Small Lake Washington Tributaries Watershed Assessment Report

prepared in support of the City of Bellevue Watershed Management Plan for Small Lake Washington tributaries within the City of Bellevue

Revision 2 (final)

April 7, 2022

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Watershed Management Plan
Our streams, our future

Document history and status

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EXECUTIVE SUMMARY

Purpose of This Assessment

The purpose of this report is to assess the conditions in the Small Lake Washington Tributaries Watershed that are limiting the health of its streams. The evaluation of potential limiting factors specifically focused on the "stressor sources" from the Conceptual Model that describe the primary effects of urban runoff on streams and their consequences for stream health.

The City of Bellevue (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'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 Small Lake Washington Tributaries Watershed

The Small Lake Washington Tributaries Watershed is comprised of six distinct subbasins and areas: Lakehurst Area (including Lakehurst Creek), Meydenbauer Creek Subbasin, Beaux Arts Area, Clyde Beach Area, Yarrow Creek Subbasin, and Point Cities Area. In addition to the larger Kelsey Creek and Coal Creek Watersheds, these smaller drainage areas cover the remaining portions of Bellevue that drain to Lake Washington.

The Lakehurst Area includes Lakehurst Creek, a small unnamed stream and associated wetlands in Newcastle Beach Park, and several other small seasonal drainages to Lake Washington. Approximately half (51 percent) of the area is located inside the City of Bellevue, with the remaining portions in the cities of Newcastle and Renton. Lakehurst Creek is piped from its mouth up to I-405; the highway runs near the Lake Washington shoreline for the entire length of the Lakehurst Area and is the highest-intensity land use in the predominantly residential area. The upper portion of Lakehurst Creek flows through residential areas that are often cleared or landscaped and may subject the stream to fertilizer and pesticide inputs. Similar to other creeks in the Small Lake Washington Tributaries Watershed, Lakehurst Creek is subject to flashy flows, with severe streambank stabilization issues that are exacerbated by failing in-stream structures where the stream flows through a steep and well-vegetated ravine. Historic fish presence within Lakehurst Creek is unknown. Today, the piped lower portion of the Lakehurst Creek is a complete fish barrier that cuts off access to fish from Lake Washington. Lakehurst Creek is occasionally dry during low-precipitation years and has limited habitat potential under current conditions. City actions are further limited by private property ownership along Lakehurst Creek, which restricted City staff access for surveying.

Meydenbauer Bay has a rich history in the settlement of the Seattle area and the origins of Bellevue. An early passenger ferry wharf promoted settlement in the area and provided ferry service across Lake Washington until 1920. Prior to World War II, Meydenbauer Bay also housed the American Pacific Whaling Company fleet during the offseason. When the business closed, that dock area became the Bellevue Marina. Today, the Meydenbauer Creek Subbasin is densely developed and drains approximately half of the City of Bellevue's Central Business District (CBD). Meydenbauer Creek has been heavily altered and is mostly piped, with only 0.4 miles of open channel remaining. A high-flow bypass was constructed in the Meydenbauer Creek Subbasin in 1983, accompanied by relaxed flow control regulations in a "No Detention Zone" for the CBD, which drains stormwater flows directly to the stream until a certain level is reached in the bypass structure. Due to the high percentage of impervious area (60 percent), flashy stream flows are a significant challenge for this subbasin, causing channel incision, streambank instability, and associated water quality concerns. Concerns over bank stabilization have prompted complaints from private land owners near the stream mouth, where beaver and nutria activity further complicate system capacity constraints. Accumulating sediment at the bypass outfall also requires regular dredging maintenance, and illicit discharges from commercial activities in the subbasin are an ongoing concern. Despite historic presence of salmon and trout, Meydenbauer Creek fish habitat has been severely degraded by development and no longer supports the historic diversity of fish species.

The Beaux Arts Area is located mainly within the City of Bellevue, but also includes the town of Beaux Arts Village. This area is predominantly single family residential (91 percent) and does not have an open stream channel. This area is not discussed in detail in this report.

The Clyde Beach Area has a small stream channel that was formerly piped and recently opened as a stream channel by the City of Bellevue Parks Department. Because flow to the entire upper drainage area is comprised of stormwater, there is an intentional fish passage barrier to keep fish out of the storm drainage system. This small enhancement project at the mouth of the stream was completed to support the Lake Washington/Cedar/Sammamish Watershed Chinook Salmon Conservation Plan (also referred to as the “WRIA 8 Plan” for Water Resource Inventory Area number 8). Recovery

goals include opening piped stream mouths around Lake Washington to improve access into small tributary streams and improve shallow water lakeshore areas for juvenile salmonids. This project may also benefit lake-spawning Sockeye Salmon. Outside this area, there is no open channel in the Clyde Beach Area, and it is minimally discussed in this report.

The Yarrow Creek Subbasin includes one mainstem channel with several significant tributaries, including Tributaries 0254 and 0256. Approximately half of the subbasin is located inside the City of Bellevue, with the remaining portions in the City of Kirkland and unincorporated King County. Yarrow Creek is unique compared to other subbasins in the Small Lake Washington Tributaries Watershed because there is an extensive wetland complex (Yarrow Bay Wetlands) at the stream outlet to Lake Washington, providing valuable lakeshore habitat. However, the Yarrow Creek riparian corridor is also severely impaired by two highways (I-405 and SR 520), multiple stream crossings, suspected failing septic systems, and high-intensity land use (commercial/office and industrial). Yarrow Creek is subject to flashy flows and exhibits a severe percentage of streambank erosion and the highest percentage of undercut banks across all City watersheds. Despite these challenges, all surveyed stream reaches in the Yarrow Creek Subbasin are fish-bearing or potentially fish-bearing. The Washington State Department of Transportation (WSDOT) and the City have undertaken fish barrier removal, mitigation, and restoration actions that have benefitted portions of the mainstem and Tributary 0254. Beaver activity is also significant in this subbasin; beaver dams are extensive in lower Yarrow Creek and a large beaver-impounded wetland has formed in the WSDOT restoration area south of SR 520.

The Point Cities Area is very small (only 9 acres), residential, and does not have an open stream channel. This area is acknowledged as a portion of the Small Lake Washington Tributaries Watershed but is not discussed in detail in this report.

Factors that Limit the Health of the Small Lake Washington Tributaries Watershed

The following were identified as limiting factors for the Small Lake Washington Tributaries Watershed per the Conceptual Model, in general order of importance across all six subbasins and areas within the watershed:

1. **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 and instream habitat quality, including fish and wildlife habitat. Lakehurst Creek, Meydenbauer Creek, and Yarrow Creek all exhibit flashy flows and have some of the highest percentages of streambank erosion and undercut banks across all City watersheds.
2. **Pollutant Loading:** Stormwater runoff from impervious surfaces transports pollutants (metals, nutrients, fecal coliform, and others) associated with urban development that are detrimental to the health of aquatic organisms and people. There are several high-intensity pollutant sources in the Small Lake Washington Tributaries Watershed. For example, the Meydenbauer Creek Subbasin drains the CBD, and Yarrow Creek Subbasin has substantial commercial/industrial development with two highways (I-405, SR 520), in addition to other pollutant sources throughout the watershed, such as residential landscaping in riparian areas.
3. **Road Culverts and Other Physical Barriers:** Several physical barriers to fish passage have been identified in all the streams of the Small Lake Washington Tributaries Watershed. In addition, there are undocumented barriers on private properties throughout the watershed. For these streams, water quality and poor habitat conditions are the primary concern, while addressing fish passage is secondary. For example, Lakehurst Creek is piped from the stream mouth to I-405, but the stream also flows through a steep ravine and runs dry seasonally, reducing the potential benefit of restoring fish access.
4. **Loss of Floodplain and Riparian Function:** Urban development has largely confined many of the stream reaches in the watershed. Much of the historic open channel of Meydenbauer Creek is now piped. While Yarrow Creek still has an extensive wetland at the stream mouth, channel alterations and multiple highway crossings have significantly impaired the riparian corridor. Canopy loss is also a concern in all of these areas, but some well-vegetated areas remain.

Past and Present Investments in the Small Lake Washington Tributaries Watershed

Compared to other watersheds across Bellevue, investments in the Small Lake Washington Tributaries Watershed have been limited. However, several large projects have occurred including WSDOT and City restoration activities in the Yarrow Creek Subbasin and construction of the high flow bypass in the Meydenbauer Creek Subbasin. Other maintenance actions, such as dredging activities and beaver management, are ongoing in these areas to address system capacity constraints.

Future Opportunities

Potential future investments in the Small Lake Washington Tributaries Watershed will address the limiting factors identified herein and include both in-stream investments and investments in the contributing drainage areas to reducing stormwater runoff and pollutant loading.

Prepared by HERRERA Jacobs

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 flow control and runoff treatment facilities or with flow control and runoff treatment facilities 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 the City'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 will be prepared for each of the City's major watersheds: Coal Creek, Greater Kelsey Creek, the Lake Sammamish Tributaries within the City of Bellevue (including Lewis Creek), and the Small Lake Washington Tributaries within the City of Bellevue.

This report is an assessment of the current conditions in the Small Lake Washington Tributaries Watershed, which includes the area within the City of Bellevue that drains to Lake Washington that is not covered in the Kelsey Creek Watershed or Coal Creek Watershed Assessment Reports. This information, along with other subsequent reports, will be used to develop the final WMP.

1. Introduction

This section discusses the watershed management planning process, introduces the Small Lake Washington Tributaries 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, Small 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 City 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.

