian buffer. The middle portion of Goff Creek (Reaches 3 – 6) is highly modified and fragmented due to commercial development and two piped conveyances. Except for Reaches 1 and 2, Goff Creek is rather confined, primarily by land use and channel modifications as well as steep hillslopes in Reach 7.

In general, Goff Creek exhibits a plane-bed channel type. The overall stream gradient is 2.9%, which is slightly higher than average for primary channels in the Greater Kelsey Creek Watershed. The upper-most extent of open stream channel is at an elevation of approximately 380 ft, which is the second highest headwater elevation in the watershed.

Channel width remains fairly consistent across all surveyed stream reaches in Goff Creek, while depth decreases as you move upstream. Across all reaches, the median wetted and bankfull widths are 5.6 ft and 6.7 ft, respectively. Channel widths are noticeably wider in Reach 2, while remaining fairly consistent throughout the rest of the stream channel (**Figure B-47**). Widths are most variable in Reach 6, likely due to channel modifications associated with commercial land development. The median representative thalweg depth across all reaches is 0.4 ft and the median maximum depth is 0.9 ft. As with width, Reach 6 shows the least variability in channel depth **(Figure B-48**), likely due to channel modifications. Shallow channel depths during low flow conditions likely pose a barrier to migratory salmonids. Adult trout and Coho Salmon generally require a minimum depth of 0.4 and 0.6 ft, respectively (Thompson 1972). However, riffle habitat in Goff Creek upstream of Reach 2 has a median representative depth of only 0.1 to 0.2 ft and a median maximum depth ranging from 0.4 to 0.9 ft.

Table B-10. Goff Creek reach attributes.

	Reach 1	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**	**Reach 6**	**Reach 7**	**Reach 8**
Reach Segment ID	81_01	81_02	81_03	81_04	81_05	81_06	81_07	81_08
River Mile Boundaries	0.00 – 0.05	0.05 – 0.64	0.64 – 0.87	0.87 – 1.26	1.26 – 1.34	1.34 – 1.43	1.43 – 1.61	1.61 – 1.76
Sediment Dynamics	Response	Response	Forced transport	Response	Forced transport	Transport	Source/ Transport	Response
Channel Type	Wetland	Plane-bed	Piped conveyance	Plane-bed	Piped conveyance	Forced step-pool*	Plane-bed	Plane-bed
Stream Gradient (%)	1.9	1.5	2.6	2.4	6.3	6.3	7.1	2.1
Riparian Canopy Cover (%)	30	71	-	23	-	52	76	58
Riparian Impervious Surface Cover (%)	0	18	93	72	54	49	25	45
Reach Length (ft)	250	3,100	1,200	2,075	450	450	950	800

* Channel modifications, including numerous weirs, force the channel type to take on a step-pool morphology.

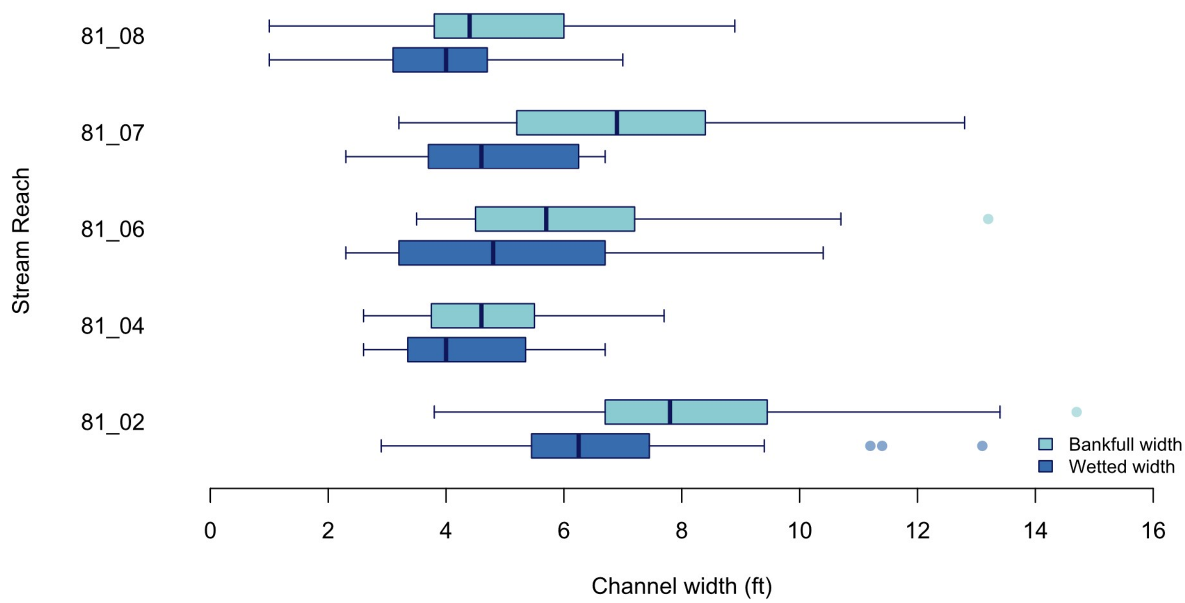


Figure B-47. Boxplot of the wetted and bankfull widths for the Goff Creek mainstem reaches.

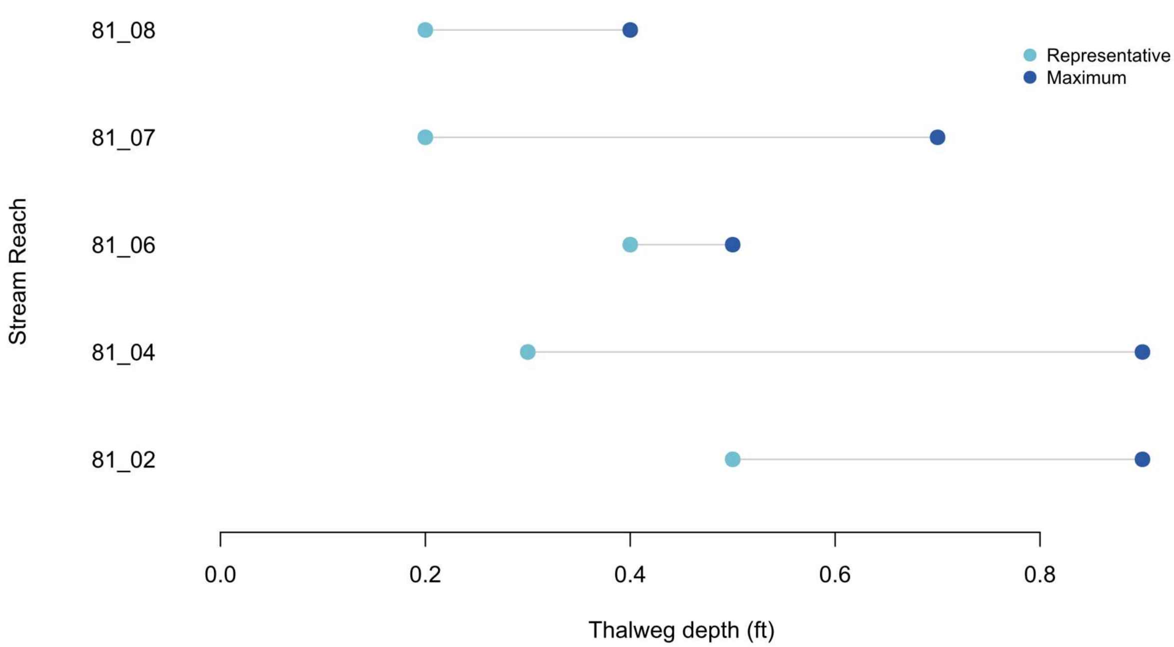


Figure B-48. Dumbbell plot of Goff Creek wetted stream depths. Points represent the median representative and maximum depth in each stream reach.

B.3.6.2 Habitat Unit Composition and Off-Channel Habitat

Channel modifications in Goff Creek impact the habitat composition, simultaneously reducing habitat diversity while, at times, also resulting in new habitat formation. Likely due to its highly confined nature, the stream is dominated by riffle habitat, which comprises 76% of the surveyed stream by area and 80% by length (**Figure B-49** and **Figure B-50**). Pool and glide habitat comprise 11% and 10% of the surveyed stream area, respectively. Approximately half of all pools observed in Goff Creek are associated with weirs. In Reach 6, frequent weirs have resulted in forced step pool habitat that encompasses nearly half (44%) of the reach.

Pool quality and frequency in Goff Creek is far below ideal levels for fish habitat. Juvenile salmonid productivity is greatest when there is an equal proportion of riffle and pool habitat area. However, Goff Creek has seven times more riffle than pool habitat area. Overall pool frequency is 19 pools/mile (1 pool per 100 m) or approximately 41 channel widths per pool with a median distance between pools of 71 ft. Similarly sized, “properly functioning” streams are expected to have over 150 pools/mile (NOAA 1996). At the time of the survey in the summer of 2019, Goff Creek had only three pools with a depth greater than 2 ft and no pools that obtained a maximum depth of 3 ft (**Figure B-51**), which is considered the minimum threshold for high quality pools in salmon-bearing streams (NOAA 1996). Beaver activity has been observed in Reach 2, and some of the deepest pools are associated with beaver dams.

Off-channel habitat is greatly limited in Goff Creek. Much of the stream is confined by channel modifications, streambank armoring, and land use. No side channel habitat was observed during surveys. Reaches 1 and 2 provide the only potential for over-bank flooding and off-channel habitat. Evidence of over-bank flooding and associated wetlands can be seen in Reach 2 upstream of 132nd Avenue NE. Several beaver dams and evidence of beaver activity were observed in the area upstream of 132nd Avenue NE, and likely responsible for this off-channel habitat.

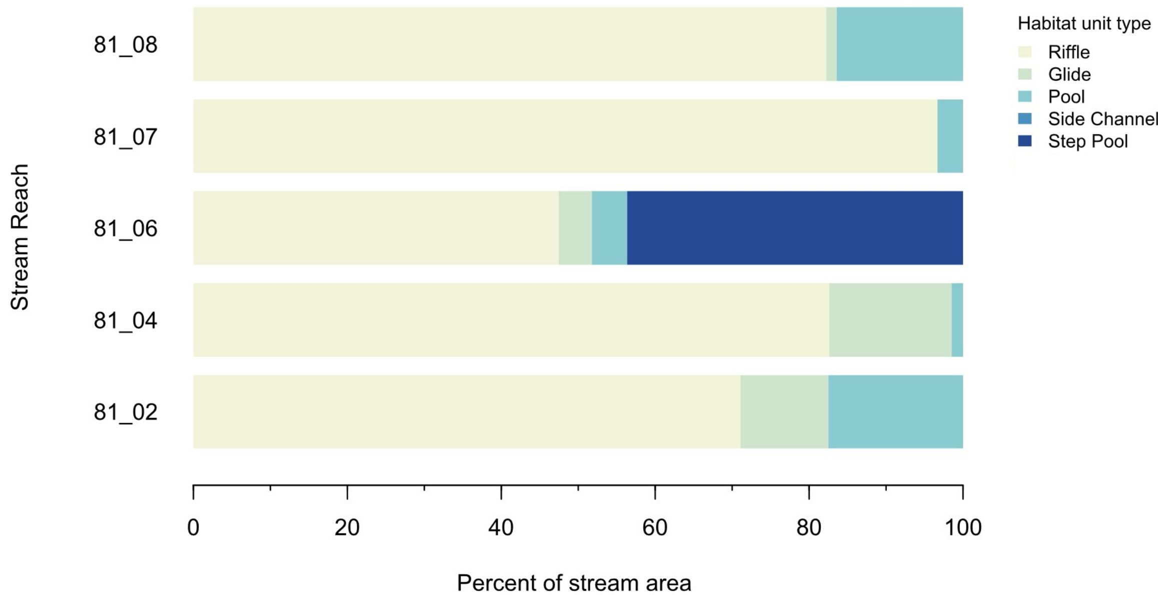


Figure B-49. Habitat unit composition (by percent area) of Goff Creek stream reaches.

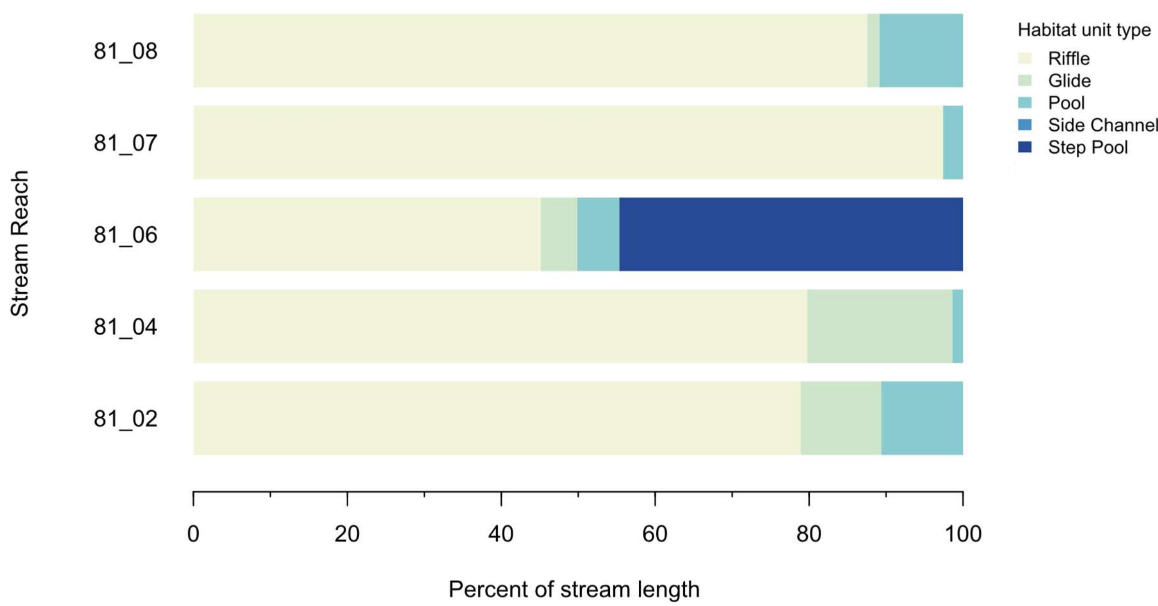


Figure B-50. Habitat unit composition (by percent length) of Goff Creek stream reaches.

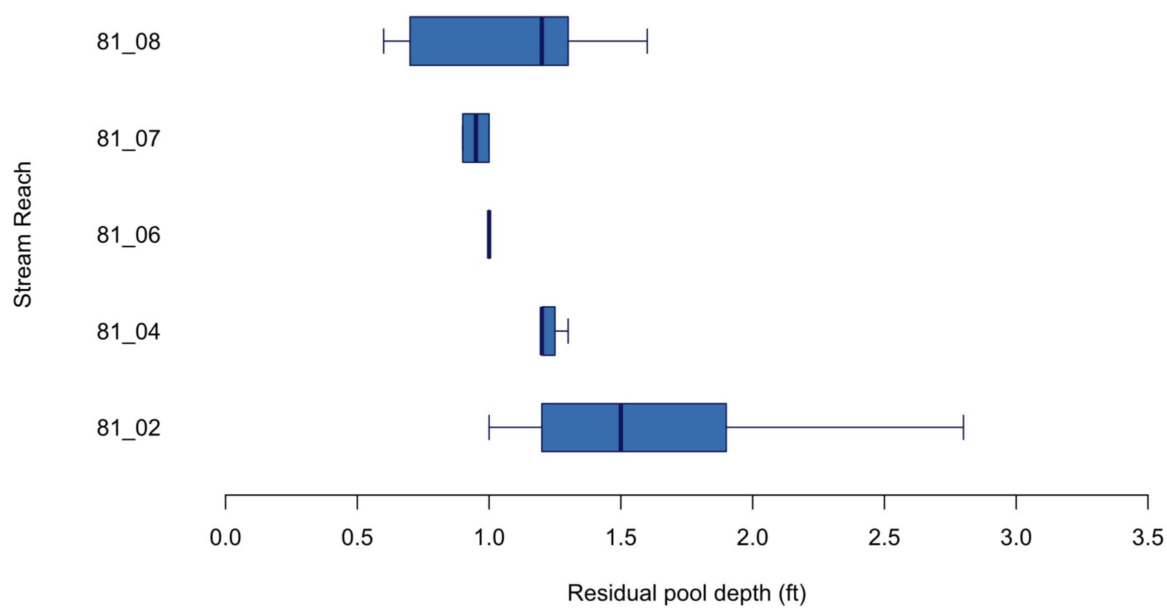


Figure B-51. Boxplot of residual pool depths observed in Goff Creek.

B.3.6.3 Large Woody Material

Like other subbasins in the Greater Kelsey Watershed, large woody material (LWM) is greatly lacking in Goff Creek (**Figure B-52**). With an average wood density of 124 pieces/mile (8 pieces/100 m), the LWM density in Goff Creek is far below the 25th percentile for similarly sized reference streams (Fox and Bolton 2007) and is slightly below average for subbasins in the Greater Kelsey Watershed.

Wood loading varies considerably among Goff Creek stream reaches. Reaches 4 and 6 only have a few pieces each, Reach 7 has LWM levels nearing the reference 25th percentile, and no LWM was observed in Reach 8. All wood observed during the surveys is believed to be of natural origin. Reaches 2, 7, and 8 have the greatest potential for natural recruitment of LWM, although outreach to inform property owners about the value of leaving fallen trees may be necessary. Reach 4 has virtually no LWM recruitment potential. The placement of LWM in Goff Creek could greatly enhance stream habitat, with the primary benefit of pool formation.