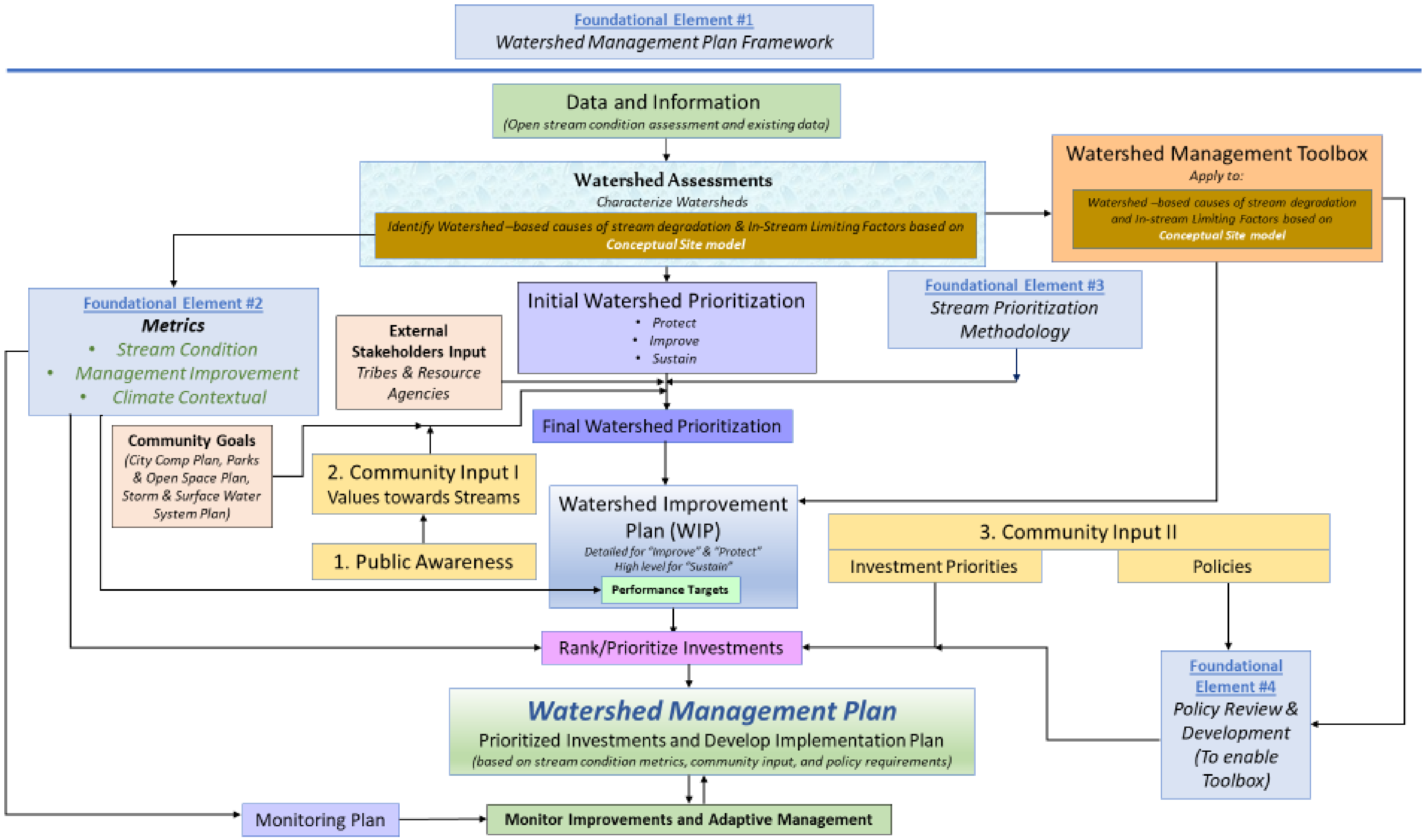


Figure 1. Watershed Management Plan Development Process.

1.2 The Small Lake Washington Tributaries Watershed

The Small Lake Washington Tributaries Watershed encompasses a total area of approximately 4,577 acres with 65 percent of this area located within the City of Bellevue's boundary (Figure 3). The remaining portions of the watershed are within the cities of Newcastle, Renton, Kirkland, Clyde Hill, and unincorporated King County. The City of Bellevue's portion of the Small Lake Washington Tributaries Watershed is comprised of 6 individual subbasins and areas that are briefly characterized below, with more detail provided within this report:

- Lakehurst Area is the southernmost subbasin of the small Lake Washington tributaries with roughly half of the subbasin located within the City of Bellevue. The remaining areas are in the cities of Renton and Newcastle. I-405 parallels Lake Washington at the western edge of this subbasin, crossing Lakehurst Creek and several small tributaries. Within the City of Bellevue, the Lakehurst Area is mainly single family residential (87 percent).
- Meydenbauer Creek Subbasin is located primarily in the City of Bellevue and is predominantly piped with a limited portion of open channel. This subbasin drains approximately half of the Central Business District (CBD; mixed-use, 34 percent). Outside the CBD, the subbasin is predominantly single family (50 percent) and multi-family residential (14 percent).
- Beaux Arts Area is located mainly within the City of Bellevue, but also includes the town of Beaux Arts Village. This area is predominantly single family residential (91 percent). This area does not have an open stream channel and will not be discussed in detail in this Watershed AR.
- Clyde Beach Area is located mainly within the City of Bellevue. This area is predominantly single family residential (74 percent) and multi-family residential (20 percent). This area does not have a natural stream channel but does have a lakeshore park, a restored open drainage channel, and lakeshore restoration activities initiated by the Bellevue Parks Department.
- Yarrow Creek Subbasin is the northernmost subbasin of the small Lake Washington tributaries and flows into Lake Washington at Point Cities. Yarrow Creek has forested headwaters in the City of Kirkland, then flows through single family residential areas before crossing Interstate 405 (I-405) and State Route 520 (SR 520). The stream corridor is substantially urbanized, with predominantly single family residential land use (56 percent), large commercial/office areas (18 percent), and multi-family developments (11 percent).

The land draining to Lake Washington within the City of Bellevue is designated as either an area or a subbasin. A subbasin generally includes one major open channel stream discharging to one location whereas an area may have several individual discharge locations to its receiving water body and may either be piped or open channel.

- Point Cities Area is a very small drainage area (9 acres) located entirely within the City of Bellevue and is 100 percent single family residential. This small area does not have an open stream channel and will not be discussed in detail in this Watershed AR.

This Watershed AR was prepared to meet the following objectives:

- Characterize the current 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 Small Lake Washington Tributaries Watershed under separate sections:

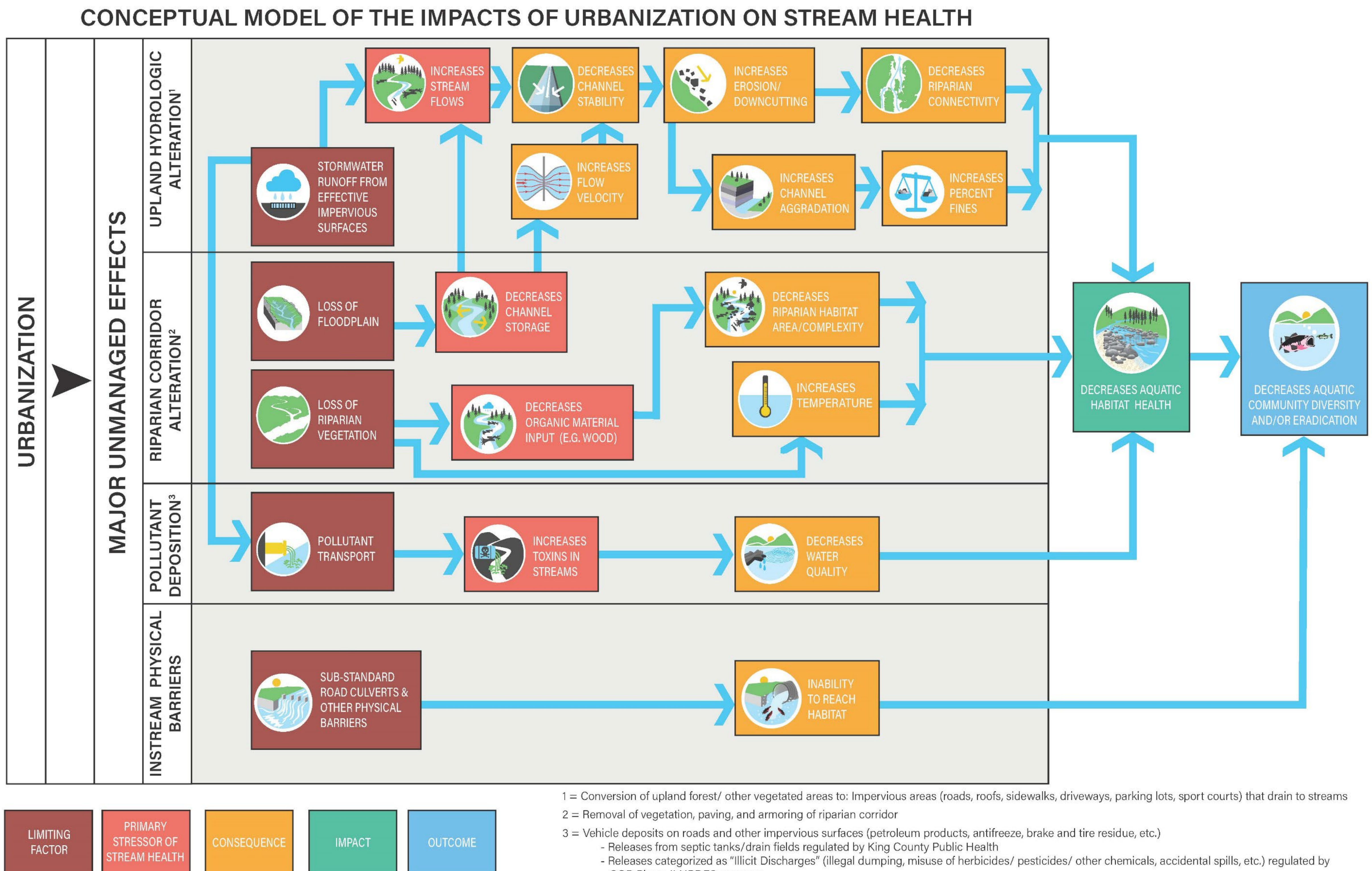
Existing conditions - a summary of existing conditions for the following attributes: watershed characteristics, built infrastructure, and natural systems.

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.

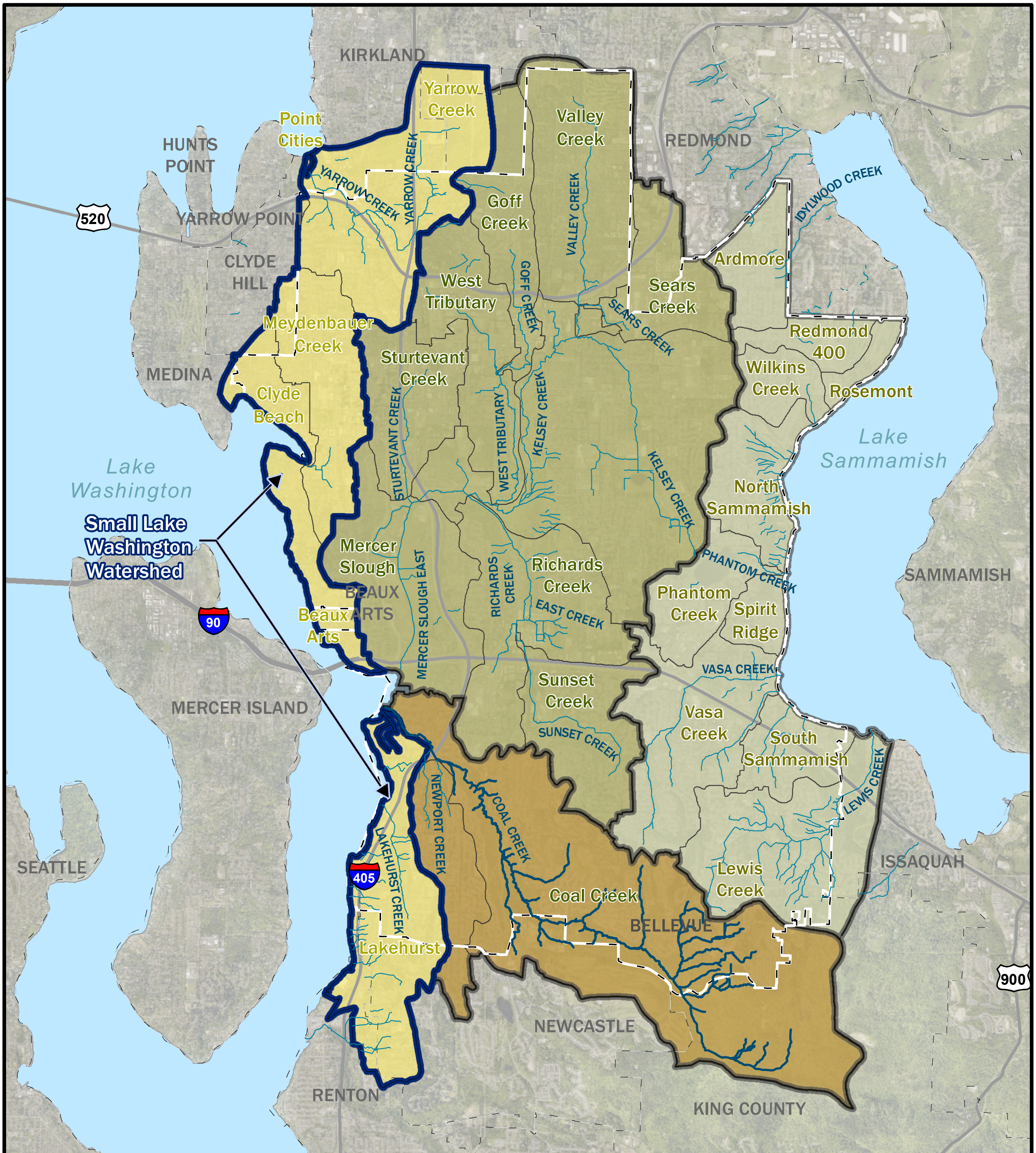


1 = Conversion of upland forest/ other vegetated areas to: Impervious areas (roads, roofs, sidewalks, driveways, parking lots, sport courts) that drain to streams

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 2. Conceptual Model for the Impacts of Urbanization on Stream Health.



Legend

- Lake Washington
- Bellevue City Limit
- Other Jurisdictions
- Stream
- Highway
- Coal
- Kelsey
- Lake Sammamish Tributaries
- Lake Washington Tributaries

*Note all data from City of Bellevue 2020

Figure 3.
City of Bellevue Watersheds Vicinity Map.

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0 3,500 7,000 14,000 Feet

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HERRERA

King County Aerial (2019)

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2. Existing Conditions

This section documents existing conditions in the Small Lake Washington Tributaries 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 Small Lake Washington Tributaries 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 through 6 show surface water features for the Lakehurst Area, the Meydenbauer Creek Subbasin (including the Beaux Arts Area and Clyde Beach Area), and the Yarrow Creek Subbasin (including the Point Cities Area).

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.

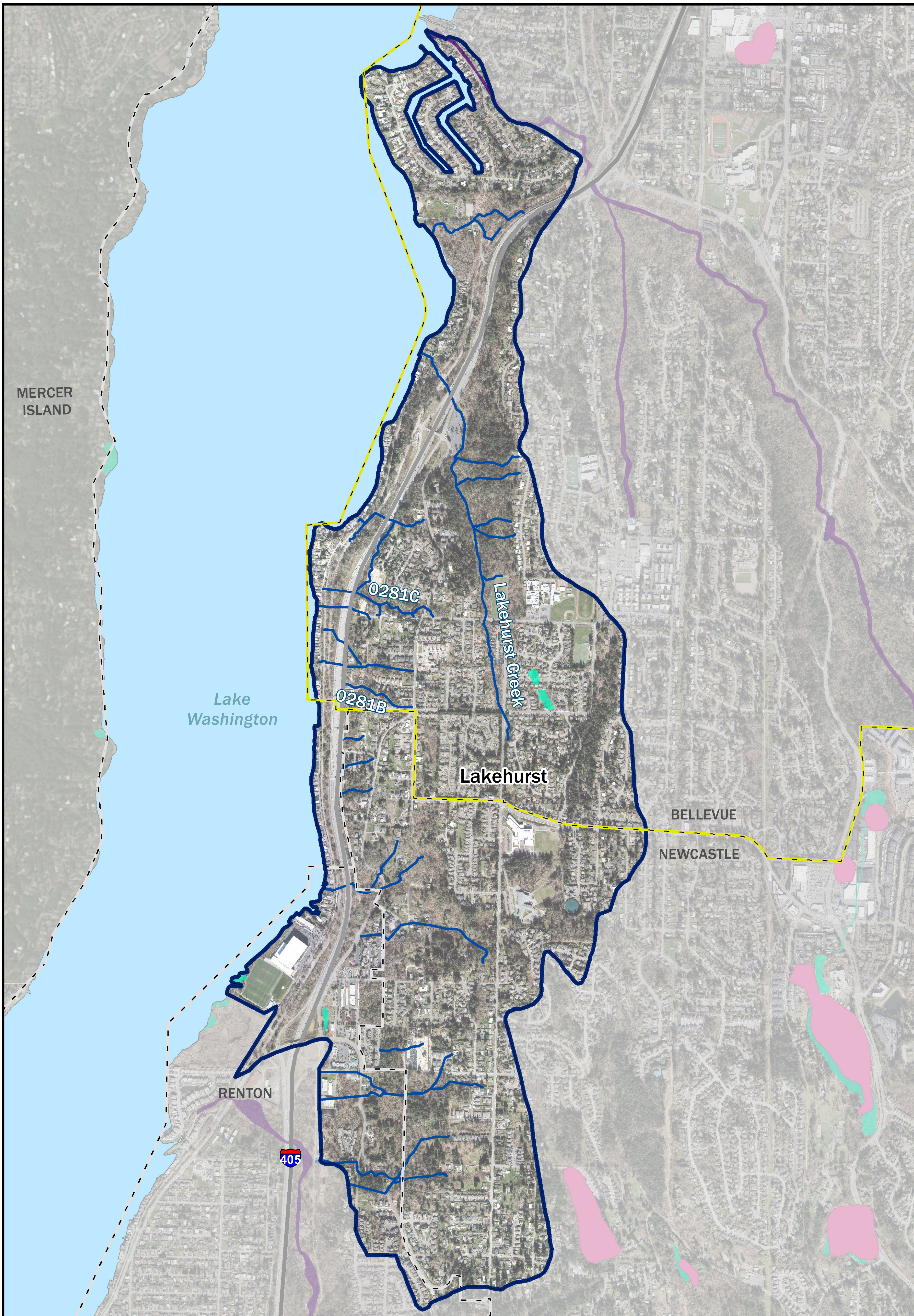
Existing climatic conditions in the Small Lake Washington Tributaries Watershed are characterized by cool, dry summers and mild, wet winters that are typical of maritime regions (Tetra Tech/KCM *et al*. 2006). Seasonal and spatial precipitation patterns within the watershed were analyzed based on data collected from two rain gauges in the watershed that are maintained by the City of Bellevue, with the associated data accessed via the King County Hydrologic Information Center (HIC):

- COB_RG05 – City of Bellevue Meydenbauer Rain Gauge (located in the Beaux Arts Area) – approximate elevation 225 ft NAVD88
- COB_RG04 – City of Bellevue Yarrow Creek Subbasin Rain Gauge – approximate elevation 146 ft NAVD88

The COB_RG05 rain gauge is located just outside of the Meydenbauer Creek Subbasin in the Beaux Arts Area, southwest of Meydenbauer Bay and northeast of Chism Beach Park (Figure 5). The COB_RG05 rain gauge has an approximate elevation of 225 feet. The COB_RG04 rain gauge is located near the intersection of I-405 and SR 520. COB_RG04 has an approximate elevation of 146 feet and is located in the middle of the Yarrow Creek Subbasin (Figure 6).