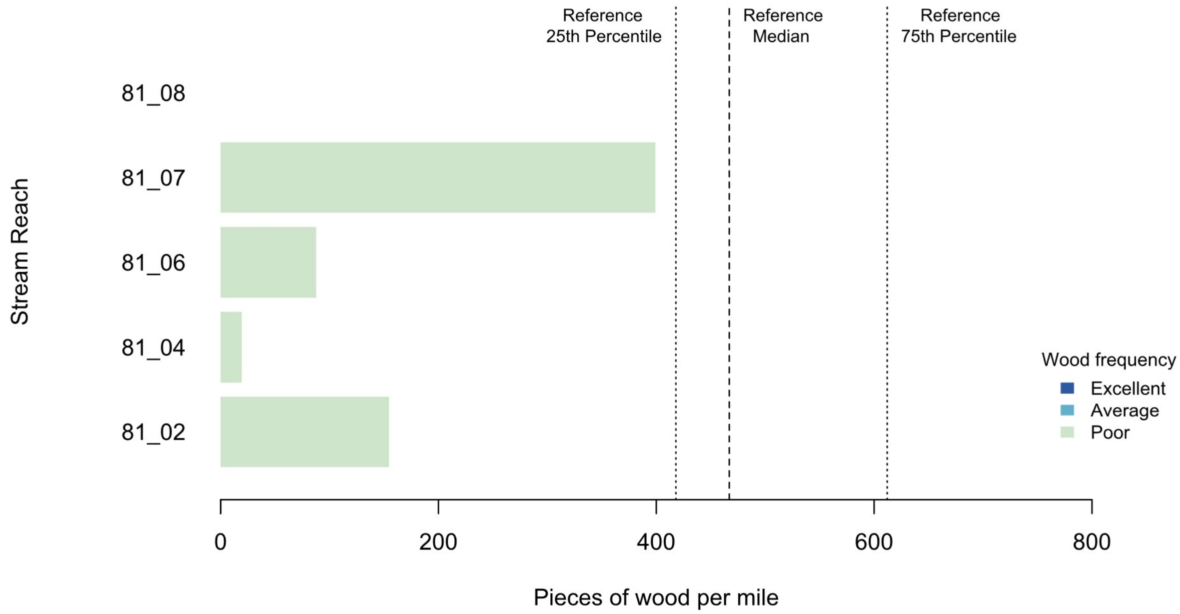


Figure B-52. Large woody material frequency in the mainstem reaches of Goff Creek compared to reference levels (Fox and Bolton 2007).

B.3.6.4 Streambed Substrate

Goff Creek's streambed substrate in riffle habitat is dominated by gravels (41%) and fines (33%) intermixed with cobbles (24%) and the occasional boulder (**Figure B-53**). Most of the boulder and some cobble substrate observed in Goff Creek likely originated from streambank armoring that has failed and fallen into the channel. The percentage of fines present in the substrate is approximately average for streams in the Greater Kelsey Watershed. However, Reach 2, which is the only reach accessible to spawning salmon, has 35% fines in riffle habitat. This is generally considered to be too high a proportion of fines for the successful spawning and incubation of Pacific salmon.

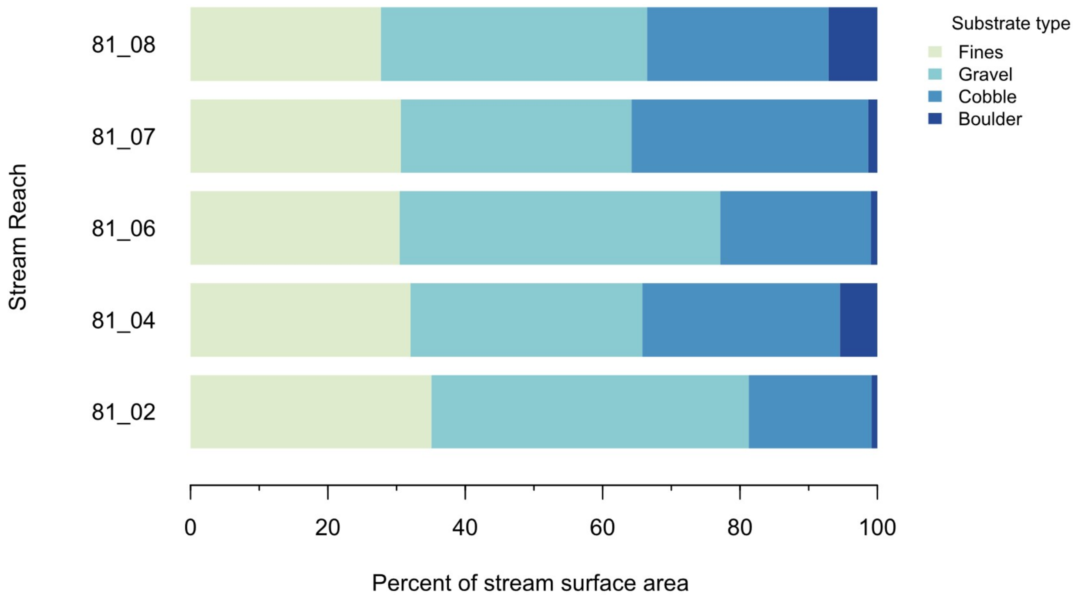


Figure B-53. Substrate composition of riffle habitat in Goff Creek stream reaches, determined by visual estimation.

B.3.6.5 Streambank Conditions

Goff Creek has the second highest percent armored streambanks of all subbasins in the Greater Kelsey Creek Watershed. A total of 33% of its streambanks are armored (**Figure B-54**). Although the majority of the streambank armoring is low (<5 ft), nearly half of the armoring in Reaches 4, 7, and 8 is between 5 and 10 ft high. The extensive urban development and associated channel modifications in Reach 4 have contributed to making this the most heavily armored reach; 55% of its streambanks are armored. All streambank armoring in Goff Creek is traditional, “hard” armoring, not bioengineering. Angular rock is the primary material used, although gabion baskets and concrete are prevalent in Reach 7. In some areas, particularly Reaches 2 and 7, the streambank armoring is failing and mobilizing into the channel.

Goff Creek has the least streambank erosion of all subbasins in the City of Bellevue. A total of 3% of its streambanks show evidence of erosion and 2% of its streambanks are undercut. Most erosion occurs in Reach 7 (**Figure B-55**) and is generally low toe scour. Only one 60 ft section of stream in Reach 7 has erosion greater than 10 ft in height, and this erosion is associated with animal burrows, presumably from mountain beaver (*Aplodontia rufa*).

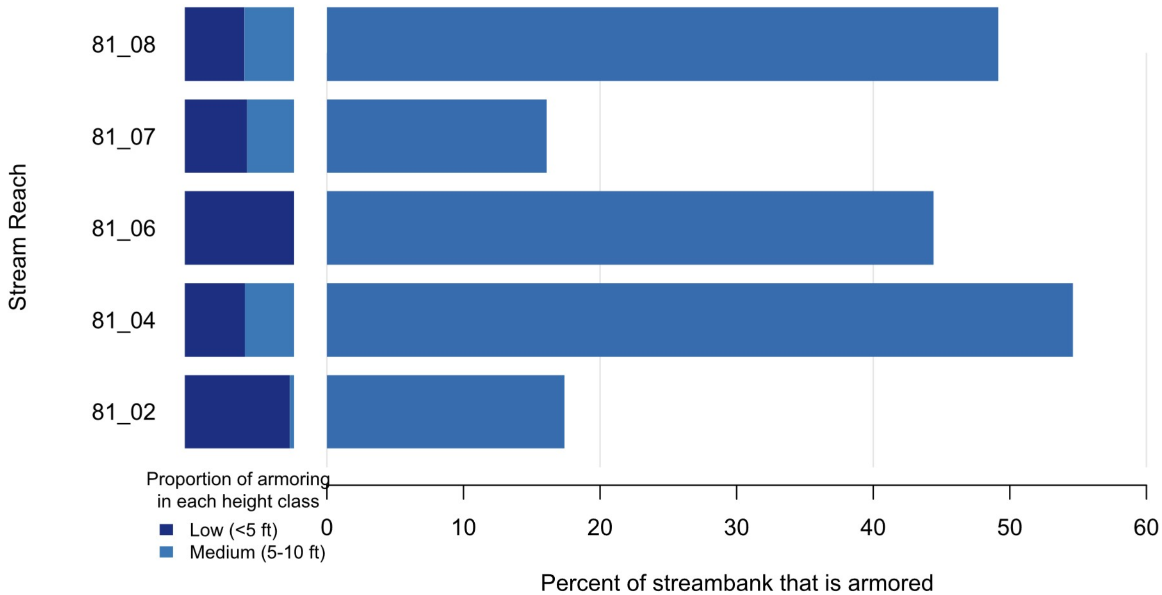


Figure B-54. Bar graph showing the proportion of each streambank that is armored as well as proportion of armoring in each height class for the Goff Creek mainstem reaches.

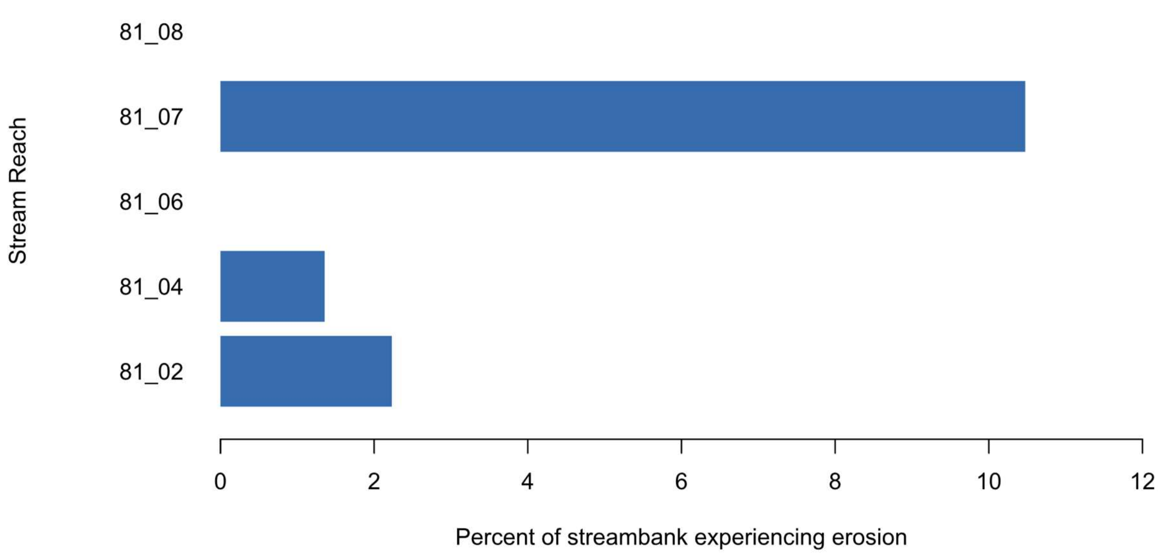


Figure B-55. Percent of each Goff Creek stream reach that is experiencing erosion.

B.3.6.6 Fish Habitat and Passage Barriers

Fish habitat is limited in Goff Creek for several reasons described above, particularly the lack of pools, lack of undercut banks that create “edge” habitat, and higher levels of fine streambed substrate. During the OSCA surveys, a small number of juvenile salmonids, presumably Cutthroat Trout, were observed in Reach 2, but no fish were observed upstream of Bel-Red Road. A lack of stream habitat complexity including pools and instream large woody material, coupled with impacts from urban development including channel modifications, loss of riparian vegetation, and stormwater inputs, have likely all contributed to the loss of fish populations in this stream. Instream and riparian conditions improve in the stream reaches north of SR 520, yet the presence of a high-flow bypass may impact sediment transport, LWM recruitment, and the safety and passage of fish.

There are numerous migratory fish barriers in Goff Creek. WDFW has identified six partial barriers and seven complete barriers (WDFW 2021). Additionally, there are numerous weirs that may impede fish migration but have not been formally surveyed as barriers. There are 53 weirs throughout Goff Creek for an average of 38 weirs per mile of stream. This is by far the highest weir density found in any stream in the Greater Kelsey Creek Watershed. The hydraulic drop associated with these weirs ranges from 0 to 2.3 ft with a median value of 0.7 ft. Fish barriers and weirs will be discussed in more detail in the Greater Kelsey Creek Watershed OSCA Reach Reports. See Appendix D of this report for a complete inventory of formally documented fish passage barriers in the watershed.

B.3.6.7 Opportunities

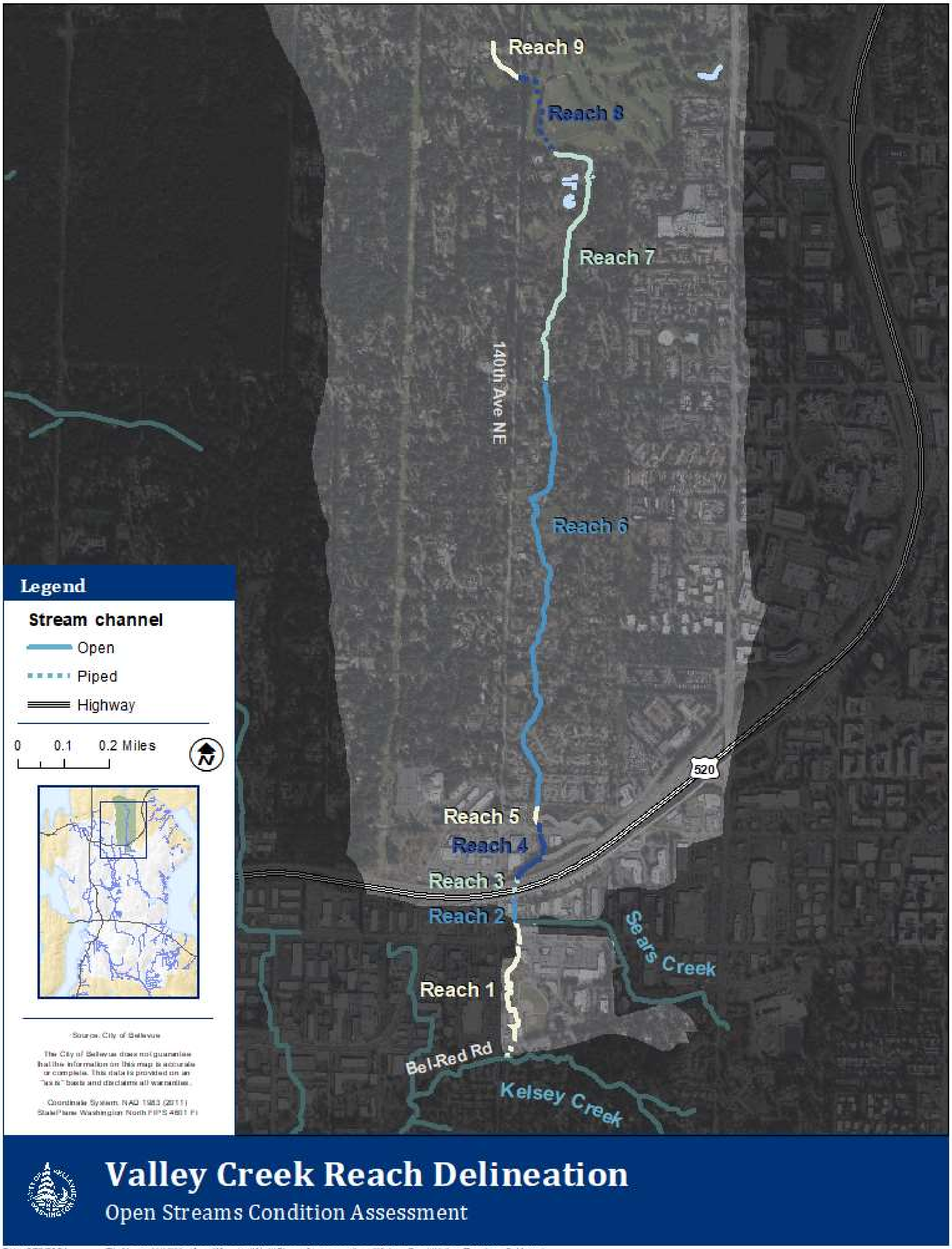
Goff Creek offers numerous opportunities to improve and protect aquatic health. Invasive plant control would be highly beneficial throughout the stream corridor. Policeman’s helmet, bindweed, and Himalayan blackberry are prevalent downstream of Bel-Red Road in the wetland associated with the Lower West Tributary Regional Detention Facility and along residential properties, and English ivy frequently chokes the stream channel throughout portions of middle and upper Goff Creek. This highly confined stream would benefit from having hard streambank armoring removed or replaced with bioengineering, and, where feasible in the area downstream of Bel-Red Road, process-based restoration could increase habitat complexity and restore floodplain connection. The addition of large woody material would likewise improve habitat complexity, sediment sorting, and overall stream function.

Fish passage can be improved in Goff Creek by removing weirs, replacing culverts, and daylighting piped portions of the stream. Slightly over 20% of the Goff Creek mainstem is piped, and opportunities should be explored to daylight the stream where feasible. Similar to other subbasins in the Greater Kelsey Creek Watershed, opportunities for fish passage improvement should take into consideration downstream subbasins (Mercer Slough, Kelsey Creek mainstem, and the West Tributary) and identify clear strategies for prioritizing barrier correction in Goff Creek and across the City. Site specific recommendations are provided in the reach descriptions of the Greater Kelsey Creek OSCA Report, which should be implemented in conjunction with the forthcoming programmatic and policy recommendations provided in the city-wide Watershed Management Plan. Similar to Sunset Creek, evaluation of the continued need for the high-flow bypass should be examined.

B.3.7 Valley Creek Subbasin

The Valley Creek subbasin is located in North Bellevue in the Bridle Trails, Bel-Red, and Crossroads neighborhoods. The subbasin encompasses 1,383 acres of primarily residential property. Elevation in the subbasin ranges from 183 ft to 527 ft. Overall, the subbasin contains 3.2 miles of open stream channel and 14.9 miles of storm drainage pipes (Bellevue 2017).

Valley Creek headwaters near the City of Kirkland boarder before flowing due south for over 2.5 river miles to the confluence with the mainstem of Kelsey Creek at Bel-Red Road (**Map B-9**). The upper reach of Valley Creek has been modified through residential parcels (Reach 9) and is piped underneath the Bellevue Golf Course (Reach 8) before meandering through large private parcels including several small equestrian farms (Reach 7). Wetland areas with a highly connected floodplain are common throughout Reach 7. A privately-owned dam is located in the upper portion of Reach 6, and Reach 5 is a wetland that makes up the Valley Creek Regional Detention Facility. The lower portion of Valley Creek south of this regional facility is highly urban and heavily constrained by commercial land use both upstream and downstream of SR 520. There is one City park that provides opportunity for a narrow riparian corridor and community access to open space slightly upstream of the confluence with Kelsey Creek.



Date: 6/23/2021 File Name: V:\Utilities\AssetMapping\Work\StreamAssessment\mxd\Kelsey Creek\Valley Reaches 8x11.mxd

Map B-9. Valley Creek stream reaches.

B.3.7.1 Channel Morphology and Riparian Corridor

The morphology of Valley Creek is strongly influenced by urban development and land use (**Map B-9**). The stream can best be described as having two distinct regions. Lower Valley Creek, downstream of NE 24th St, is typified by an altered and/or confined channel, varying stream gradient, moderate to low riparian canopy cover, and moderate to high impervious surfaces within the 100 ft riparian buffer (**Table B-11**). Conversely, upper Valley Creek has moderately good riparian canopy cover and little impervious surfaces directly adjacent to the stream. Overall, the stream gradient is 1.6%, which is about average for the Greater Kelsey Creek Watershed. The upper-most extent of the open stream channel is at an elevation of approximately 365 ft, which is higher than average for the watershed.

Riparian vegetation is also distinctly different between lower and upper Valley Creek. Lower Valley Creek is dominated by the usual cast of invasive plants, including nightshade, Himalayan blackberry, English ivy, and reed canary grass, in addition to willows and dogwoods. Although these invasive plants are still present in upper Valley Creek, they are less predominant and are replaced by more native vegetation as well as ornamental landscaping.

Compared to the other primary streams in the Greater Kelsey Creek Watershed, Valley Creek is average in width although somewhat shallower in depth. Across all surveyed reaches, the median wetted and bankfull widths are 6.5 ft and 7.8 ft, respectively. Channel width varies by stream reach and does not narrow as expected towards the headwaters (**Figure B-56**). Channel depth remains somewhat consistent across all surveyed reaches with median representative and maximum depths of 0.4 ft and 0.8 ft, respectively (**Figure B-57**). Valley Creek has the second highest wetted width to depth ratio observed in the Greater Kelsey Creek Watershed.

Table B-11. Reach attributes for Valley Creek.

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
Reach Segment ID	82_01	82_02	82_03	82_04	82_05
River Mile Boundaries	0.00 – 0.36	0.36 – 0.42	0.42 – 0.46	0.46 – 0.62	0.62 – 0.66
Sediment Dynamics	Response	Response	Forced transport	Response	Response
Channel Type	Forced dune-ripple*	Plane-bed	Piped conveyance	Forced dune-ripple†	Wetland
Stream Gradient (%)	0.6	5.1	3.8	2.6	1.5
Riparian Canopy Cover (%)	46	22	-	37	61
Riparian Impervious Surface Cover (%)	54	61	60	39	13
Reach Length (ft)	1,925	275	250	800	225

	Reach 6	Reach 7	Reach 8	Reach 9
Reach Segment ID	82_06	82_07	82_08	82_09
River Mile Boundaries	0.66 – 1.70	1.70 – 2.28	2.28 – 2.45	2.45 – 2.57
Sediment Dynamics	Response	Response	Forced transport	-
Channel Type	Plane-bed	Plane-bed	Piped conveyance	Ditched wetland
Stream Gradient (%)	1.7	1.1	3.2	0.3
Riparian Canopy Cover (%)	59	59	-	52
Riparian Impervious Surface Cover (%)	18	9	12	19
Reach Length (ft)	5,475	3,110	890	600

* Land use has likely altered this channel from its natural morphology.
† Beaver activity through this reach continually alters the channel morphology.

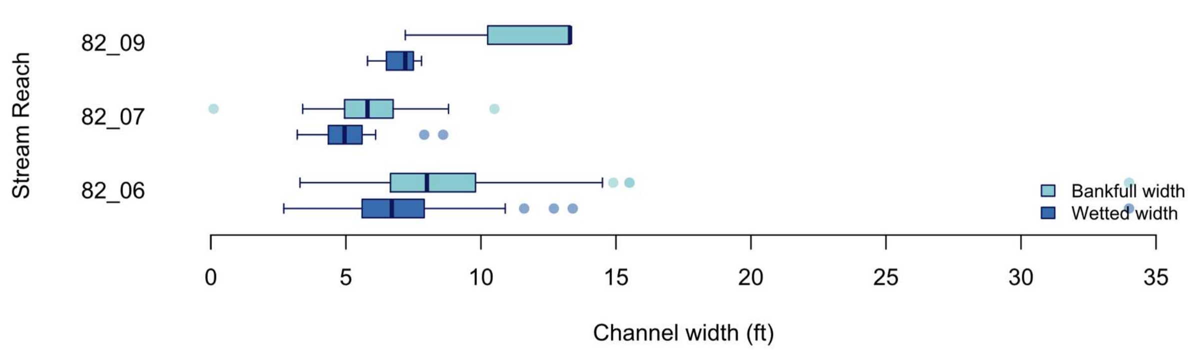


Figure B-56. Boxplot of the wetted and bankfull channel widths for stream reaches in Valley Creek.

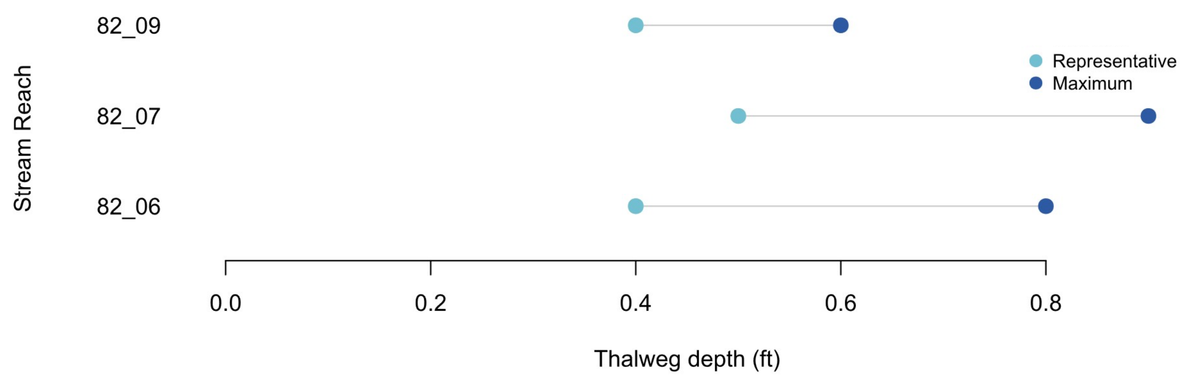


Figure B-57. Dumbbell plot of wetted stream depths in Valley Creek. Points represent the median representative and maximum depths for each stream reach.

B.3.7.2 Habitat Unit Composition and Off-Channel Habitat

Habitat unit composition in Valley Creek varies by stream reach (**Figure B-58** and **Figure B-59**). Across all surveyed channels, riffle habitat comprises 45% of the stream area and 49% of the stream length. However, riffle habitat is only dominant in Reach 5. As you proceed upstream, riffle habitat is replaced by glide habitat, which accounts for 35% of the stream area and 40% of the stream length across all surveyed reaches which is higher than average for streams in the Greater Kelsey Creek Watershed. Pool habitat accounts for 12% of the stream area and 8% of the stream length but is almost entirely restricted to Reach 6. Also unique to Reach 6 is pond habitat created by a privately-owned dam with a step-pool fish ladder.

Pool habitat is limited in Valley Creek but is average for the Greater Kelsey Creek Watershed. The surveyed reaches of Valley Creek have an average pool spacing of 32 channel widths per pool or 21 pools per mile (1 pool per 100 m), which is far below the expected frequency of 140 pools per mile in healthy, “properly functioning” streams (NOAA 1996). Even Reach 6, where most of the pools in Valley Creek are located, falls short of ideal with only 31 pools per mile. The pools that are present tend to be rather shallow (**Figure B-60**). The median residual pool depth is 1.1 ft, which is sufficient for sustaining trout populations (Behnke 1992), but no pools achieved the 3 ft residual depth considered necessary for Pacific salmon (NOAA 1996).

Off-channel habitat and opportunities are somewhat limited in Valley Creek. Reaches 1 through 4 are constrained by urban development and lack an intact floodplain. Reach 5 is a regional detention pond that supports beaver activity and other natural wetland processes that aid stream health. Reaches 6, 7, and 9 pass through residential properties and generally have an intact riparian buffer that permits of some channel migration. There were only three short side channel habitat units documented in Valley Creek during the OSCA surveys and they are located in Reaches 6 and 7. The portion of Reach 7 that passes through the Parks-owned parcel adjacent to the Ginzburg Property is surrounded by a dense and very healthy wetland with extensive floodplain that supports good off-channel habitat for aquatic species as well as flood control and sediment storage. This valuable resource should be protected.

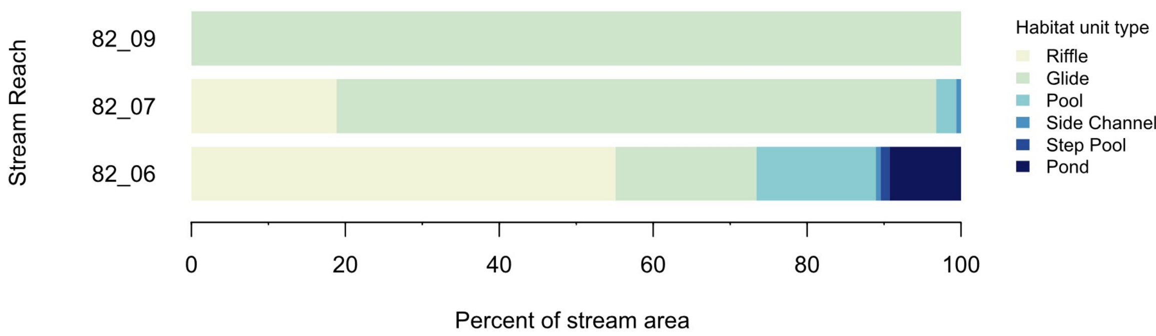


Figure B-58. Habitat unit composition (by percent area) in Valley Creek.

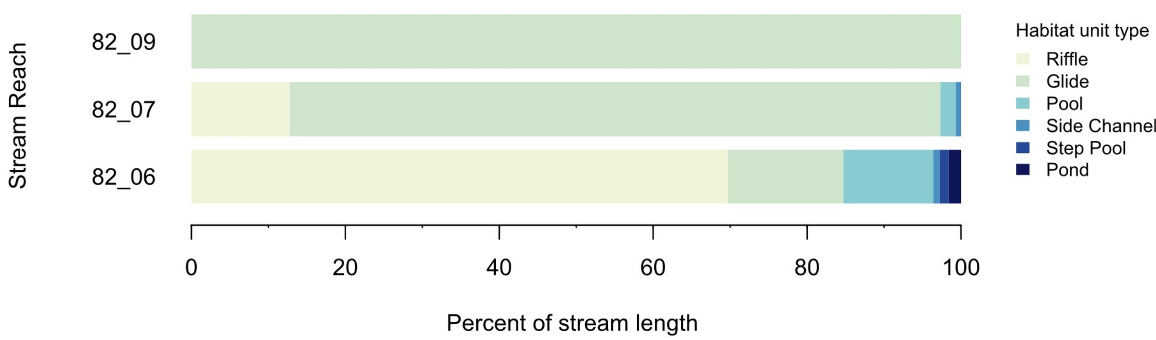


Figure B-59. Habitat unit composition (by percent length) in Valley Creek.

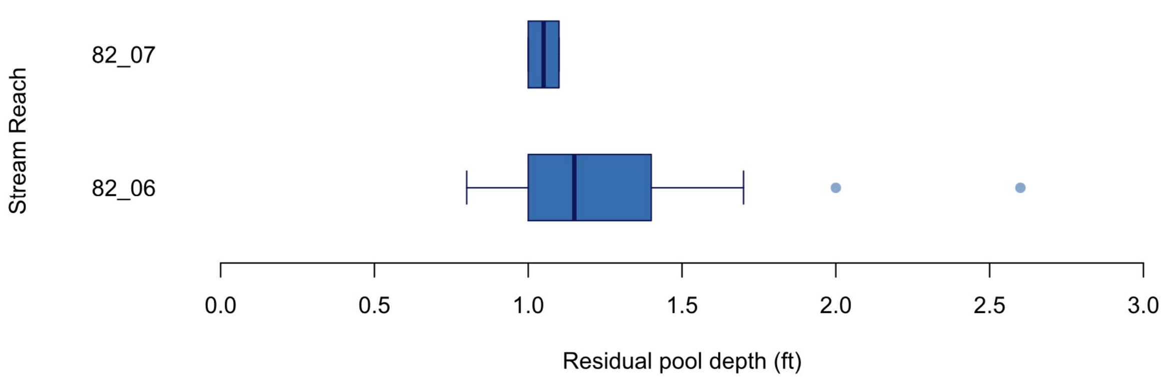


Figure B-60. Boxplot of residual pool depths in stream reaches of Valley Creek. Reach 9 is omitted as it contained no pool habitat.

B.3.7.3 Large Woody Material

Large woody material (LWM) frequency in Valley Creek is lower than average for the Greater Kelsey Creek Watershed and far below reference levels for similarly sized streams in Western Washington (**Figure B-61**). The average LWM frequency for surveyed stream reaches in Valley Creek is 103 pieces per mile (6 pieces per 100 m). Nearly all LWM is of natural origin; only a few pieces were placed in Reach 6. There is low to moderate potential for natural LWM recruitment from trees in the riparian zone (**Table B-11**).

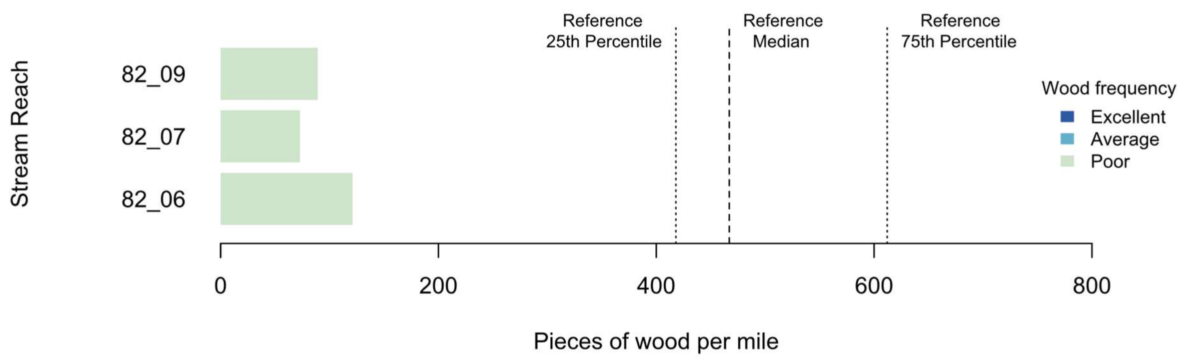


Figure B-61. Large woody material frequency in Valley Creek compared to reference levels (Fox and Bolton 2007).

B.3.7.4 Streambed Substrate

Streambed substrate in the surveyed reaches of Valley Creek tends to be smaller than average for primary streams in the Greater Kelsey Creek Watershed. Fines comprise 52% of the substrate in fast water habitat, followed by gravel (33%), cobble (15%), and the occasional boulder (1%). This is the second highest proportion of fines observed in any subbasin in the Greater Kelsey Creek Watershed. Even riffle habitat has a high proportion of fines (**Figure 62**). Reach 6 has the lowest proportion of fines (35%) in riffle habitat but is still at the very upper range of conditions tolerable for the successful spawning and survival of Pacific salmon.

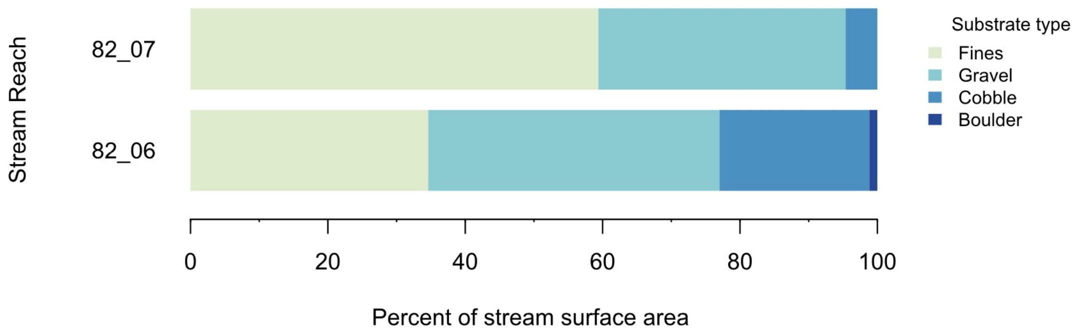


Figure 62. Substrate composition of riffle habitat in Valley Creek, determined by visual estimation. Reach 9 is excluded because it contained no riffle habitat.

B.3.7.5 Streambank Conditions

The surveyed reaches of Valley Creek have the lowest proportion of armored streambanks of all primary channels in the Greater Kelsey Creek Watershed. However, it should be noted that the non-surveyed reaches in lower Valley Creek are in a highly urbanized area and likely contain streambank armoring that is not presented here. Across all surveyed reaches, 7% of the streambanks are armored and most of this armoring is focused in Reach 6 (**Figure B-63**). Most of the armoring consists of large angular rock; "soft" armoring or bioengineering is not present. A little less than 20% of all streambank armoring present in the surveyed reaches of Valley Creek is failing, which is about average for streams in the Greater Kelsey Creek Watershed.

The surveyed reaches of Valley Creek have slightly less than average streambank erosion compared to other primary streams in the Greater Kelsey Creek Watershed. Across all surveyed reaches, 10% of the streambank is eroding and 8% is undercut (**Figure B-64** and **Figure B-65**). Most streambank erosion is less than 5 ft in height, and around a quarter of all erosion is low toe scour with stable but undercut banks which provide valuable habitat for fish and other aquatic species.

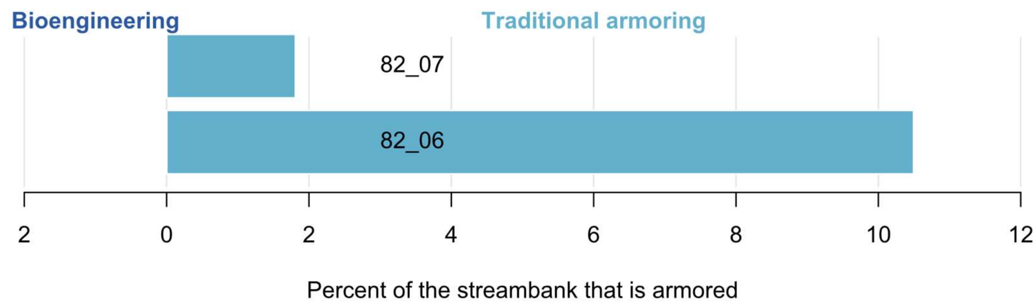


Figure B-63. Diverging bar graph showing the proportion of the streambank in Valley Creek that is armored using traditional materials (right) and bioengineering (left).

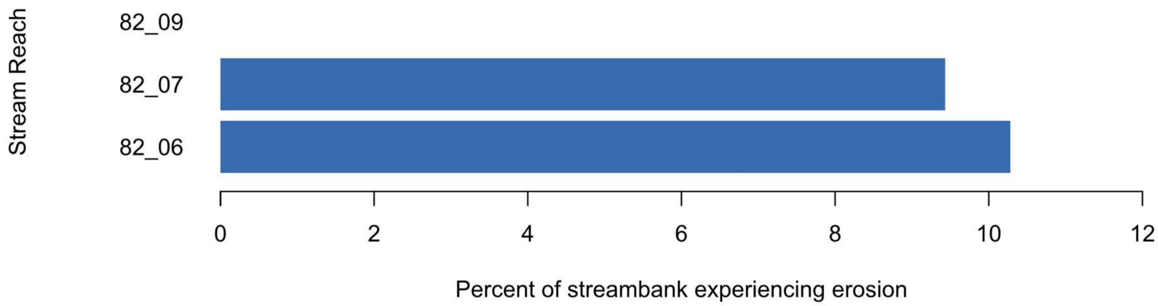


Figure B-64. Percent of each stream reach in Valley Creek that is experiencing erosion.