Data for the aforementioned rain gauges were analyzed based on their availability. COB_RG04 and COB_RG05 were analyzed for the period spanning from January 1, 2015 to December 31, 2019. For this time period, the average annual precipitation for COB_RG04 was 41.7 inches and the average annual precipitation for COB_RG05 was 39.7 inches, respectively. On average, the watershed received the most precipitation during the months of November and December. As shown in Figure 7, COB_RG04 and COB_RG05 measured similar amounts of precipitation over that period. These data suggest that the entire Small Lake Washington Tributaries Watershed receives spatially consistent rainfall on a monthly basis.

While limited data from the gauges identified above makes it difficult to infer any long-term trends, 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 (Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Highway (City of Bellevue 2020)
- Stream (City of Bellevue 2020)
- FEMA 100 Year Floodplain (King County 2020)
- King County Sensitive Area Ordinance Wetlands (2020)
- NWI Wetlands (2020)

Note: Federal Emergency Management Area (FEMA), National Wetland Inventory (NWI).

Figure 4. Lakehurst Area Surface Water Features and Monitoring Sites.

0 650 1,300 2,600 Feet

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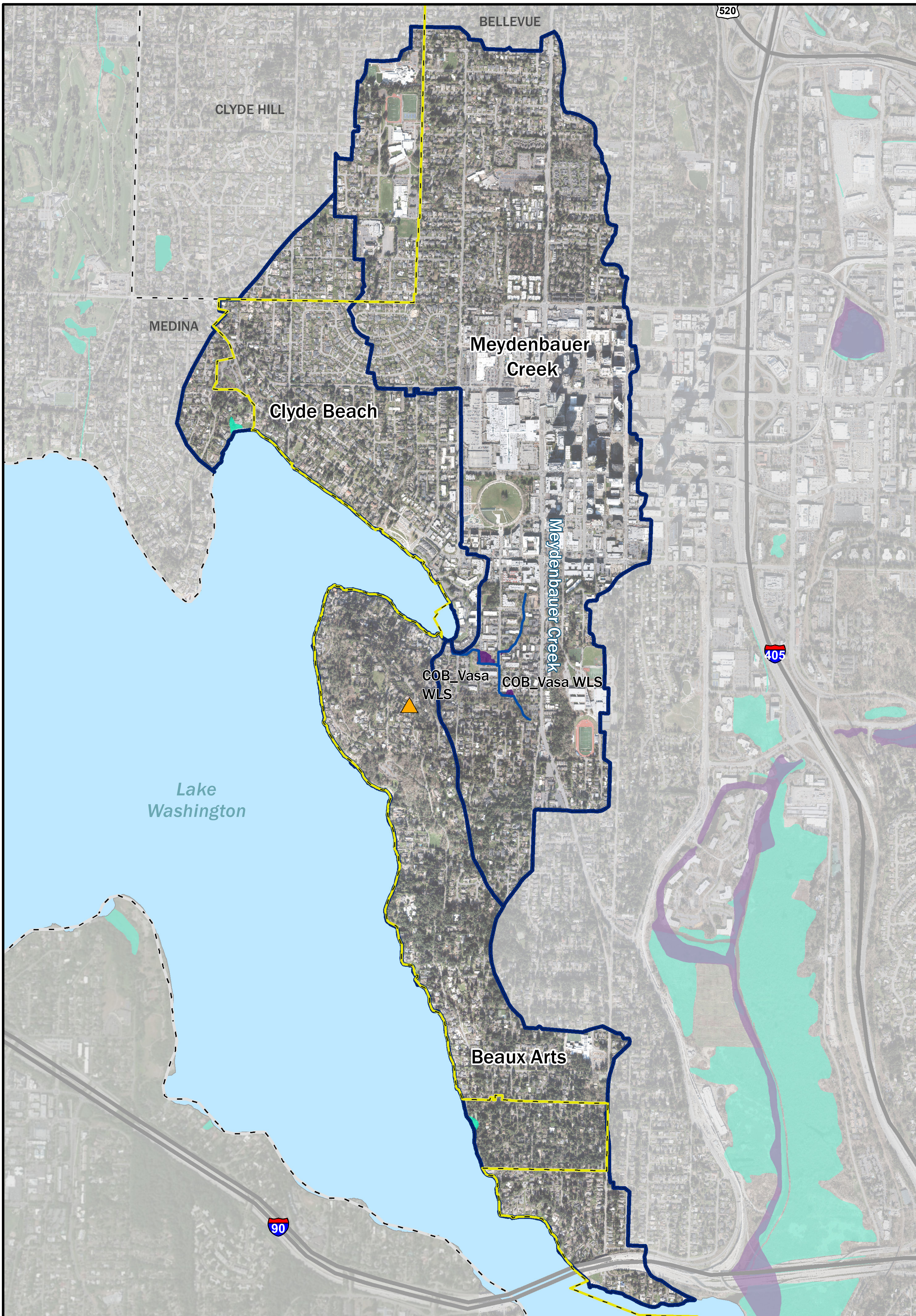

Legend

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

King County Monitoring (King County 2020)

- Precipitation Gauge, Active

Note: Federal Emergency Management Area (FEMA), National Wetland Inventory (NWI).

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

0 700 1,400 2,800 Feet

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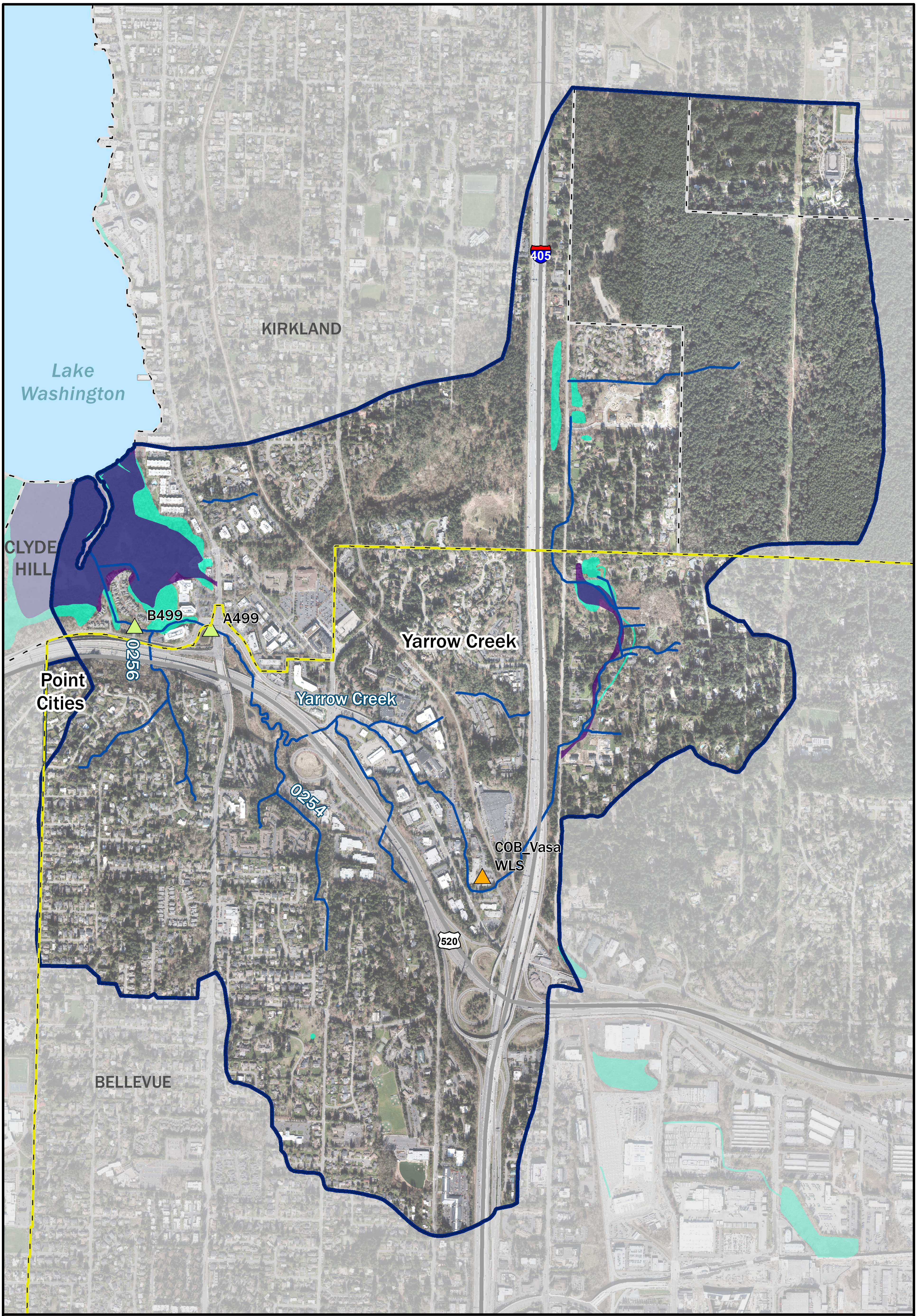

Legend

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

King County Monitoring (King County 2020)

- Precipitation Gauge, Active
- Water Quality Index (Recording), Active

Note: Federal Emergency Management Area (FEMA), National Wetland Inventory (NWI).

Figure 6. Yarrow Creek Subbasin Surface Water Features and Monitoring Sites.