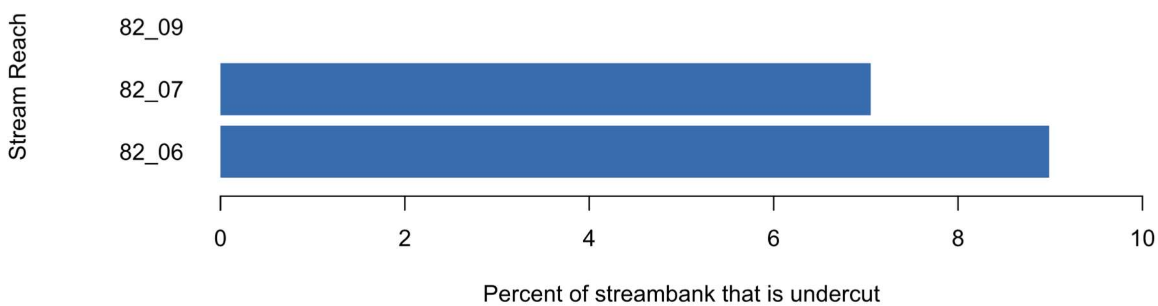


Figure B-65. Percent of each stream reach in Valley Creek that has undercut streambanks.

B.3.7.6 Fish Habitat and Passage Barriers

Valley Creek, especially upstream of NE 24th Street, offers surprisingly good fish habitat for a small urban stream. A healthy riparian buffer, few stormwater outfalls, and the wetland area in Reach 7 all contribute to presumably good water quality and fish habitat in middle to upper Valley Creek. During OSCA surveys, trout were observed in Reaches 6 and 7 in pool, riffle, and glide habitats. Fish were most abundant in Reach 6 where pool habitat is more frequent and where undercut banks provide good refuge. Residents in Reaches 6 report that salmon previously spawned on their properties, but the fish abruptly stopped returning in the mid-2000s. This coincides with the time period when salmon returns declined precipitously in both the Greater Kelsey Creek Watershed and the City as a whole, although downstream fish passage barriers could be a contributing factor.

Channel depth may be a limiting factor for fish habitat and migration during the summer low flow period. Adult trout and Coho Salmon generally require a minimum depth of 0.4 and 0.6 ft, respectively

(Thompson 1972). With a median representative depth of 0.4 ft in fast-water habitat and a shortage of pool habitat, Reaches 6 and 7 are barely suitable for migrating adult Pacific salmon.

There are several potential fish passage barriers in Valley Creek that may be contributing to the disappearance of spawning salmon in this subbasin (Appendix D). Most of these of these barriers are on private property and were observed during the OSCA surveys but have not been formally documented in the WDFW database at this time. These barriers are primarily private road crossings (culverts or bridges) that potentially do not comply with current fish passage standards. The surveyed reaches of Valley Creek have at least 20 culverts or bridges for an average of 15.2 crossings per mile, the highest such density observed in the Greater Kelsey Creek Watershed. There is only formally documented partial barrier: a city-owned culvert under NE 40th St (WDFW 2021). Additionally, a privately-owned dam with a fish ladder exists in the upper portion of Reach 6 and should be officially assessed for passability by WDFW. This private facility presents an eligible opportunity for grant funding to restore unimpeded fish passage and enhance instream conditions through the upper portion of the reach.

B.3.7.7 Opportunities

The lower reaches of Valley Creek (especially Reaches 1-4) are impacted by human activity (homeless encampments and litter) including a considerable number of pharmaceuticals, drug paraphernalia, and personal care products that enter the stream. This is a human health and safety issue as well as a primary concern for the health of the stream, fish, and wildlife that inhabit the area. City and community policies and programs are necessary to improve the conditions in lower Valley Creek, a stream that once supported one of the most abundant Coho Salmon populations found in tributary streams around the Lake Washington Watershed (Morrice and Johnson 1982).

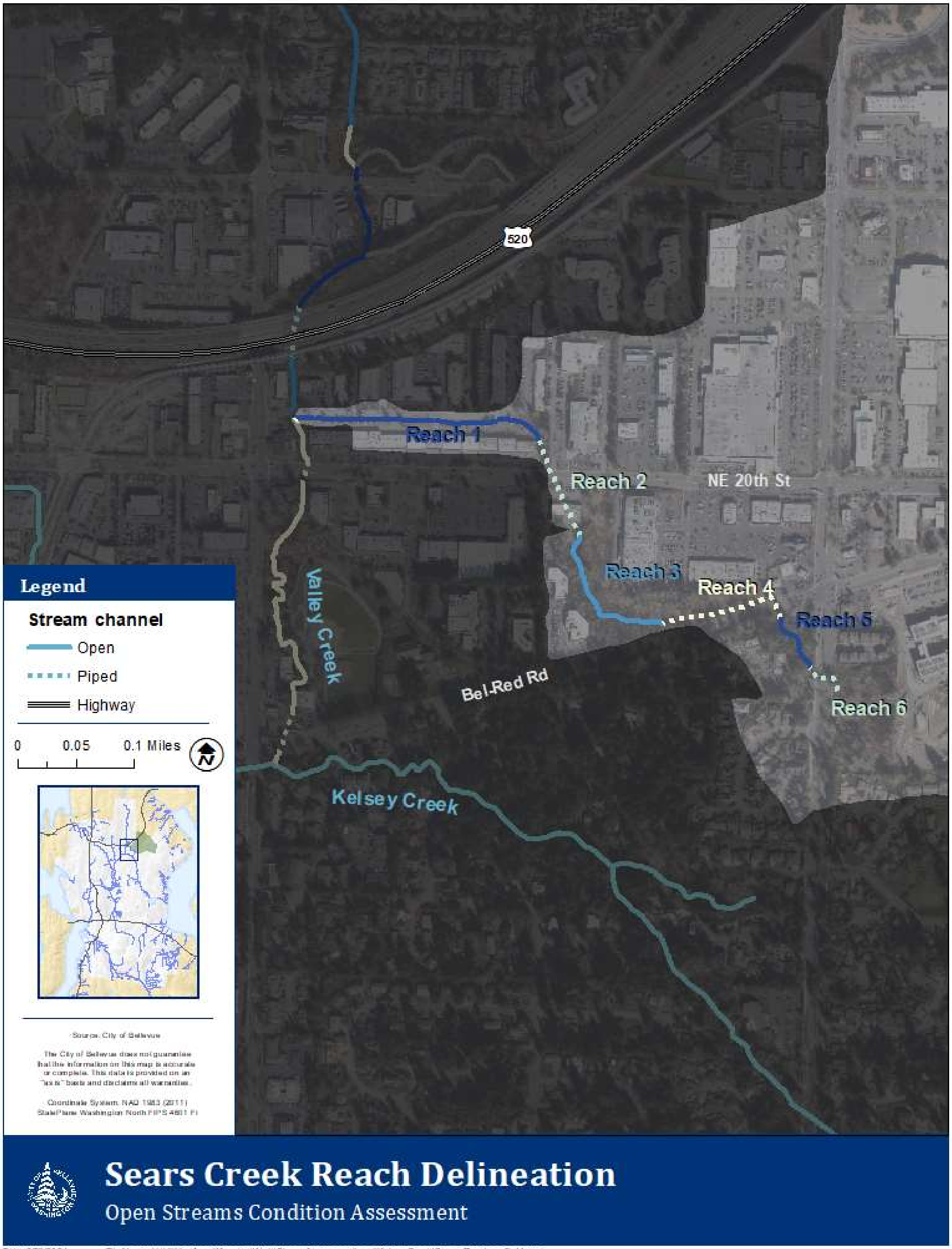
Compromised water quality and degraded instream habitat dominates the lower reaches of Valley Creek. Habitat and fish passage improvements should be prioritized for the lower reaches of Valley Creek. Enhancement of the confluence with Kelsey Creek should be prioritized along with a study to evaluate the need for the high-flow bypass (located in Reach 1) and potential decommissioning or modification of this flood control structure that was developed prior to regulations to protect fish life and fish passage. A second project that requires study is located at the Valley Creek Regional Detention Facility in Reach 5. This facility provides good holding and rearing for fish, but also may impact fish passage due to beaver conflicts within the wetland and at the controlled outlet structure of the pond.

Opportunities for improvement on both public and private property need to be explored to improve access to the 1.6 river miles of quality fish habitat observed in Reaches 6 and 7. In addition to the opportunity described in the section above to improve fish passage in upper Reach 6, installation of LWM throughout these middle to upper reaches would help promote deeper thalweg depths by concentrating streamflow into a low flow channel and create scour (or pocket) pools for adult holding and juvenile rearing. Prioritization strategies and City policies and programs should focus on correcting privately-owned and City-owned fish barriers throughout Valley Creek to enable migratory fish to access quality habitat in Reaches 6 and 7.

B.3.8 Sears Creek Subbasin

Sears Creek is a tributary to Valley Creek and flows through the Bel-Red neighborhood. The upper portions of the subbasin extend into the Crossroads and Northeast Bellevue neighborhoods as well as the City of Redmond. The subbasin encompasses 565 acres of highly varied land use dominated by commercial, office, and mixed-use parcels. Elevation in the subbasin ranges from 194 ft to 445 ft. Within the City of Bellevue, there is only 0.4 miles of open stream channel and 9.5 miles of storm drainage pipes (Bellevue 2017). Approximately 40% of the subbasin is within the City of Redmond in a highly developed area which likely has a dense network of storm drainage pipes as well.

Sears Creek headwaters near the City of Redmond boarder in Northeast Bellevue and flows into a highly modified wetland at the Commissioners Waterway Regional Facility. Sears Creek is highly urban, constrained, and fragmented between busy arterials that intersect the Bel-Red and Crossroad neighborhoods (**Map B-10**). The Sears Creek ravine (Reach 3) offers good riparian canopy and fish enhancement opportunities, yet it is sandwiched between NE 20th Street and Bel-Red Road. The lower reach of Sears Creek is highly confined along NE 21st Street and regularly is backwatered by the Valley Creek confluence which is located just east of 140th Avenue NE.



Map B-10. Sears Creek stream reaches.

B.3.8.1 Channel Morphology and Riparian Corridor

Sears Creek channel morphology is highly influenced by urban development (**Map B-10**), resulting in a simplified, confined, and intermittently piped stream. The channel type is predominantly plane-bed (**Table B-12**). Overall, the stream gradient is about 2.7% which is slightly higher than average for the primary streams in the Greater Kelsey Creek Watershed.

Riparian vegetation cover and composition varies strongly by stream reach. Reach 1 is essentially a roadside ditch with mown grass banks, very little canopy cover, and a large proportion of impervious surfaces (**Table B-12**). Reaches 3 and 5 have far less impervious surfaces and rather good riparian cover with a canopy consisting mostly of big leaf maple and western red cedar. Frequent invasive plant species include English ivy, Himalayan blackberry, nightshade, and bindweed. Human activities in and around the stream including former and current encampments have resulted in damaged riparian vegetation and litter in the stream.

Due to its altered and confined nature, Sears Creek is slightly smaller in width though average in depth compared to the other primary channels in the Greater Kelsey Creek Watershed. The median wetted and bankfull widths are 6.5 ft and 8.3 ft, respectively (**Figure B-66**). The median representative thalweg depth is 0.6 ft and the median maximum depth is 1.0 ft (**Figure B-67**). Sears Creek has the lowest wetted width to depth ratio (10.8) of any stream in the watershed, indicating channel confinement and entrenchment. Reach 5 is markedly smaller in both width and depth than the preceding reaches.

Table B-12. Reach attributes for Sears Creek.

	Reach 1	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**	**Reach 6**
Reach Segment ID	83_01	83_02	83_03	83_04	83_05	83_06
River Mile Boundaries	0.00 – 0.22	0.22 – 0.31	0.31 – 0.45	0.45 – 0.57	0.57 – 0.62	0.62 – 0.69
Sediment Dynamics	Response	Transport	Source/ Transport	Forced transport	Response	-
Channel Type	Plane-bed	Piped conveyance	Plane-bed	Piped conveyance	Forced dune-ripple*	Wetland
Stream Gradient (%)	2.1	3.6	2.0	5.0	0.3	-
Riparian Canopy Cover (%)	22	-	88	-	69	-
Riparian Impervious Surface Cover (%)	79	72	8	44	22	-
Reach Length (ft)	1,175	475	700	650	250	435

* Land use and channel modifications have substantially altered this reach from its natural morphology, which was likely a transitional wetland.

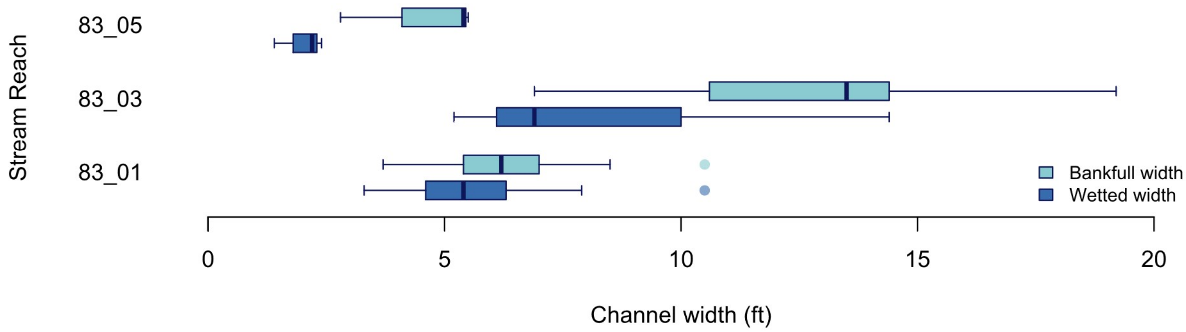


Figure B-66. Boxplot of the wetted and bankfull channel widths for stream reaches in Sears Creek.

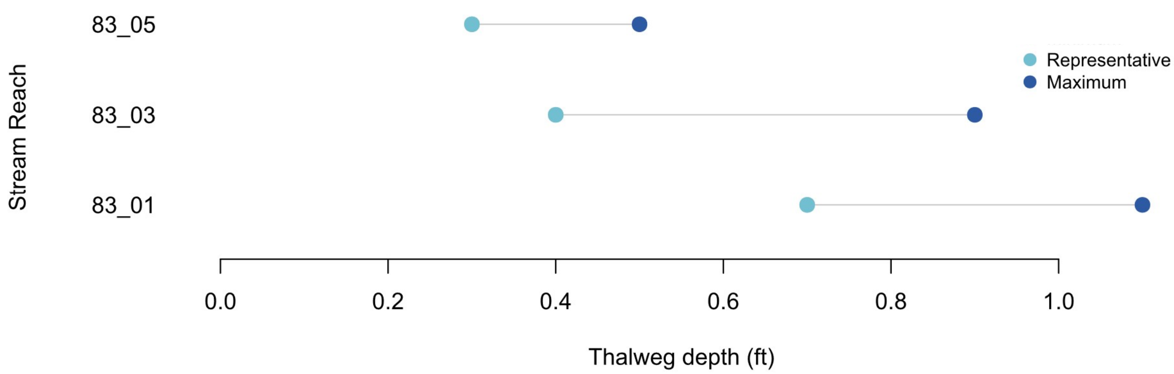


Figure B-67. Dumbbell plot of wetted stream depths in Sears Creek. Points represent the median representative and maximum depths for each stream reach.

B.3.8.2 Habitat Unit Composition and Off-Channel Habitat

Sears Creek is dominated by riffle habitat, although Reach 5 is markedly distinct (**Figure B-68** and **Figure B-69).** Across all surveyed reaches, riffle habitat comprises 66% of the stream area followed by glide habitat (21%), pool habitat (9%), and pond habitat (4%). Pond habitat is created by the Commissioners' Regional Pond in Reach 5 and accounts for more than half of the stream habitat area in that reach. Another stormwater detention facility, the Overlake Regional Pond at the downstream end of Reach 3, provides stormwater storage capacity, but does not alter base flow habitat conditions.

Pool habitat is very limited in Sears Creek. With an average pool frequency of 19 pools per mile of surveyed stream, Sears Creek ties with Richards Creek and Goff Creek for having the lowest pool frequency in the Greater Kelsey Creek Watershed. Healthy, similarly sized pools are expected to have approximately 120 pools per mile (NOAA 1996). Pools are more frequent in the downstream reaches and are often associated with failed streambank armoring or other channel modifications. No pools are present upstream of Reach 3. The median residual pool depth is 1.2 ft and ranges from 0.9 ft to 2.1 ft (**Figure B-70**). While sufficient for resident trout, these pool depths are inadequate for Pacific salmon.

Off-channel habitat is likewise limited in Sears Creek. No side channel habitat was observed during stream surveys. Reach 1 is highly confined an offers no opportunities for off-channel habitat or floodplain connectivity. The downstream end of Reach 3 at the Overlake Regional Pond has a small floodplain bench that diminishes upstream as the streambanks become increasingly steep. Reach 5 is a small, low gradient channel transitioning to the headwater wetlands. It offers stormwater detention via the Commissioners' Regional Pond but no off-channel habitat.

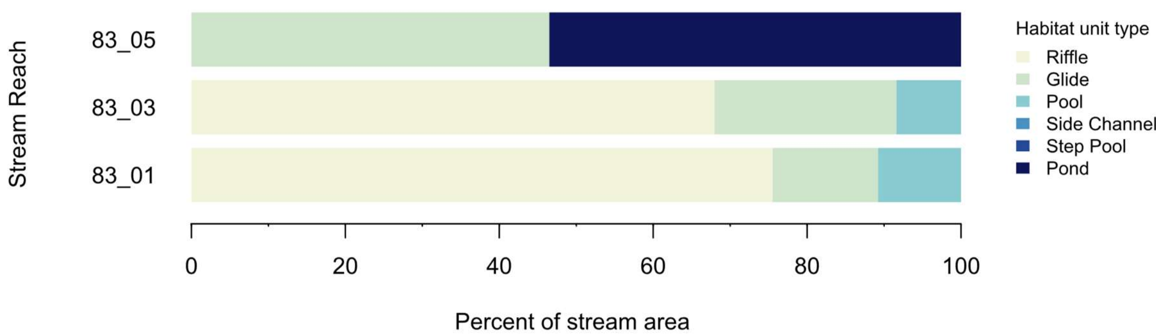


Figure B-68. Habitat unit composition (by percent area) in Sears Creek.