0 500 1,000 2,000 Feet

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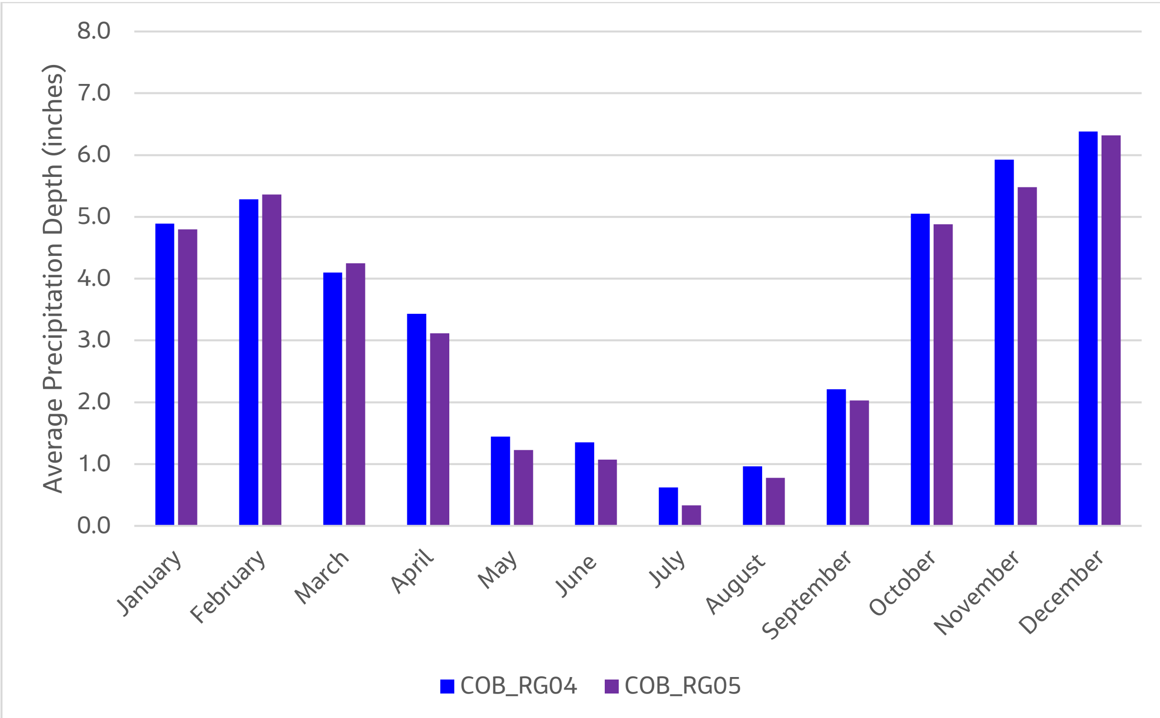


Figure 7. Precipitation Depth by Month in the Small Lake Washington Tributaries Watershed

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 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 Small Lake Washington Tributaries 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 Small Lake Washington Tributaries Watershed is primarily characterized by a combination of glacial (e.g., glacial till and glacial outwash) and post-glacial deposits (e.g., alluvium). Figures 8 through 10 show the geology of the Lakehurst Area, the Meydenbauer Creek Subbasin (including the Beaux Arts Area and Clyde Beach Area), and the Yarrow Creek Subbasin (including the Point Cities Area). Table 1 provides a summary of the percentages of the mapped surface geologic types by subbasin as well as for the entire Small Lake Washington Tributaries Watershed (USGS 2016).

The surface geology of the Small Lake Washington Tributaries Watershed (Figures 8 through 10) consists primarily of glacial till in the upslope areas and a combination of outwash and alluvium underlying the lower drainage areas and valleys. There is a significant area of artificial till in the central Meydenbauer

Creek Subbasin and a small bedrock outcrop in the mid-eastern portion of the of the Lakehurst Area Subbasin.

The valleys that contain the streams and drainage courses were 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 formed within and deposited above the glacial geologic layers influence the feasibility of using infiltration-focused stormwater management BMPs in the Small Lake Washington Tributaries Watershed. Table 2 provides a summary of the percentages of different soil types within individual subbasins and areas as well as the entire City of Bellevue Small Lake Washington Tributaries Watershed. Figures 11 through 13 show the soils of the Lakehurst Area, the Meydenbauer Creek Subbasin (including the Clyde Beach Area and Beaux Arts Area), and the Yarrow Creek Subbasin (including the Point Cities Area) (Bellevue 2020).

Alderwood and Arent (Alderwood material) soils are the predominant soil types found in the Small Lake Washington Tributaries Watershed, each covering approximately 40 percent of the watershed. Of the remaining Small Lake Washington Tributaries Watershed area, 7 percent of the area is covered by Everett gravelly sandy loam soils, 7 percent of the area is covered by Kitsap silt loam, 4 percent is underlain by unclassified/ unidentified soils, and 2 percent is covered by Norma sandy loam.

Alderwood soils belong to hydrologic soil group B and consist of moderately deep, moderately well-drained gravelly sandy loams that have formed above either a very slowly permeable layer of consolidated glacial till or glacial outwash that is underlain by dense glaciomarine deposits. Alderwood soils are found in the glaciated foothills of Western Washington with rolling to very steep slopes (Snyder *et al.* 1973) and comprise the predominant soil type in the Yarrow Creek Subbasin and the Lakehurst Area. Although most Alderwood soils in the watershed have formed on slopes that are mapped as between 8 and 15 percent, Alderwood soils can be erosive and have severe erosion potential for slopes greater than 15 percent.

Arent soils (Alderwood material) consist of soils that have been disturbed through urbanization (e.g., compaction, grading) that they are no longer classified as Alderwood (Snyder *et al*. 1973). The Arent (Alderwood material) soils belong to hydrologic soil group B/D and which have moderate infiltration potential in the drained condition, but only very slow infiltration potential in the high water table or undrained conditions. 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.

Everett gravelly sandy loam soils belong to hydrologic soil group A and have a high infiltration potential. Kitsap silt loam soils belong to hydrologic soil group C and have a low infiltration potential. Norma sandy loam soils belong to hydrologic soil group A/D and generally have a high infiltration potential in a drained condition and a low infiltration potential in areas where groundwater levels are high.

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 soil 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)

The heavily compacted glacial till geology underlying the majority of the Small Lake Washington Tributaries Watershed is a deposit that is generally more resistant to change. This consistency 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 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, 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 can also limit the effectiveness of infiltration-focused stormwater management techniques in the watershed. However, this is not uniformly the case in the Small Lake Washington Tributaries Watershed as there are large areas with moderate to high capacity for infiltration as shown by the extents of hydrologic soil groups A and B on Figures 11 through 13.

The Lakehurst Area is primarily underlain by hydrologic soil group B and B/D soils, with some patches of hydrologic soil group A soils near upper Lakehurst Creek and the tributaries that drain directly to Lake Washington. Thus, the majority of the Lakehurst Area has moderate to high relative infiltration potential. Although as mentioned above, infiltration to hydrologic soil group B soils steeper than 15 percent should be avoided. See Figure 11 for a representation of the hydrologic soil group of the soils within the Lakehurst Area.

The Meydenbauer Creek Subbasin is primarily underlain by hydrologic soil group B/D and B soils, with some patches of hydrologic soil group A and A/D soils. Thus, the majority of the Meydenbauer Creek Subbasin has moderate to high relative infiltration potential. See Figure 12 for a representation of the hydrologic soil group of the soils within the Meydenbauer Creek Subbasin.

The Yarrow Creek Subbasin is primarily underlain by hydrologic soil group B and B/D soils, with a large patch of hydrologic soil group A soils and smaller areas of hydrologic soil group A, A/D, and C soils. Thus, the majority of the Yarrow Creek Subbasin has moderate to high relative infiltration potential. Although as mentioned above, infiltration to hydrologic soil group B soils steeper than 15 percent should be avoided. See Figure 13 for a representation of the hydrologic soil group of the soils within the Yarrow Creek Subbasin.

Table 1. Surface Geology in the City of Bellevue Portion of the Small Lake Washington Tributaries Watershed