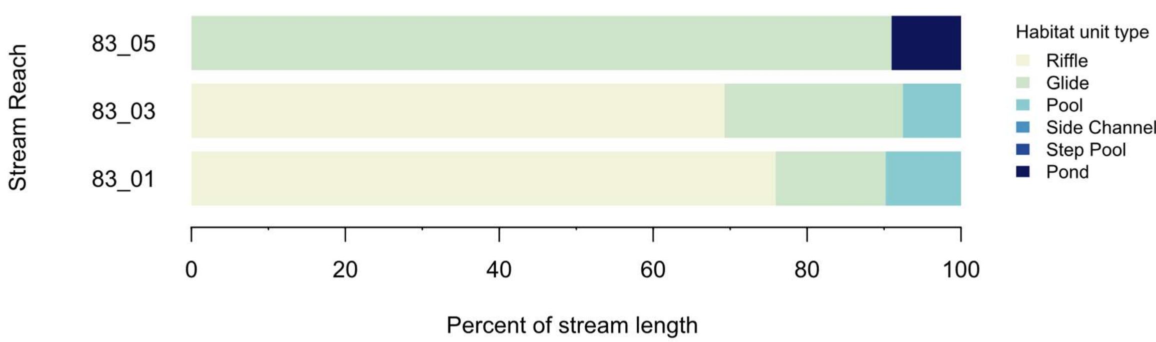


Figure B-69. Habitat unit composition (by percent length) in Sears Creek.

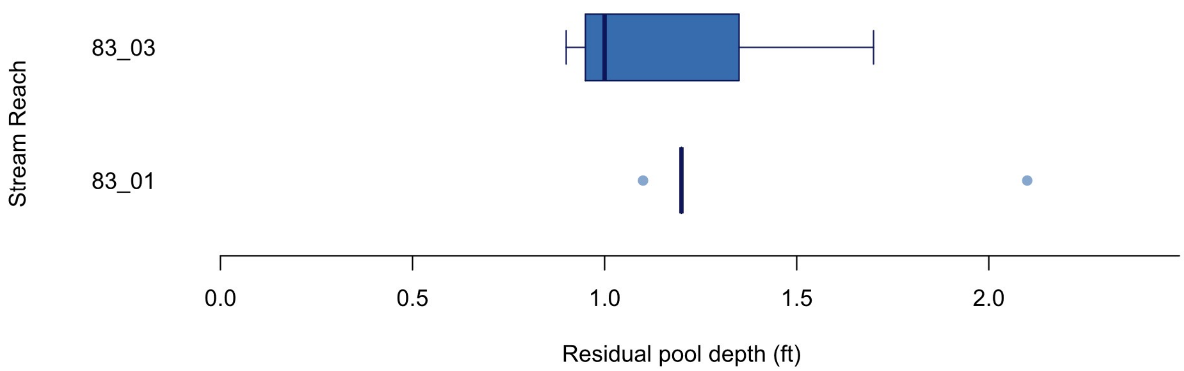


Figure B-70. Boxplot of residual pool depths in stream reaches of Sears Creek.

B.3.8.3 Large Woody Material

Sears Creek has the lowest frequency of large woody material (LWM) observed in the City of Bellevue. Across all surveyed reaches, the average wood frequency is 34 pieces per mile (2 pieces per 100 m) which is far below reference levels for healthy streams (**Figure B-71)**. One piece of LWM was placed, and the other 13 pieces are presumed to be of natural origin. Almost all LWM is located in Reach 3 and, at the time of the OSCA surveys, there was no LWM present in Reach 5. There is the potential for natural recruitment of LWM in Reaches 3 and 5 but hardly any natural recruitment potential in Reach 1.

Figure B-71. Large woody material frequency in Sears Creek compared to reference levels (Fox and Bolton 2007).

B.3.8.4 Streambed Substrate

The streambed substrate in fast water habitat in Sears Creek is predominantly fines, gravels, and cobbles in equal proportions, with a lesser abundance of boulders and exposed glacial till (**Figure B-72**). Across all surveyed reaches, fines account for 26% of the substrate in all fast water habitat and 22% in riffle habitat. This is the lowest percent fines observed in the entire Greater Kelsey Creek Watershed. However, Reach 5, which is composed of glide and pond habitat, has substrate composed of 100% fines.

The substrate composition in Reaches 1 and 3 is ideal for spawning salmonids. Reach 3 is occasionally scoured down to glacial till, which accounts for 13% of the substrate composition in that reach. This is the second highest occurrence of glacial till observed in any stream reach in the watershed.

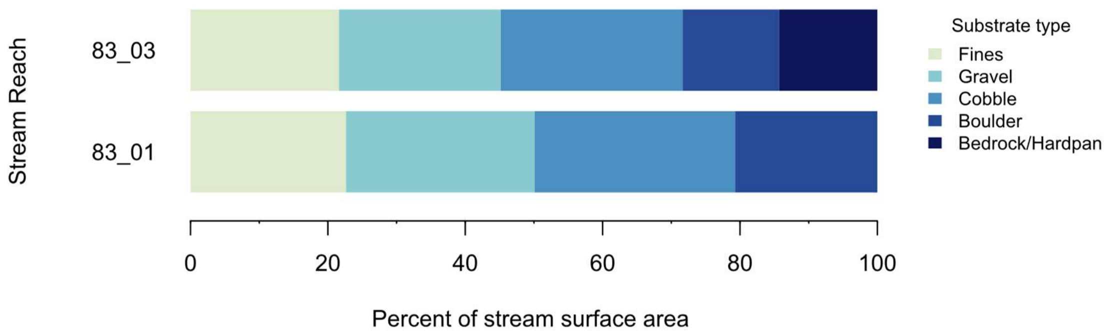


Figure B-72. Substrate composition of riffle habitat in Sears Creek, determined by visual estimation. Reach 5 is omitted because it does not contain riffle habitat.

B.3.8.5 Streambank Conditions

Sears Creek has the greatest proportion of armored streambanks of all subbasins in the City of Bellevue. Across all surveyed reaches, 34% of the streambank is armored. However, nearly all of that armoring is found in Reach 1 where it covers 65% of the streambank (**Figure B-73**). No bioengineering or “soft” armoring is present in Sears Creek. Nearly all armoring is composed of large angular boulders. Greater than 60% of this armoring is at least partially failing, which is a far greater failure rate than that seen in any other subbasin in the Greater Kelsey Creek Watershed which usually averages less than 20% failure. Armoring boulders that have fallen into the channel obstruct flow but also create habitat complexity. Around half of the pools present in Sears Creek are associated with failed armoring.

Sears Creek has an average amount of streambank erosion compared to other subbasins in the Greater Kelsey Creek Watershed. Across all surveyed reaches, 10% of the streambanks are eroded and undercut, but nearly all of that erosion takes place in Reach 3 where it accounts for 27% of the stream reach (**Figure B-74** and **Figure B-75**). All erosion is less than 5 ft in height and the undercut banks provide potential refuge for fish and other aquatic species.

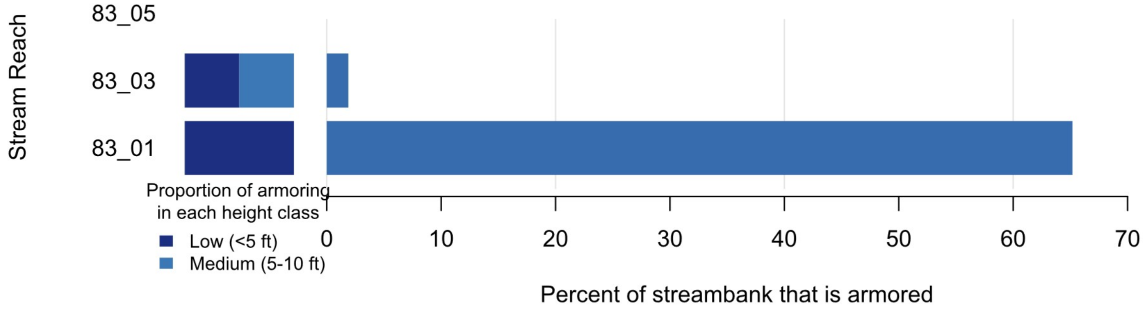


Figure B-73. Bar graphs showing the percent of each Sears Creek reach that is armored as well as the proportion of armoring in each armoring height class.

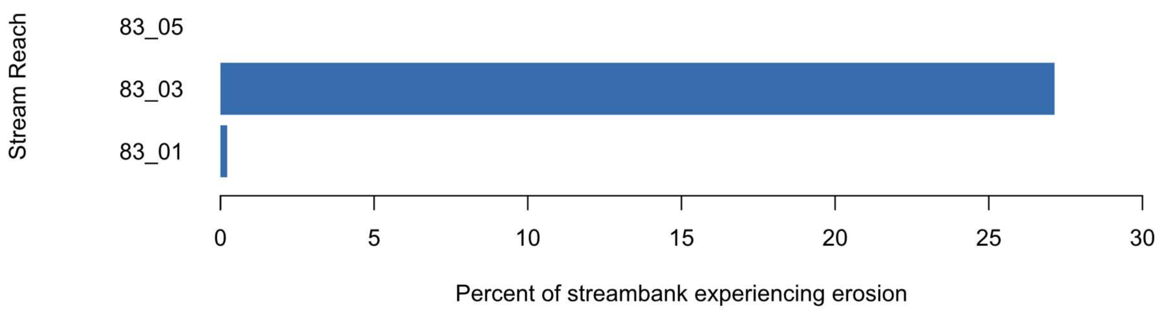


Figure B-74. Percent of each stream reach in Sears Creek that is experiencing erosion.

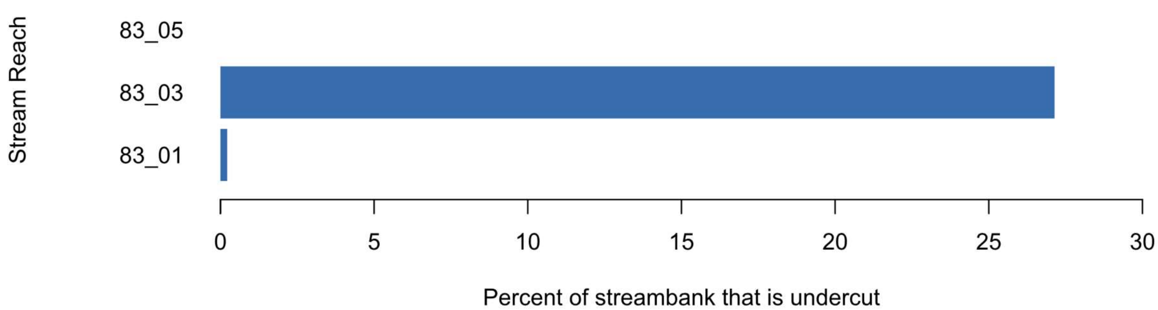


Figure B-75. Percent of each stream reach in Sears Creek that has undercut streambanks.

B.3.8.6 Fish Habitat and Passage Barriers

Sears Creek has the potential to provide fish habitat, although no fish were observed during the OSCA surveys. Streambed substrate in Reaches 1 and 3 is suitable for spawning salmon and trout. The healthy riparian canopy and presence of undercut banks makes Reach 3 the most attractive fish habitat. However, the Sears Creek Subbasin drains a very urban area with a high percentage of impervious surfaces. Water quality may be a limiting factor for fish habitat in this stream, although this is currently a data gap. Although no fish were observed in Sears Creek during OSCA surveys, two crayfish (presumably Signal Crayfish *Pacifastacus leniusculus*) were observed in Reach 1.

There are no formally documented fish passage barriers in Sears Creek (WDFW 2021). However, fish passage may be impeded by several City-owned culverts for driveways in Reach 1 and the piped conveyances of Reaches 2, 4, and 6. The Reach 4 pipe is currently the only culvert that forms a hydraulic drop, which is slightly less than 1 ft in height.

B.3.8.7 Opportunities

There are several opportunities for sustaining and improving stream health in Sears Creek. Given the highly urbanized nature of this subbasin, understanding and addressing water quality should be prioritized. Given the presence of good spawning substrate in Reaches 1 and 3 and healthy riparian conditions in Reach 3, this stream has the potential to support trout and salmon populations if instream conditions can be improved. This includes correcting potential fish passage barriers and increasing channel complexity and pool habitat with the addition of large woody material as well as removing or softening the armoring in Reach 1, adding stream meanders and roughness, and establishing healthy riparian vegetation.

Similar to the lower reaches of Valley Creek, Reaches 3 and 5 of Sears Creek are impacted by human activity (homeless encampments) where a considerable number of pharmaceuticals, drug paraphernalia, and other litter that have entered the stream. This is a human health and safety issue as well as a primary concern for the health of the stream, fish, and wildlife that inhabit the area. City and community policies and programs are necessary to improve the conditions in Valley and Sears Creeks.

Additional opportunities relate to the stormwater detention ponds located in Sears Creek. Studies are recommended to evaluate their efficacy and continued need. This is particularly true for the Commissioners' Regional Detention Pond because it is substantially altering stream habitat at base flow.

B.4 REFERENCES

Behnke, R.J. 1992. Native trout of western North America. AFS Monograph No. 6. American Fisheries Society, Bethesda, MD.

Bellevue. 2010. Fish Use of Stream Drainage Basins in the City of Bellevue. Prepared by the City of Bellevue, March 2010.

Bellevue. 2015. The City of Bellevue Storm and Surface Water Plan. October 2015.

Bisson, P.A., 1987. Large woody debris in forested streams in the Pacific Northwest: past, present, and future. Streamside management: forestry and fishery interactions, pp.143-190.

Bjornn, T. and Reiser, D.W., 1991. Habitat requirements of salmonids in streams. American Fisheries Society Special Publication, 19(837), p.138.

CDFG. 1998. A status review of the spring-run Chinook salmon (*Oncorhynchus tshawytscha*) in the Sacramento River drainage. Report to the Fish and Game Commission: Candidate Species Status Report 98-01. California Department of Fish and Game. Sacramento, CA.

Chin, A. 2006. Urban Transformation of River Landscapes in a Global Context. Geomorphology. 79. 460-487. 10.1016/j.geomorph.2006.06.033.

Ecology. 2005. Stormwater Management Manual for Western Washington, Volume 1. Washington State Department of Ecology, Olympia, WA.

Ecology. 2009. Status and Trends Monitoring for Watershed Health and Salmon Recovery: Field Data Collection Protocol for Wadeable Streams. Washington State Department of Ecology, Olympia, WA.

Hicks, B. J., J. D. Hall, P. A. Bisson, and J. R. Sedell, 1991. Responses of salmonids to habitat change. 459-479483-518.

May, C.W., Horner, R.R., Karr, J.R., Mar, B.W. and Welch, E.B., 1998. The cumulative effects of urbanization on small streams in the Puget Sound Lowland Ecoregion. *in* Proceedings of the Puget Sound Research.

Montgomery, D. R. and J. M. Buffington. 1998. Channel processes, classification, and response. *River ecology and management*, Pages 13-42.

Morrice R. and A. Johnson. 1982. Salmon spawning ground report- 1981. Washington Department of Fisheries. Olympia, Washington.

Naman, S.M., J.S. Rosenfeld, P.M. Kiffney, and J.S. Richardson. 2018. The energetic consequences of habitat structure for forest stream salmonids. Journal of Animal Ecology.

Nash, C.S., G. E. Grant, S. Charnley, J.B. Dunham, H Gosnell, M.B. Hausner, D.S. Pilliod, and J.D. Taylor, Great Expectations: Deconstructing the Process Pathways Underlying Beaver-Related Restoration, *BioScience*, Volume 71, Issue 3, March 2021, Pages 249-267, https://doi.org/10.1093/biosci/biaa165

Nickelson, T. E., W. M. Beidler, M. Willard, and M. J. Willis. 1979. Streamflow requirements of salmonids. Final Report, Federal Air Project, AFS-62. Oregon Department of Fish and Wildlife, Portland

NOAA. 1996. Coastal Salmon Conservation: Working Guidance for Comprehensive Salmon Restoration Initiatives on the Pacific Coast. National Marine Fisheries Service.

Riley, S.P.D., G.T. Busteed, L.B. Kats, T.L. Vandergon, L.F.S Lee, R.G. Dagit, J.L. Kerby, R.N. Fisher, and R.M. Savajot. 2005. Effects of urbanization on the distribution and abundance of amphibians and invasive species in southern California streams. Conservation Biology 19:1894-1907.

Robison, E.G. 1998. Reach Scale Sampling Metrics and Longitudinal Pattern Adjustments of Small Streams. Ph.D. Dissertation. Dept. of Forest Engineering and Hydrology. Oregon State University, Corvallis, OR. 254 p.

Seixas, G., M. Olis, D. Marks, A. Roorbach. 2019. Stream gradient and anadromous fish use analysis. Technical report, Department of Natural Resources. https://www.dnr.wa.gov/sites/default/files/publications/bc_fpb_skagitsamishanadanalysis_20190717.pdf

Stein, E.D., Cover, M.R., Elizabeth Fetscher, A., O'Reilly, C., Guardado, R. and Solek, C.W., 2013. Reach-scale geomorphic and biological effects of localized streambank armoring. JAWRA Journal of the American Water Resources Association, 49(4), pp.780-792.

Tetra Tech. 2016. West Tributary Habitat Assessment. Final report submitted to the City of Bellevue, WA, by Tetra Tech, Inc., Seattle, WA.

Thompson, K., 1972. Determining stream flows for fish life. Pages 31-50 *in* Proceedings, instream flow requirements workshop. Pacific Northwest River Basins Commissions.

WDFW. 2020. Bellevue Salmon Spawner Surveys (1999 – 2020). Final report submitted to the City of Bellevue, WA, by Washington Department of Fish and Wildlife, Mill Creek, WA.

WDFW. 2021. Washington State Fish Passage Webmap. Accessed April 2021. https://geodataservices.wdfw.wa.gov/hp/fishpassage/index.html

Williams, R. W., R. M. Laramie, and J. J. Ames. 1975. A Catalog of Washington Streams and Salmon Utilization. Washington Department of Fisheries, Olympia, Washington

Appendix C
Kelsey Creek Stream Flow Metrics Data Provided by the Washington State Department of Ecology

Mining Sixty Years of Flow Data from Bellevue's Kelsey Creek

Bobb Nolan
Washington State Department of Ecology
RNOL461@ecy.wa.gov

Props:

Nearly sixty year record of daily flows available on-line from USGS 12120000. Thank you United States Geological Service and City of Bellevue for funding and maintaining this gauging station!

Over sixty year record of daily rainfall totals available free from NWS Seatac. Thank you National Weather Service for maintaining weather data!

Shout out to Dan Bricklin, who along with Bob Frankston, developed the first electronic spreadsheet (VisiCalc). Way to go, Dan and Bob!

Slops:

NWS Seatac rainfall data is gathered more than a dozen miles from the Kelsey Creek basin.

Terms:

TQ_mean: Fraction of the year that daily mean flow exceeds the annual mean flow.