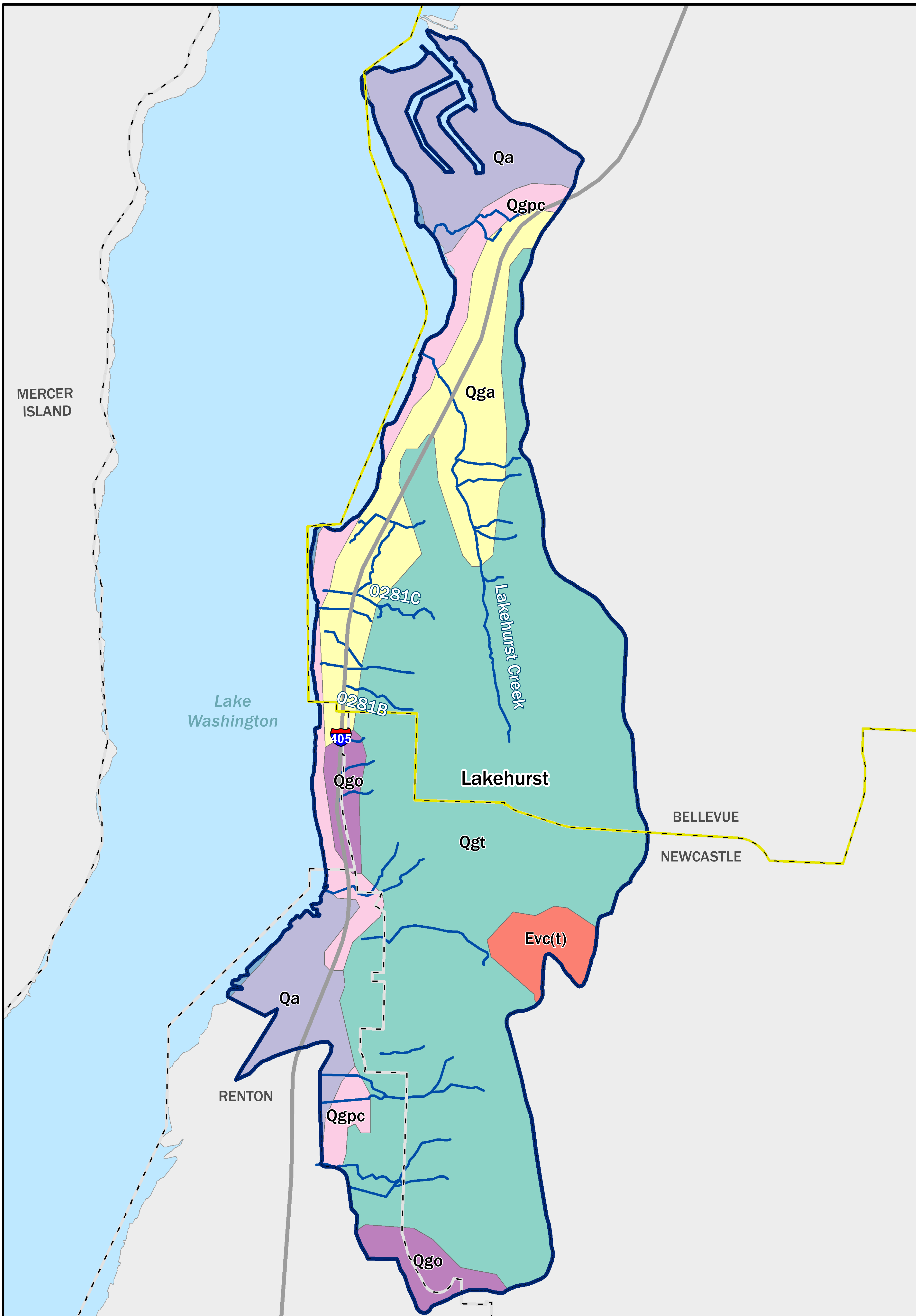
Subbasin/Area	Geologic Map Unit	Geologic Unit Age	Geologic Type	Geologic Description	Area (Acres)	Subbasin Area (Acres)	Percent of Subbasin (%)	Percent of the Small Lake Washington Tributaries Watershed (%)
Beaux Arts Area	Qa	Holocene	alluvium	Quaternary alluvium	1	372	-	-
Clyde Beach Area	Qa	Holocene	alluvium	Quaternary alluvium	2	233	1%	-
Lakehurst Area	Qa	Holocene	alluvium	Quaternary alluvium	101	651	15%	3%
Meydenbauer Creek	Qa	Holocene	alluvium	Quaternary alluvium	15	801	2%	-
Point Cities Area	Qa	Holocene	alluvium	Quaternary alluvium	2	9	26%	-
Yarrow Creek	Qa	Holocene	alluvium	Quaternary alluvium	28	918	3%	1%
Meydenbauer Creek	Qf	Holocene	artificial fill, including modified land	Holocene artificial fill and modified land	116	801	14%	4%
Beaux Arts Area	Qga	Pleistocene	advance continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	128	372	34%	4%
Lakehurst Area	Qga	Pleistocene	advance continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	157	651	24%	5%
Meydenbauer Creek	Qga	Pleistocene	advance continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	69	801	9%	2%
Yarrow Creek	Qga	Pleistocene	advance continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	171	918	19%	6%
Yarrow Creek	Qga(t)	Pleistocene	advance continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	2	918	-	-
Beaux Arts Area	Qgo	Pleistocene	continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	8	372	2%	-
Meydenbauer Creek	Qgo	Pleistocene	continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	31	801	4%	1%
Yarrow Creek	Qgo	Pleistocene	continental glacial outwash, Fraser-age	Pleistocene continental glacial drift	167	918	18%	6%
Clyde Beach Area	Qgpc	Pleistocene	continental glacial drift, pre-Fraser, and nonglacial deposits	Pleistocene glacial and nonglacial deposits	1	233	-	-
Lakehurst Area	Qgpc	Pleistocene	continental glacial drift, pre-Fraser, and nonglacial deposits	Pleistocene glacial and nonglacial deposits	46	651	7%	2%
Beaux Arts Area	Qgt	Pleistocene	continental glacial till, Fraser-age	Pleistocene continental glacial till	230	372	62%	8%
Clyde Beach Area	Qgt	Pleistocene	continental glacial till, Fraser-age	Pleistocene continental glacial till	229	233	98%	8%
Lakehurst Area	Qgpc	Pleistocene	continental glacial drift, pre-Fraser, and nonglacial deposits	Pleistocene glacial and nonglacial deposits	345	651	53%	12%
Meydenbauer Creek	Qgt	Pleistocene	continental glacial till, Fraser-age	Pleistocene continental glacial till	570	801	71%	19%
Point Cities Area	Qgt	Pleistocene	continental glacial till, Fraser-age	Pleistocene continental glacial till	7	9	74%	-
Yarrow Creek	Qgt	Pleistocene	continental glacial till, Fraser-age	Pleistocene continental glacial till	550	918	60%	18%
Beaux Arts Area	wtr	Holocene	water	Water	5	372	1%	-
Clyde Beach Area	wtr	Holocene	water	Water	0	233	-	-
Lakehurst Area	wtr	Holocene	water	Water	2	370	1%	-

SOURCE: 100k USGS Washington Division of Geology and Earth Resources, 2016, Surface geology, 1:100,000--GIS data (USGS 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 City of Bellevue Portion of the Small Lake Washington Tributaries Watershed

Hydrologic Soil Group	Soil Classification	Relative Infiltration Potential	Soil Notation	Lakehurst Area	Meydenbauer Creek Subbasin	Beaux Arts Area	Clyde Beach Area	Yarrow Creek Subbasin	Point Cities Area	Small Lake Washington Tributaries Watershed
A	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 Pilchuck loamy fine sand Ragnar-Indianola association, sloping	High	EvB EvC EvD InC PC RdE	9%	1%	-	-	14%	-	7%
A/D	Norma sandy loam	High (drained condition); Very low (undrained/high water table condition)	No	-	6%	-	-	3%	-	2%
B	Alderwood and Kitsap soils, very steep Alderwood gravelly sandy loam, 8 to 15 percent slopes Alderwood gravelly sandy loam, 15 to 30 percent slopes Everett-Alderwood gravelly sandy loams, 6 to 15 percent slopes	Moderate	AkF AgC AgD EwC	64%	14%	55%	7%	48%	-	40%
B/D	Arents, Alderwood material, 6 to 15 percent slopes Briscott silt loam Seattle muck	Moderate (drained condition); Very slow (undrained/high water table condition)	AmC Br Sk	14%	79%	-	92%	27%	72%	40%
C	Kitsap silt loam, 2 to 8 percent slopes Kitsap silt loam, 15 to 30 percent slopes	Slow	KpB KpD	2%	-	44%	-	2%	28%	7%
Hydrologic Soil Group Not identified	Pits Urban land	NA	Pits Ur	10%	-	-	-	6%	-	4%
Unclassified				1%	-	-	-	-	-	-
Areas (acres)	N/A	N/A	N/A	651.0	800.6	372.4	232.7	917.8	9.1	2983.6

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



Legend

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

USGS Geology 100k (2020)

- Qa, Quaternary, Alluvium
- Qgt, Continental glacial till Fraser-age, Pleistocene
- Qga, Pleistocene, Advance continental glacial outwash
- Qgo, Pleistocene, Continental glacial outwash,Fraser-age
- Qgpc, Pleistocene, Continental glacial drift pre-Fraser, and nonglacial deposits,
- Evc(t), Volcaniclastic deposits or rocks, Eocene
- Wtr, Present, Water,

Note: United States Geological Survey (USGS).

Figure 8.
Lakehurst Area Geology.

0 650 1,300 2,600 Feet

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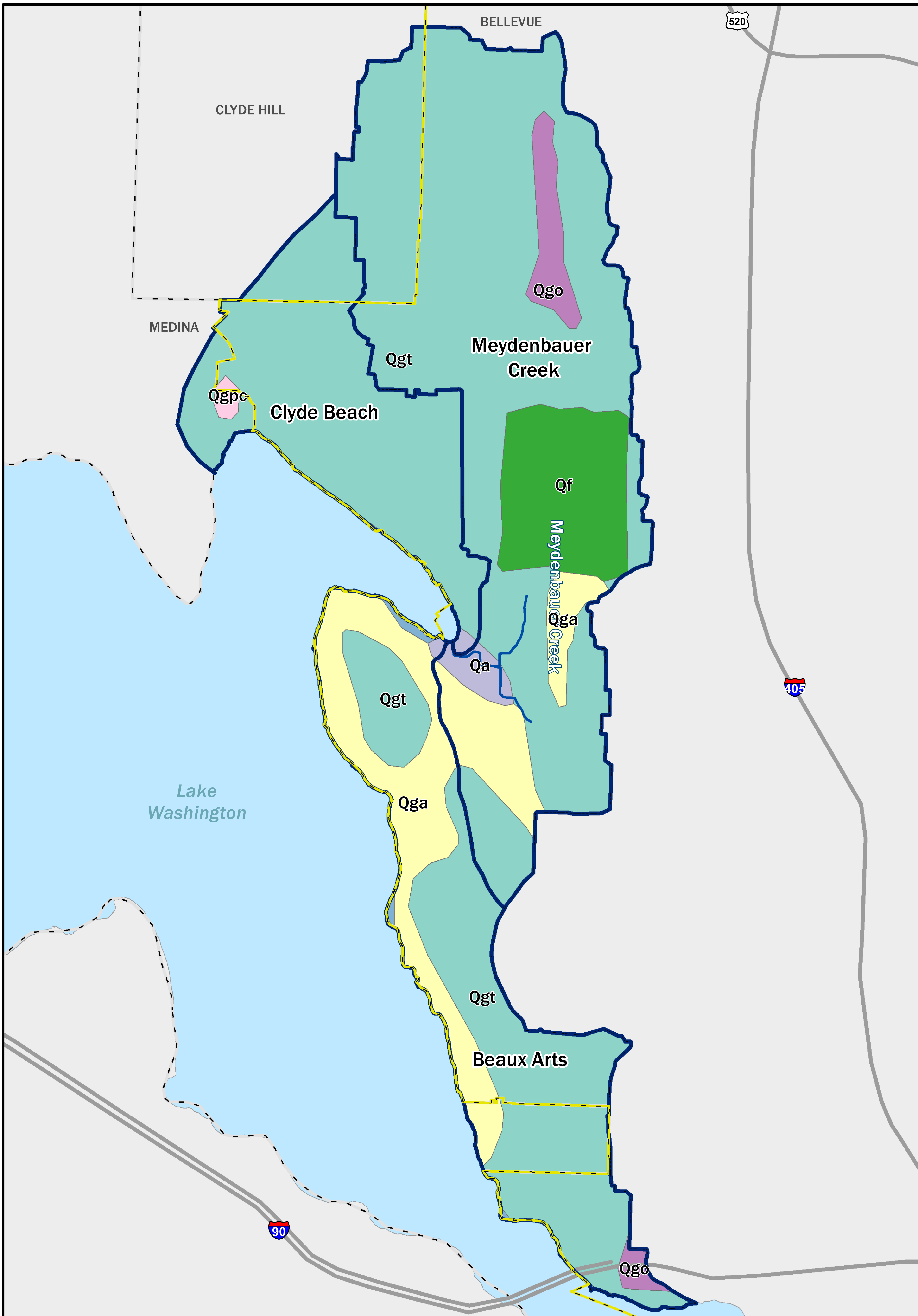

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Subbasin (City of Bellevue 2020)	
Bellevue City Limit (Bellevue 2020)	
Other Jurisdictions (King County 2020)	
Stream (City of Bellevue 2020)	
Highway (City of Bellevue 2020)	

USGS Geology 100k (2020)

- Qf:artificial fill, including modified land:Holocene
- Qa, Quaternary, Alluvium
- Qgt, Continental glacial till Fraser-age, Pleistocene
- Qga, Pleistocene, Advance continental glacial outwash
- Qgo, Pleistocene, Continental glacial outwash,Fraser-age
- Qgpc, Pleistocene, Continental glacial drift pre-Fraser, and nonglacial deposits,
- Wtr, Present, Water,

Note: United States Geological Survey (USGS).

Figure 9. Meydenbauer Creek Subbasin, Beaux Arts Area, and Clyde Beach Area Geology.

0 700 1,400 2,800 Feet

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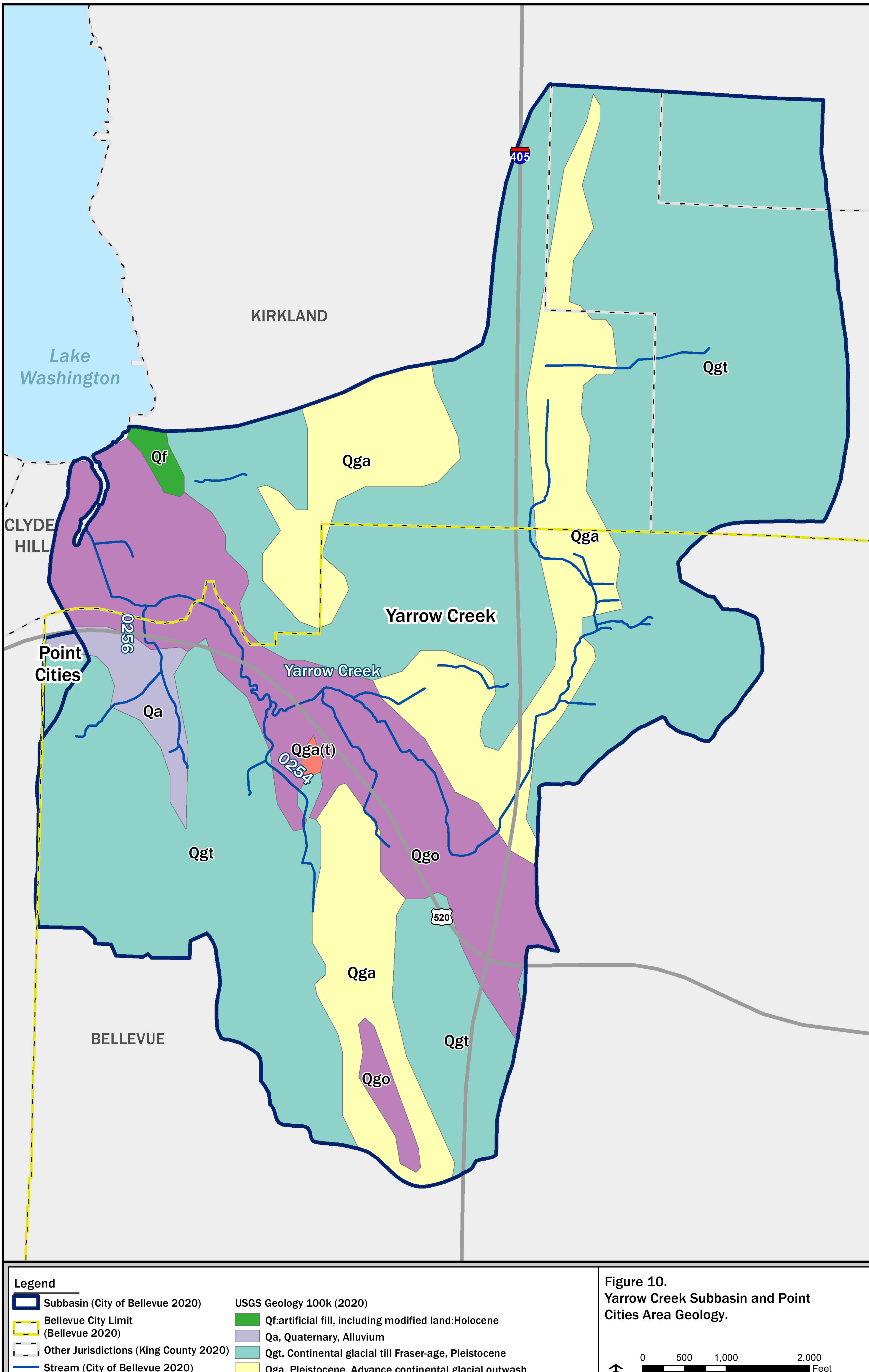

Legend

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

USGS Geology 100k (2020)

- Qf:artificial fill, including modified land:Holocene
- Qa, Quaternary, Alluvium
- Qgt, Continental glacial till Fraser-age, Pleistocene
- Qga, Pleistocene, Advance continental glacial outwash
- Qga(t):advance continental glacial outwash, Fraser-age:Pleistocene
- Qgo, Pleistocene, Continental glacial outwash,Fraser-age

Note: United States Geological Survey (USGS).

Figure 10.
Yarrow Creek Subbasin and Point Cities Area Geology.

0 500 1,000 2,000 Feet

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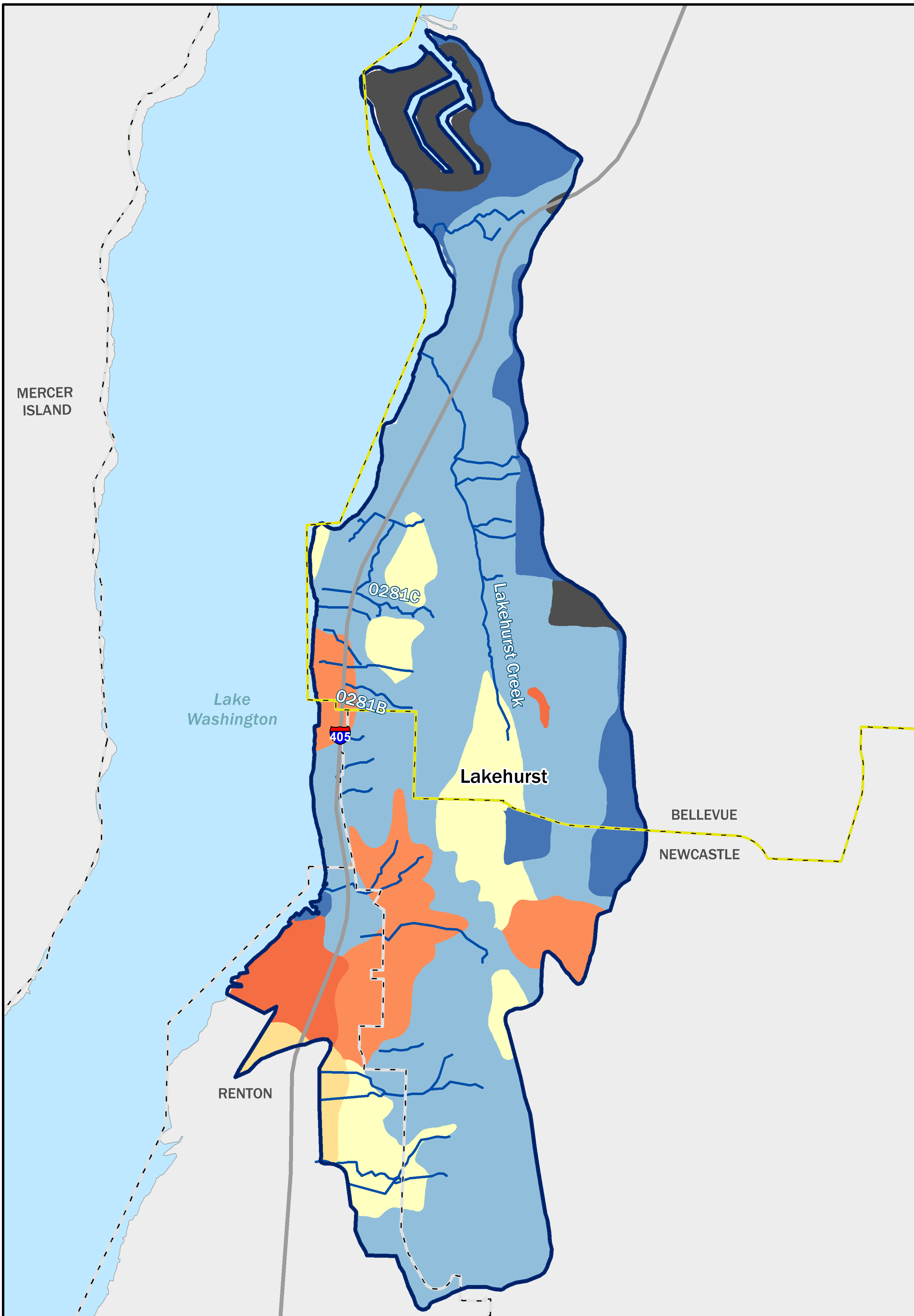

Legend

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

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 11. Lakehurst Area Soils.