Richards-Baker Flashiness Index: Sum of the absolute values of the day-to-day changes in mean daily flow, normalized for total flow by dividing by total annual flow.

High Pulse Count: The number of times per year that discrete high flow (2X daily long-term average) pulses occur.

High Pulse Duration: Annual average duration of high flow pulses.

Low Pulse Count: Number of times per year that discrete low flow (50% of long term average) pulses occur.

Low Pulse Duration: Annual average duration of low flow pulses.

Trend line: the trend line shown on hydrologic metrics is a five year moving average of values.

Conclusions:

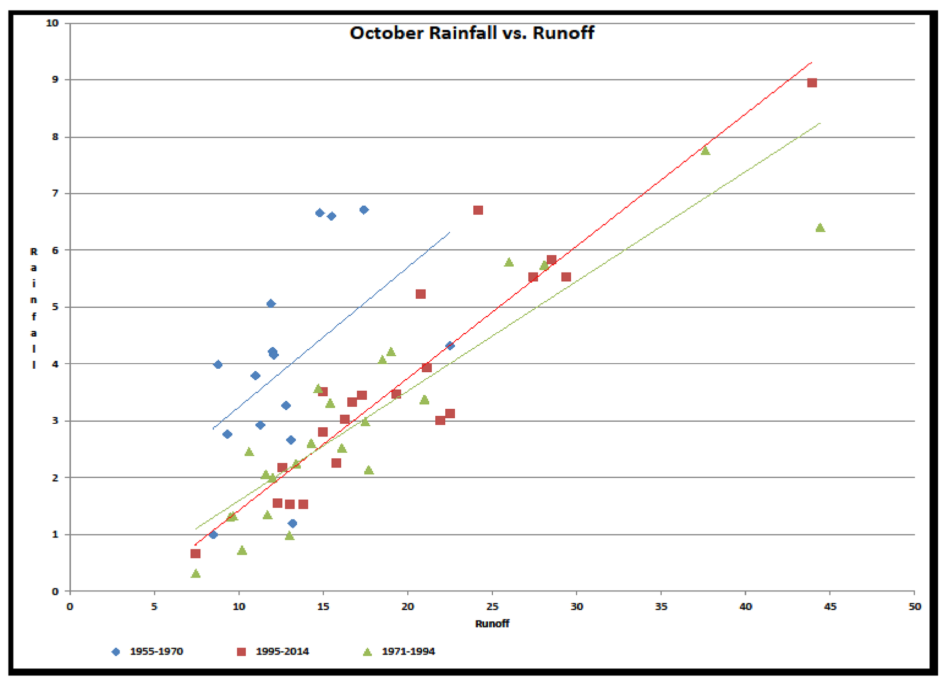
Flow monitoring can provide important information on stream health and on-going changes.

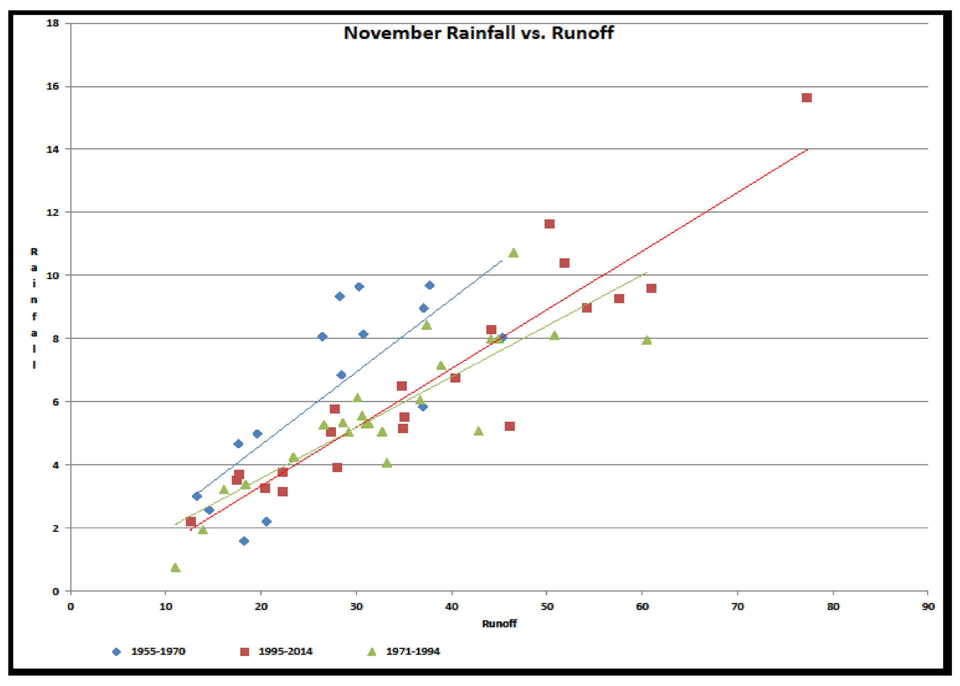
As Kelsey Creek has urbanized, more runoff (per unit rainfall) is occurring in the spring, summer and fall. Curiously, total runoff in late winter (once the soil profile is saturated) has not significantly changed over the last sixty years.

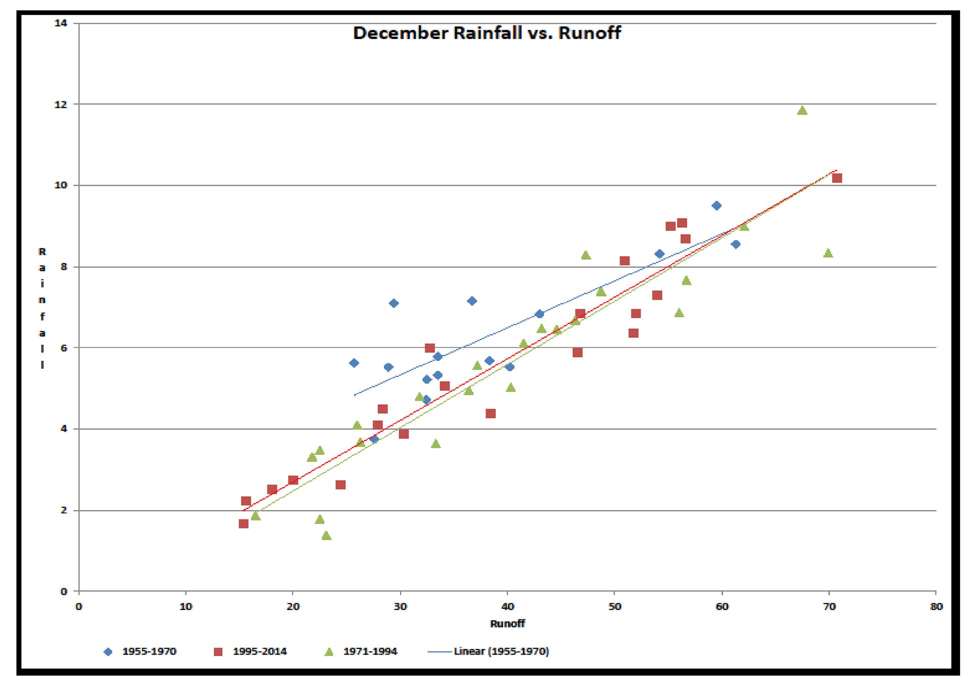
Kelsey's hydrologic health appears to have stabilized, as the basin is largely built-out, and new development is mitigated by flow control investments.

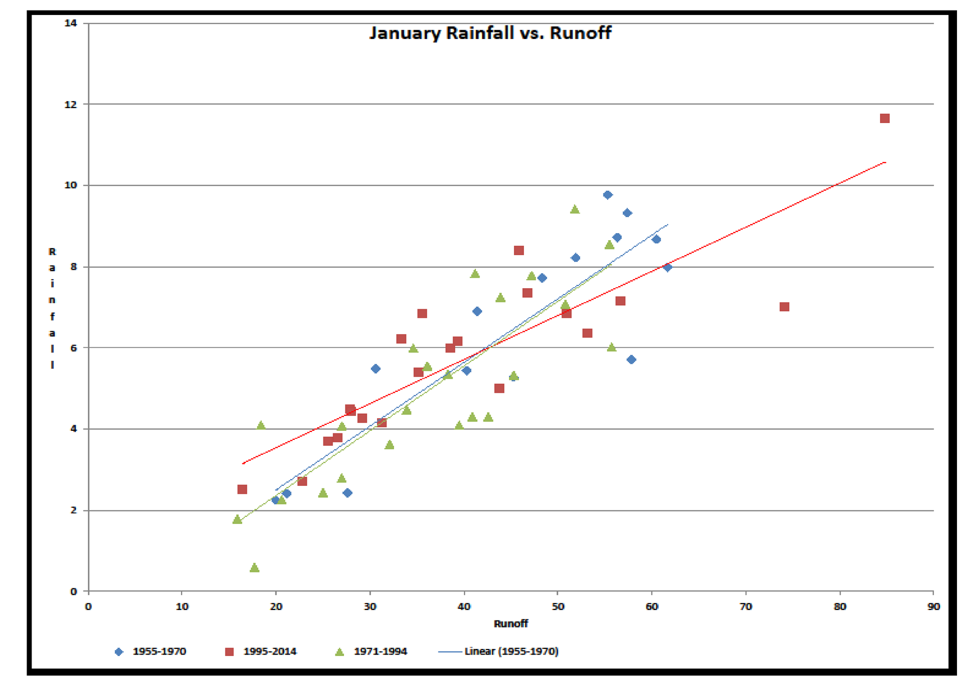
Using a linear "best fit" on sixty years of data does not accurately represent recent hydrologic trends.

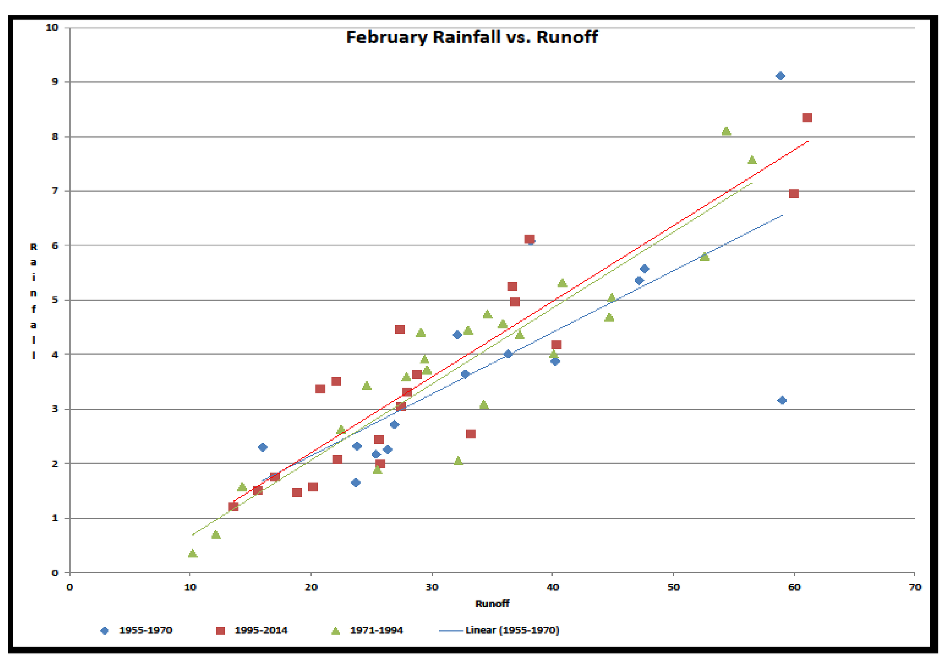
Rainfall and runoff vary from year to year. Presenting scattered data in a meaningful way can be difficult. I apologize if you don't understand this poster! The most sensitive hydrologic metrics normalize flow data with rainfall.

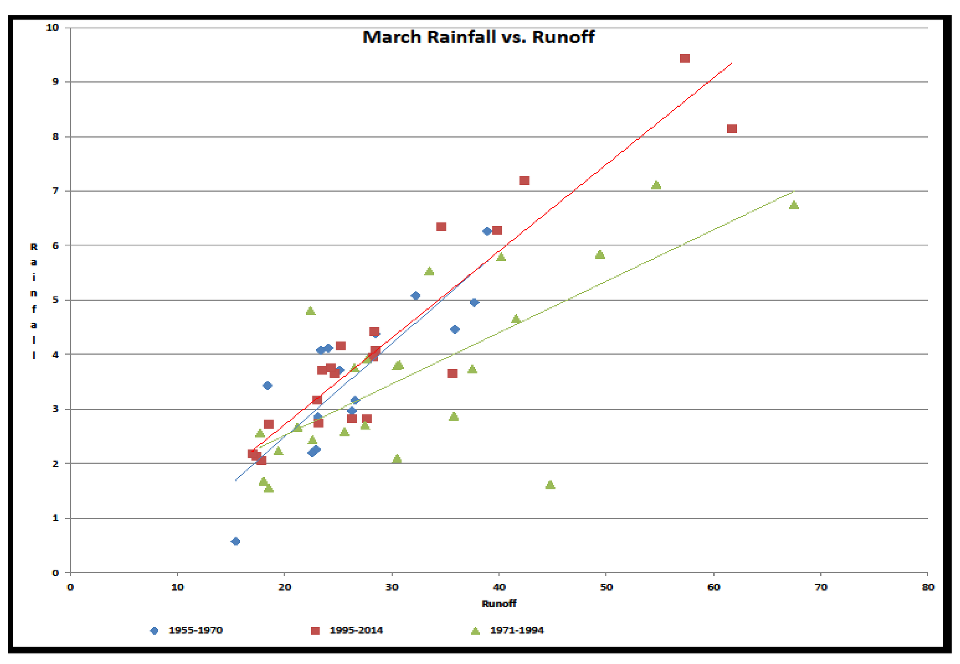


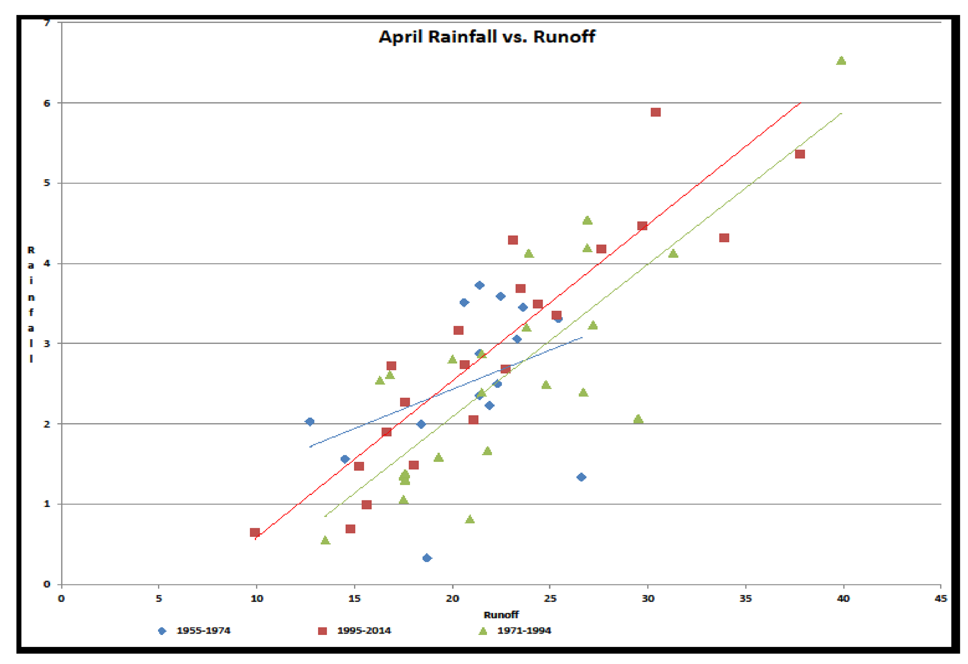


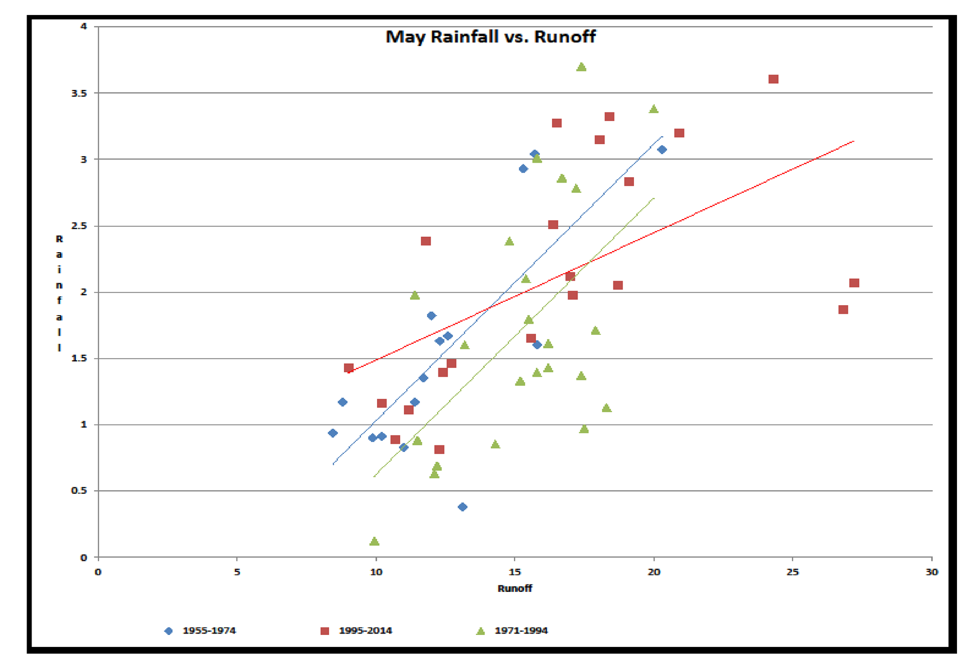


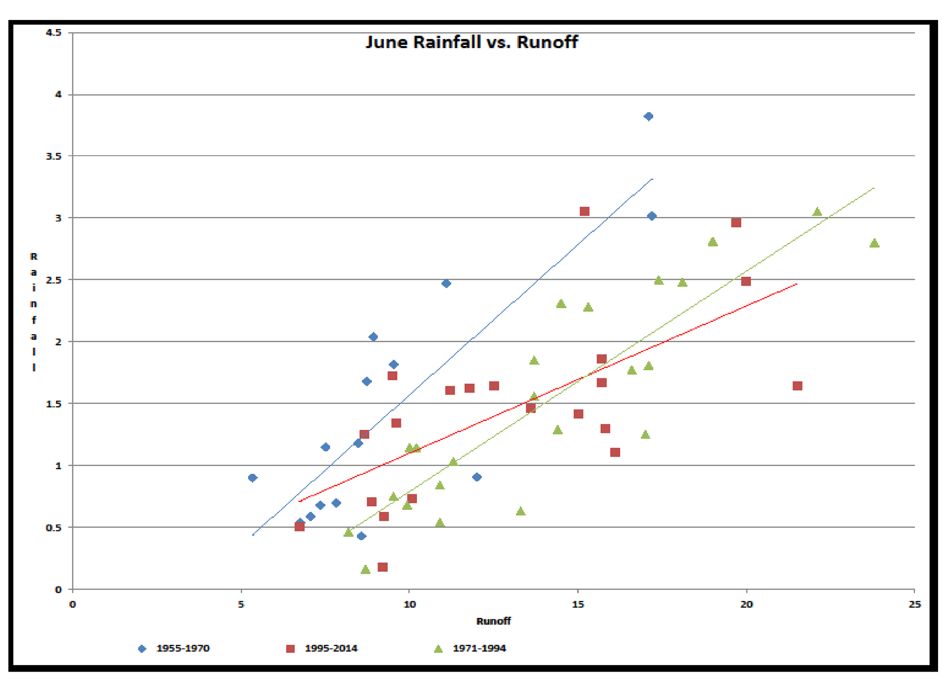


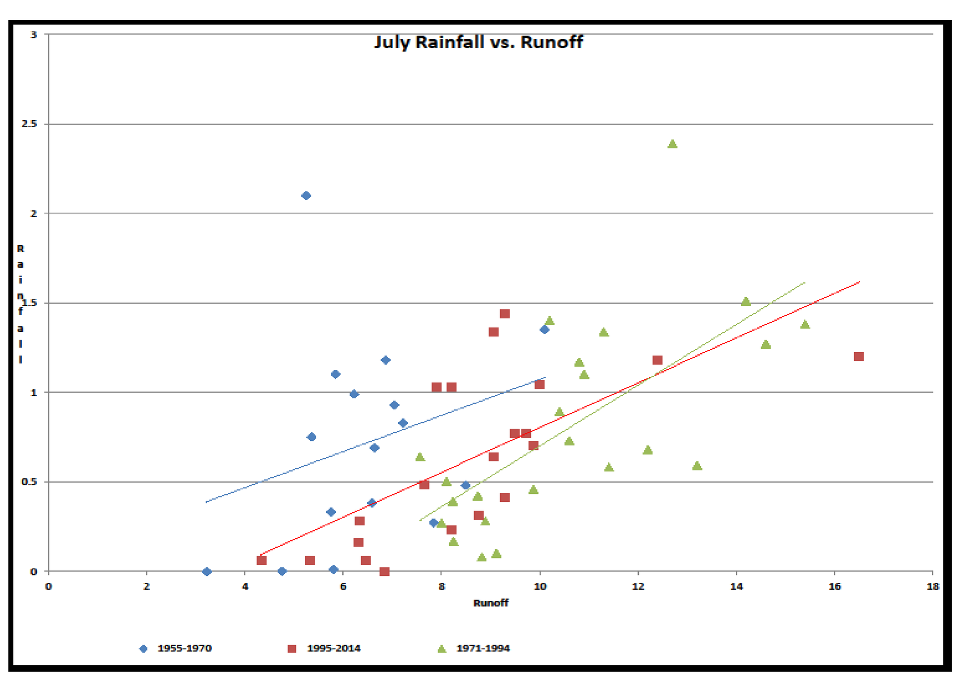


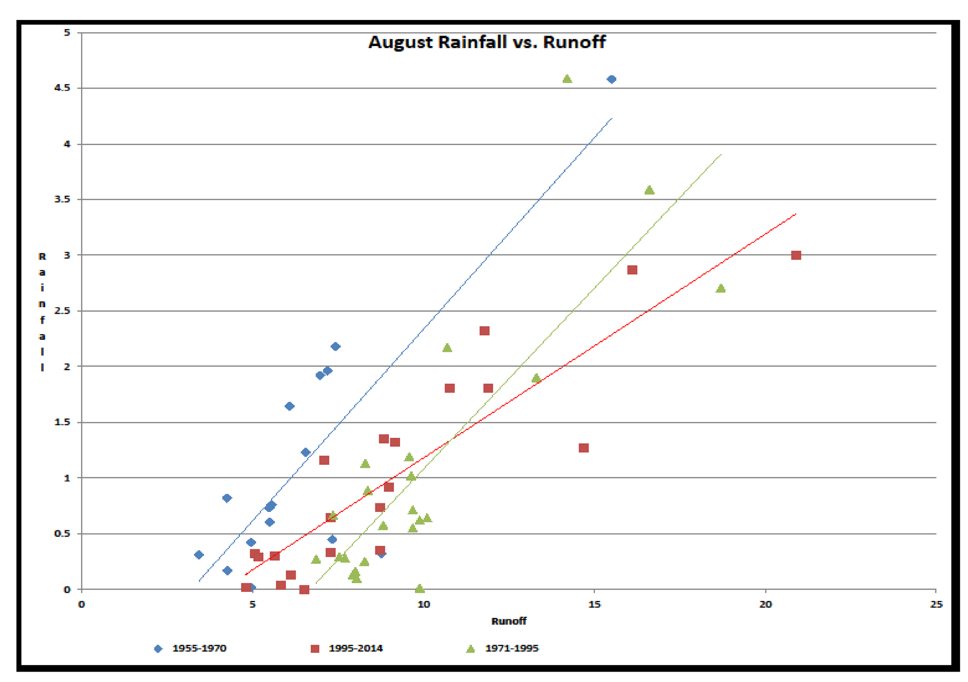


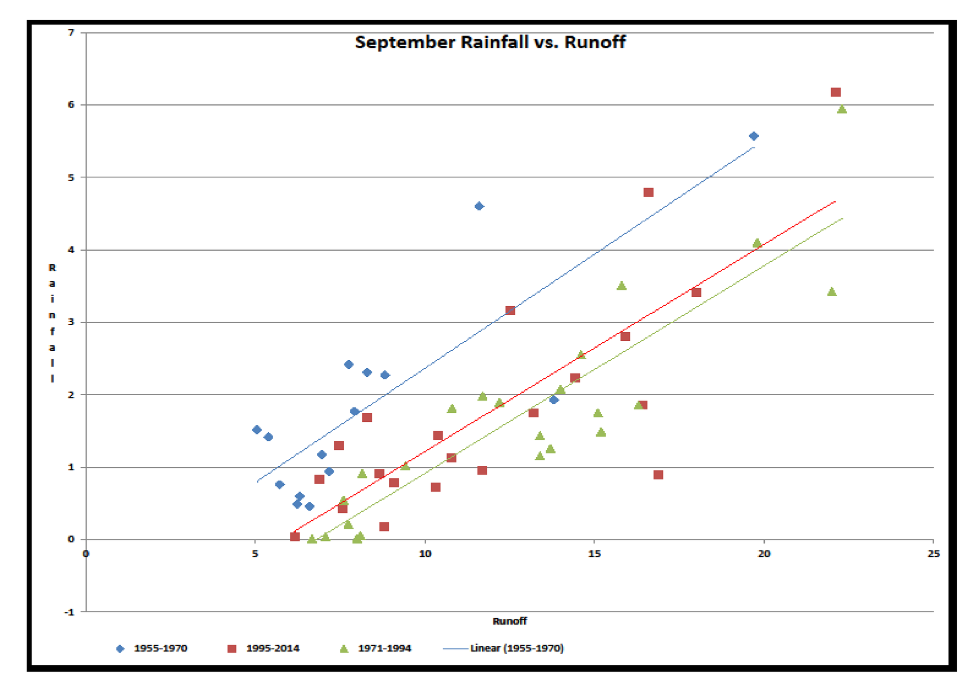


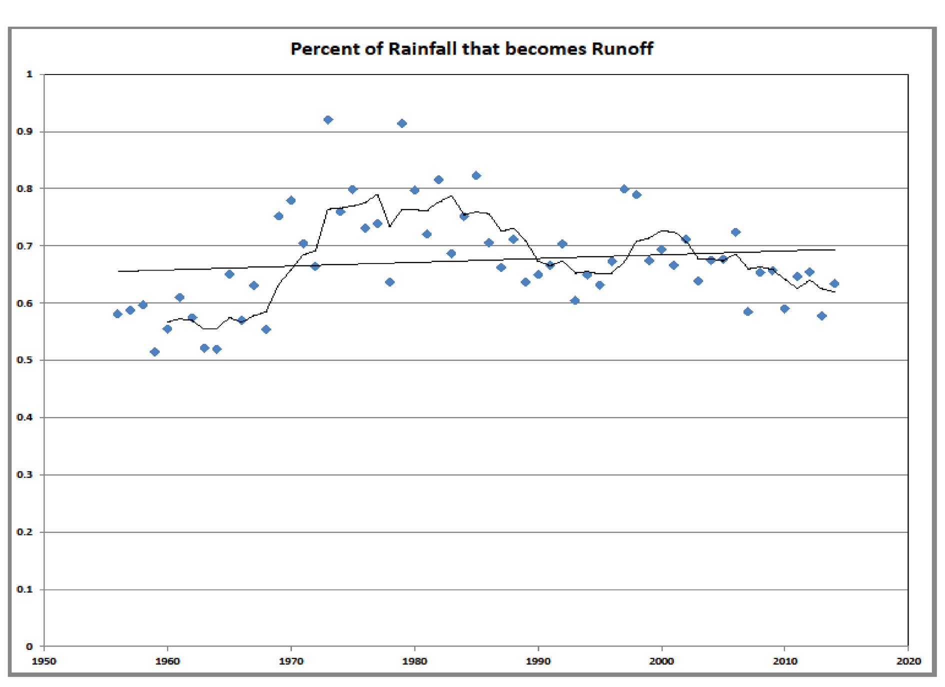


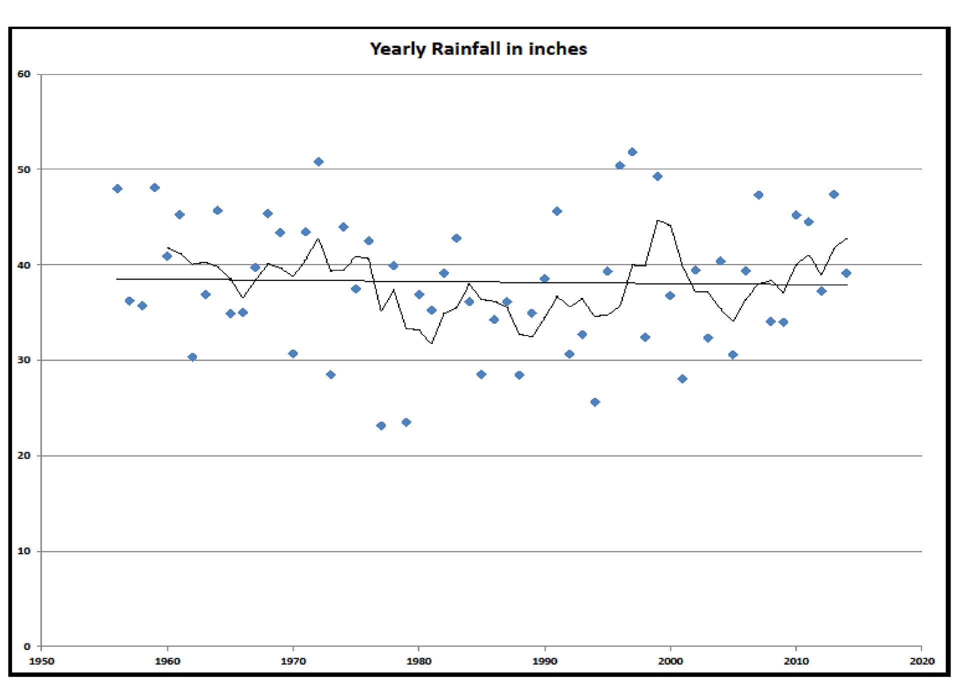


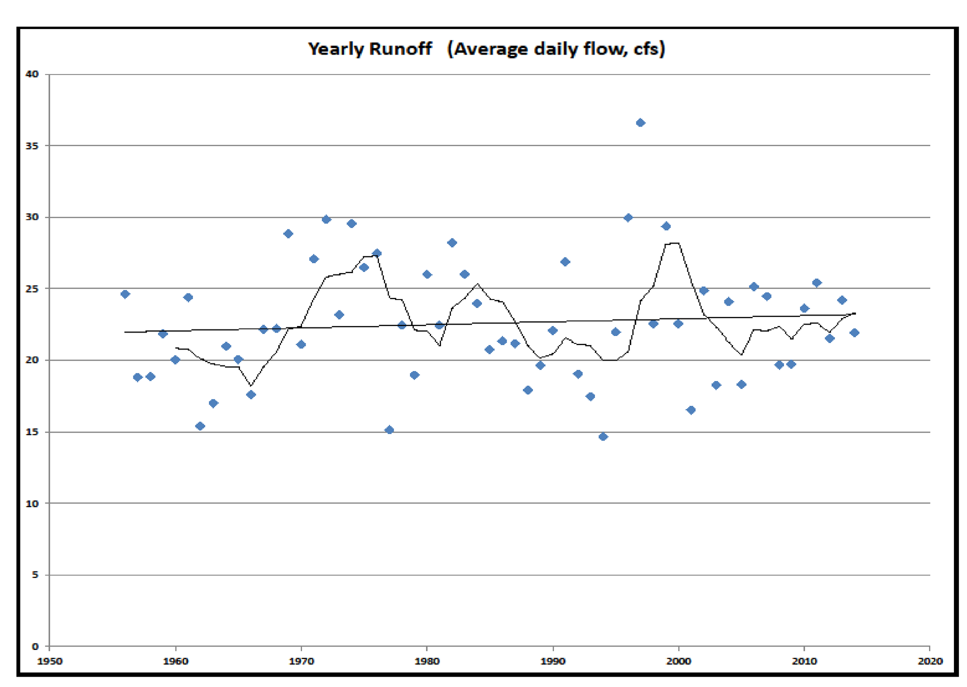


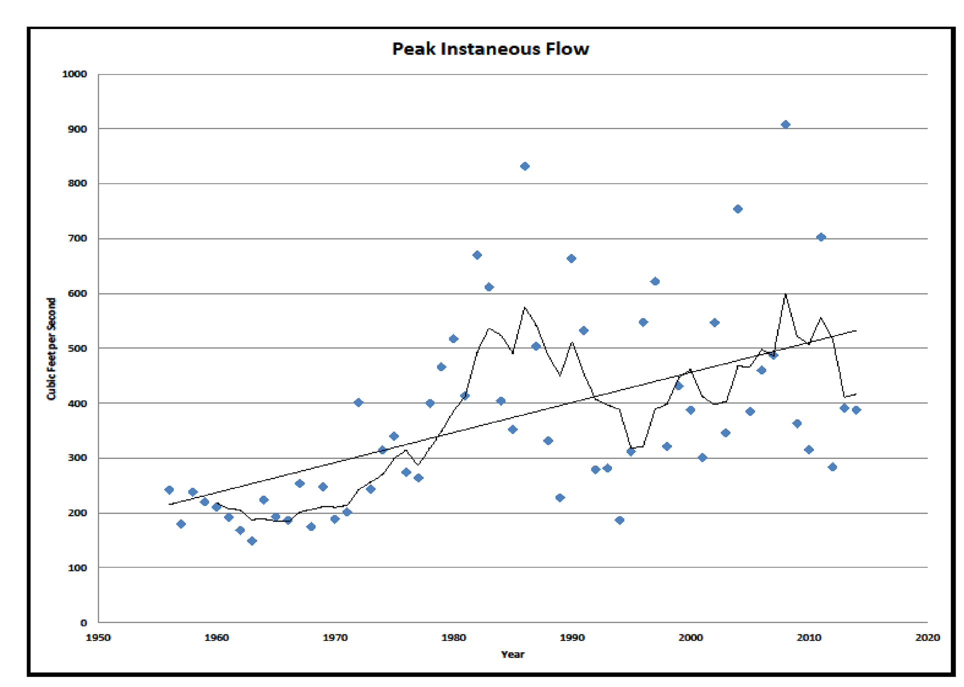


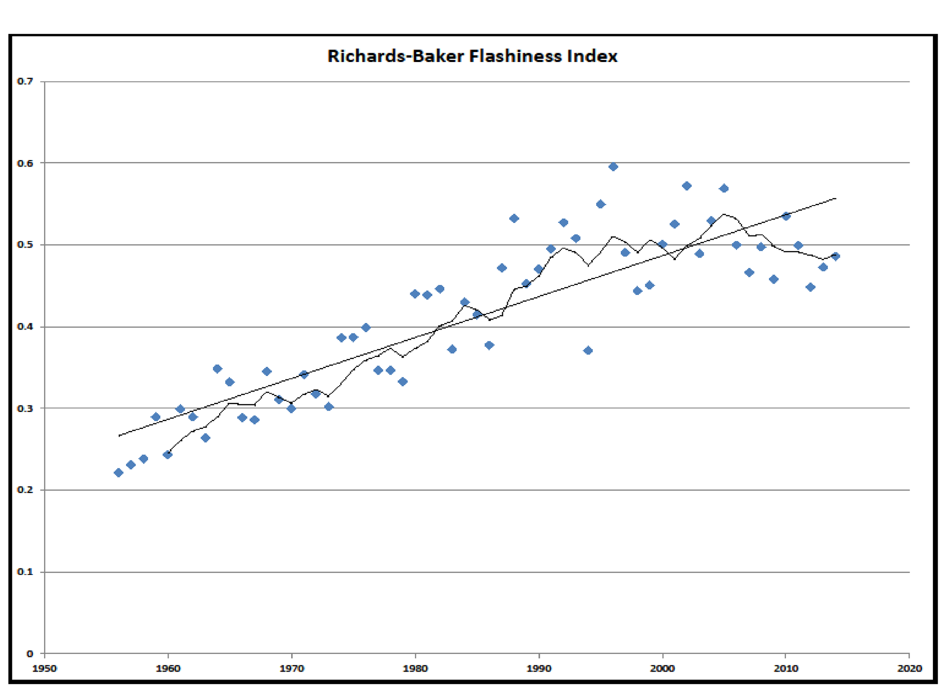


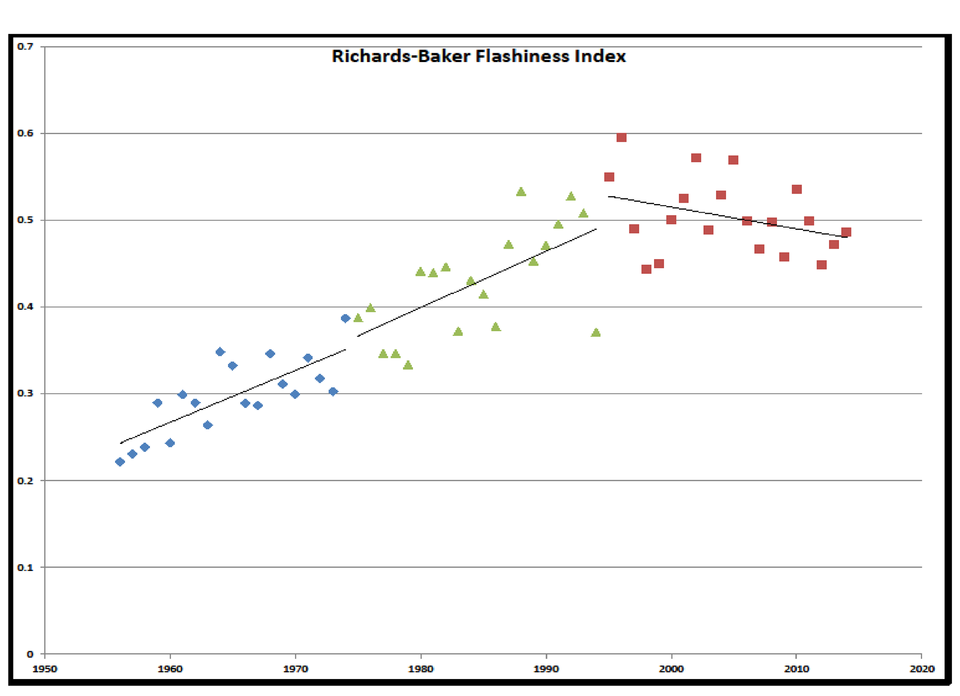


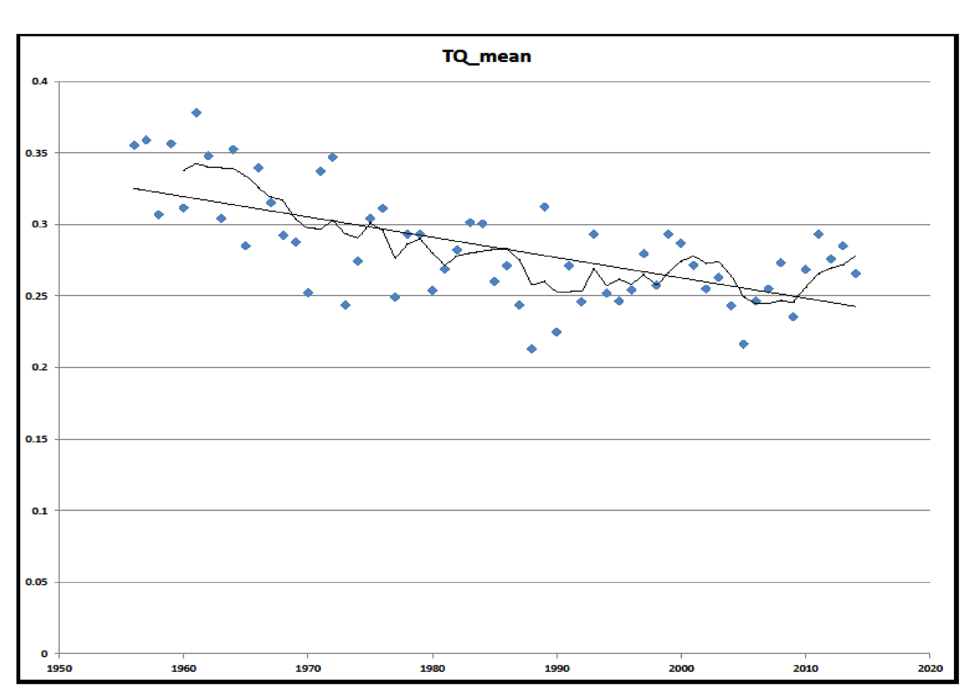


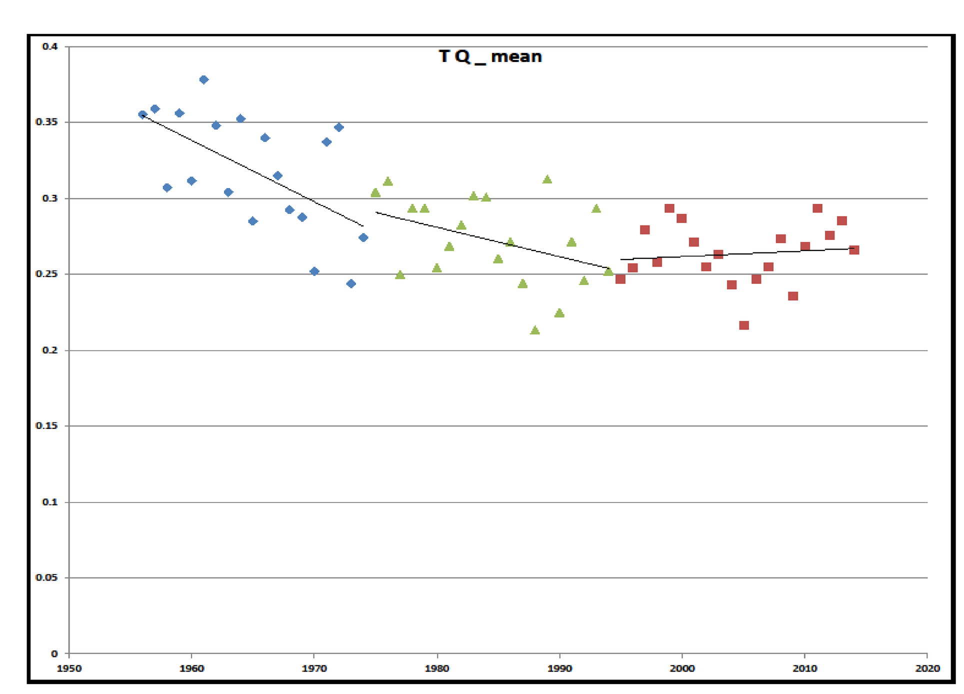


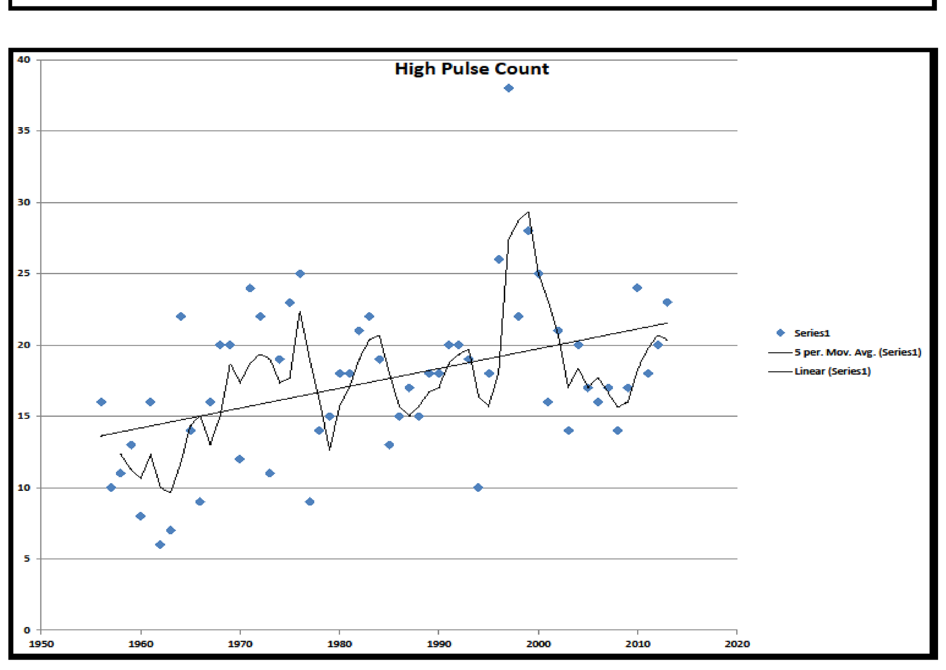


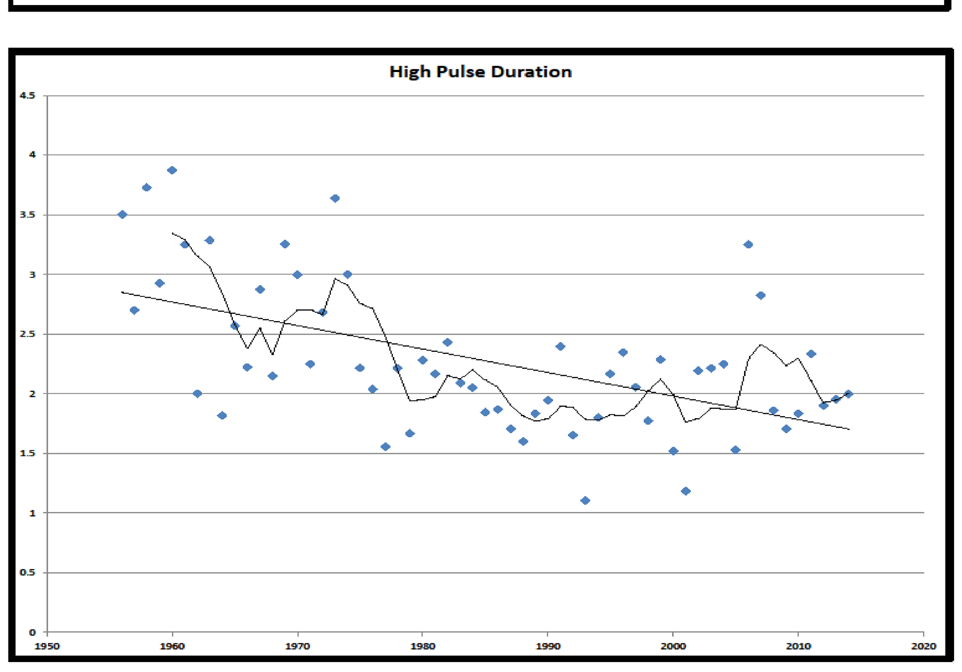


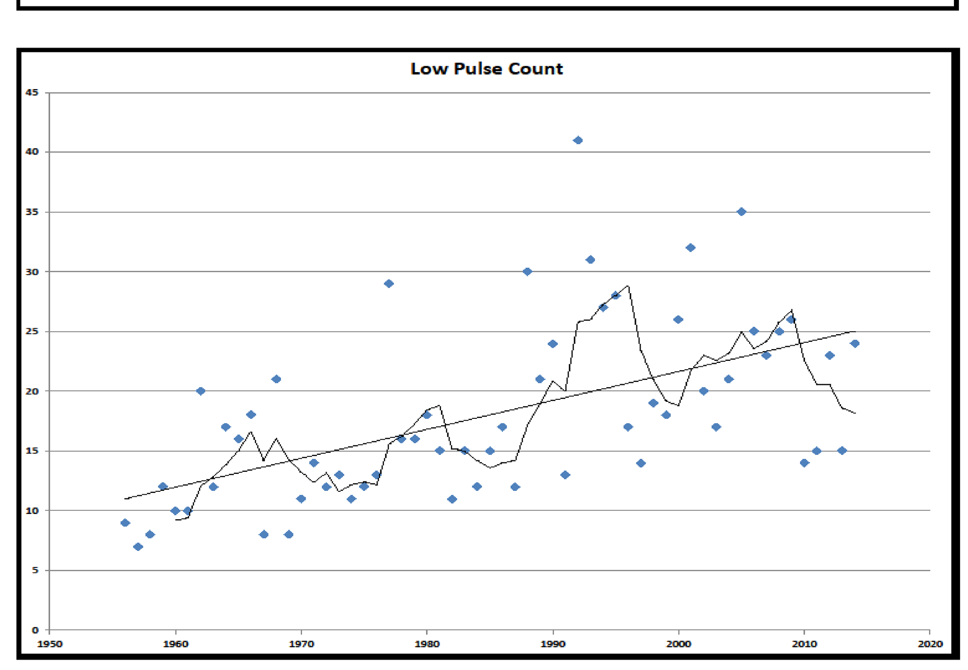


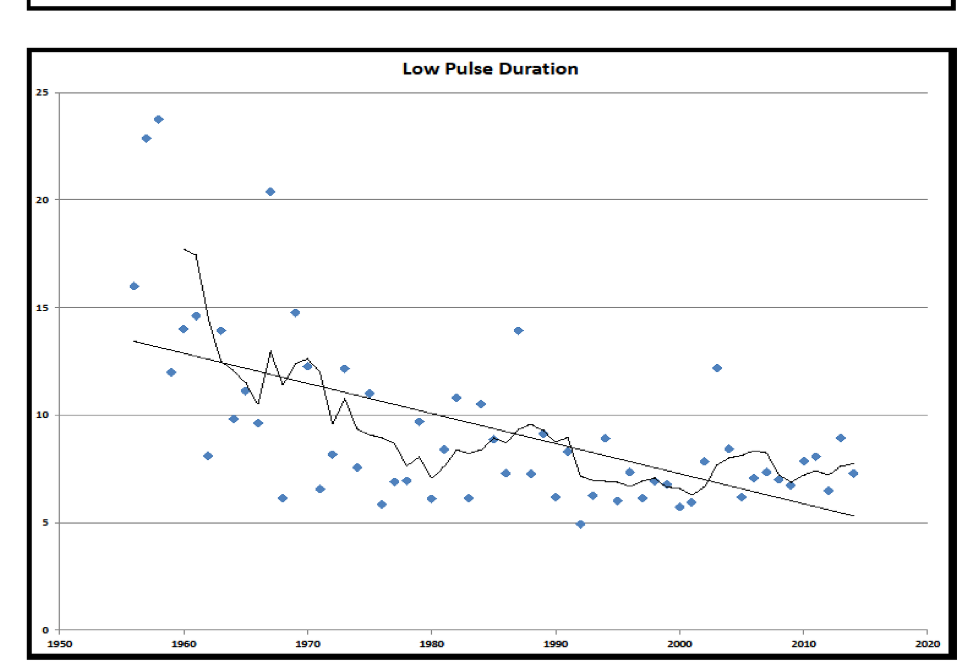












Appendix D
Inventory of WDFW-documented Fish Passage Barriers

Crossings Documented by Washington Department of Fish and Wildlife (WDFW) in the Greater Kelsey Creek Watershed

Subbasin	Barrier Type (WDFW Classifications)	Total Count
Mercer Slough	Passable Crossing	3
	Partial Fish Passage Block	1
	Total Fish Passage Block	3
	Total crossings documented by WDFW	**7**
Kelsey Creek	Corrected Barriers	2
	Culvert	1
	Culvert, Fishway	1
	Passable Crossing	16
	Partial Fish Passage Block	3
	Total Fish Passage Block	1
	Total crossings documented by WDFW	**24**
Sturtevant Creek	Culvert	3
	Passable Crossing	4
	Partial Fish Passage Block	4
	Total Fish Passage Block	1
	Total crossings documented by WDFW	**12**
Richards Creek	Unknown	1
	Corrected Barriers	1
	Natural Barrier Not Verified	1
	Passable Crossing	3
	Partial Fish Passage Block	2
	Total Fish Passage Block	1
	Total crossings documented by WDFW	**9**
Sunset Creek	Corrected Barriers	1
	Dam	1
	Diversion	1
	Passable Crossing	3
	Partial Fish Passage Block	1
	Total Fish Passage Block	6
	Total crossings documented by WDFW	**13**
West Tributary	Passable Crossing	3
	Partial Fish Passage Block	3
	Total crossings documented by WDFW	**6**
Goff Creek	Diversion	1
	Passable Crossing	4
	Partial Fish Passage Block	6
	Total Fish Passage Block	7
	Total crossings documented by WDFW	**18**
Valley Creek	Passable Crossing	1
	Partial Fish Passage Block	1
	Total crossings documented by WDFW	**2**
Sears Creek	Partial Fish Passage Block	1
	Total Fish Passage Block	2
	Total crossings documented by WDFW	**3**
Greater Kelsey Creek Watershed	**Total crossings documented by WDFW**	**94**

Source: Washington State Fish Passage Webmap. Accessed October 1, 2021. https://geodataservices.wdfw.wa.gov/hp/fishpassage/index.html Wild Fish Conservancy Northwest. 2021.

Appendix E
Kelsey Creek Watershed Benthic Index of Biotic Integrity Scores

Greater Kelsey Creek Watershed Benthic Index of Biotic Integrity Scores

Subbasin	Agency	Site Code	Latitude	Longitud	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Goff Creek	City of Bellevue	GoffBelRM1.4	47.631	-122.17					19.2			11.9	13.7																		
Goff Creek	City of Bellevue	GoffBelRM1.6	47.634	-122.17					3.9			13.4	9.6																		
Goff Creek	City of Bellevue	GoffBelRM1.7	47.635	-122.17					7.5			6.4	9.4																		
Goff Creek	City of Bellevue	GoffMouthRM0.1	47.619	-122.17																	6.4										
Kelsey Creek	City of Bellevue	KelBelRM0.2	47.603	-122.18					10.2			11.2	10.6											20.8		17.3					
Kelsey Creek	City of Bellevue	KelBelRM1.6	47.605	-122.16												1.9									8.5			8.8			
Kelsey Creek	City of Bellevue	KelBelRM1.8	47.608	-122.16					16.5			1.2	4.4			1.9	7.6									12.5					
Kelsey Creek	City of Bellevue	KelBelRM2.3	47.614	-122.16					7.7			5.5	3.7																		
Kelsey Creek	City of Bellevue	KelBelRM2.4	47.616	-122.16					8.4			4	9.3																		
Kelsey Creek	City of Bellevue	KelBelRM3.7	47.623	-122.15					15.6			10.5	1.4															4.6			
Kelsey Creek	City of Bellevue	KelBelRM3.9	47.622	-122.15												10	9.3								5.9						
Kelsey Creek	King County - DNRP	08EAS2272	47.623	-122.16									6.1	0		4.5	2.8	4.4	10.7	9	4.7	13.9	9.2	8.9	24.9	14.8	17.1	10.6	33	20.6	26.8
Kelsey Creek	King County - DNRP	D444 Kelsey	47.606	-122.16								9.4																			
Kelsey Creek	King County - DNRP	WAM06600-038087	47.624	-122.15																3	13.5	8.3	8.5	11.9							
Kelsey Creek	King County - DNRP	WAM06600-080407	47.605	-122.16																10.8	7.5	12.5	13	9.7							
Kelsey Creek	University of Washington	KE	47.606	-122.16	8.5	4.9																									
West Tributary	City of Bellevue	WestTribFarmRM0.4	47.605	-122.16																	11.4			17.7		14.6					
Valley Creek (Bellevue)	City of Bellevue	ValleyBelRM0.2	47.627	-122.15												5.6	6.4														
Richards Creek	City of Bellevue	RichBelRM0.9	47.594	-122.16					15.3																						
Sunset Creek	City of Bellevue	Sunset/RichardsRM0	47.585	-122.16																		1.4			0			15.3			