0 650 1,300 2,600 Feet

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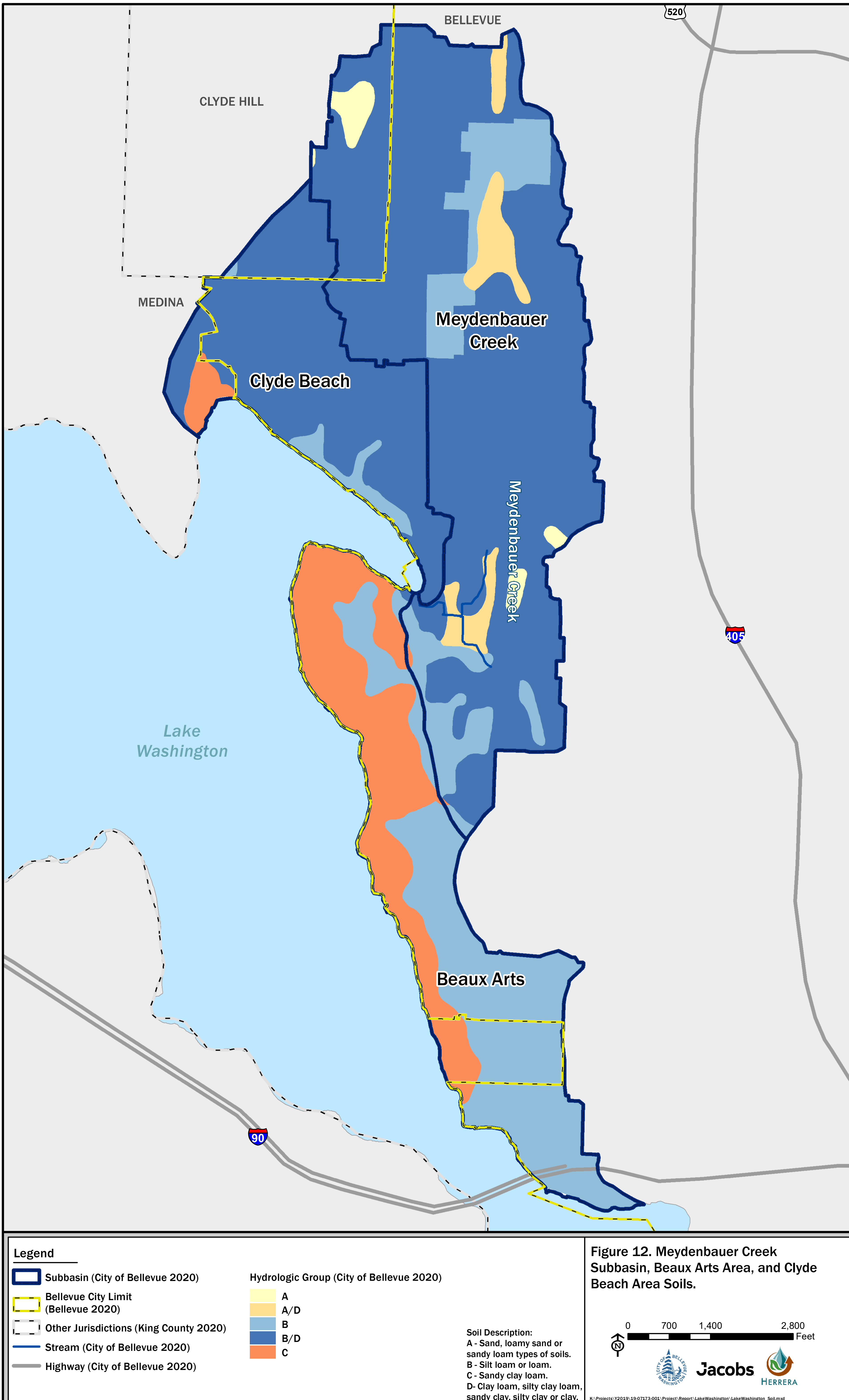

Figure 12. Meydenbauer Creek Subbasin, Beaux Arts Area, and Clyde Beach Area Soils.

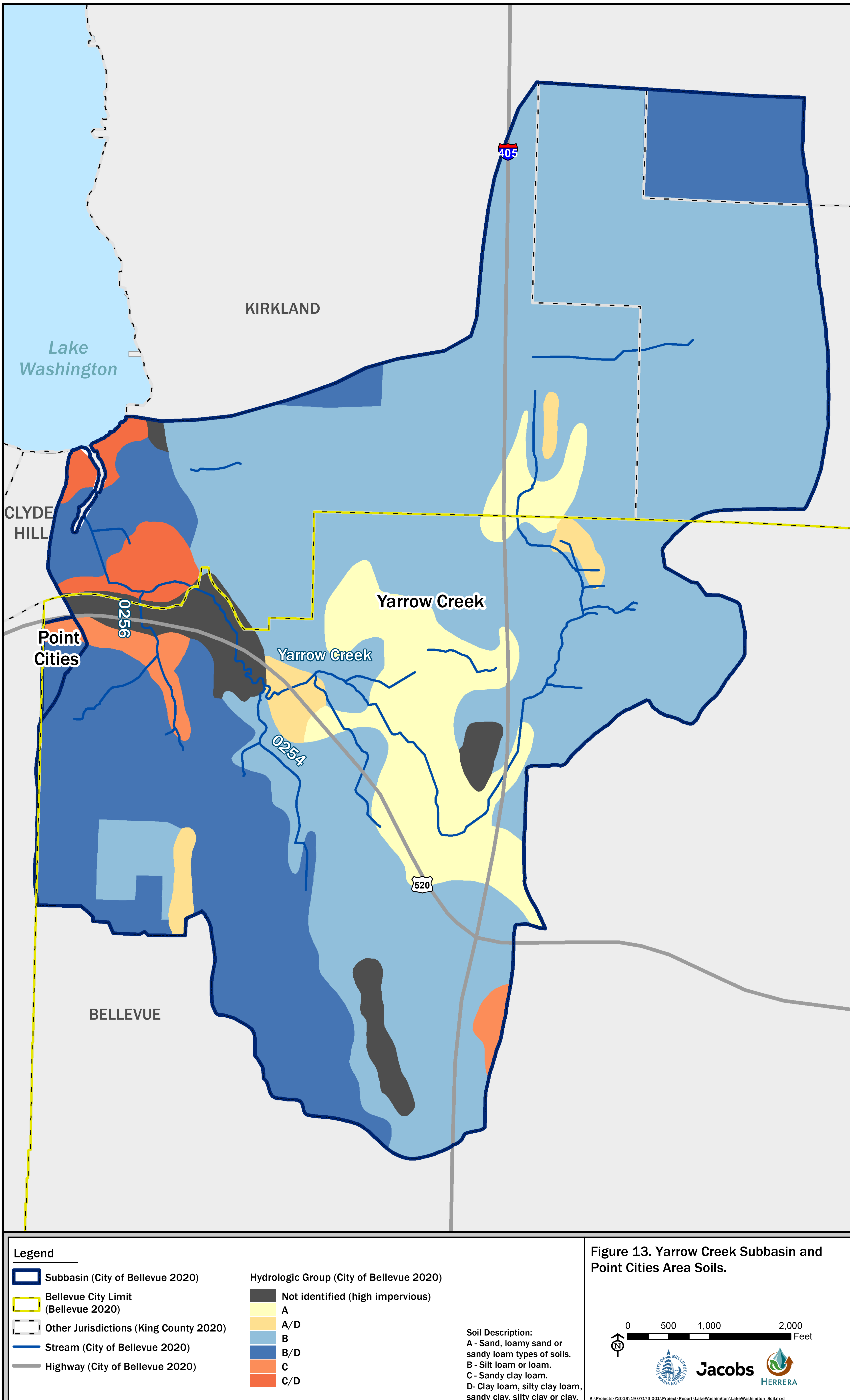

Figure 13. Yarrow Creek Subbasin and Point Cities Area Soils.

2.1.3 Topography and Geomorphology

The topography of the Small Lake Washington Tributaries Watershed is shown in Figure 14. The various subbasins are generally small but relatively steep, where the Yarrow Creek Subbasin elevations range from 15 to 537 feet (NAVD88), the Meydenbauer Creek Subbasin elevations range from 18 to 392 feet, and the Lakehurst Basin elevations range from 17 to 569 feet. The average channel gradients in these basins are also 3.2 percent, 2.3 percent, and 4.6 percent, respectively. This topographic relief provides the subbasins with a significant potential for generating and transporting sediment to downstream reaches. If downstream reaches were unaltered and unconfined, with connected floodplains, alluvial fans, and deltas, they would have the capacity for storing sediment, accommodating geomorphic change, and attenuating pollutants. However, when development and related hydrologic and geomorphic changes inhibit this capacity and restrict floodplain functions, channels are prone to losing their dynamic equilibrium and instead develop reach-scale trends of chronic vertical channel change (e.g., chronic aggradation or incision) or lateral bank instability (Booth 1990; Buffington and Montgomery 1999; Komura and Simmons 1967; Williams and Wolman 1984).

The existing geomorphic conditions within the Small Lake Washington Tributaries Watershed are a product of the topography, geology, and soil conditions, combined with the hydrologic changes and hydromodifications associated with land use and land cover change within the last century. The portion of streamflow conveyed as open channel versus storm drainage pipe is 11 percent for the Yarrow Creek Subbasin, 1 percent for the Meydenbauer Creek Subbasin, and 38 percent for the Lakehurst Area. Although the Yarrow Creek Subbasin does have some protected forested areas within Bridle Trails State Park, Watershed Park, and the Yarrow Bay Wetlands (all in the City of Kirkland), the Small Lake Washington Tributaries Watershed is highly urbanized, and includes some of the most altered areas within Bellevue, such as downtown Bellevue and significant portions of I-405 and SR 520. Development of the upper watershed has cut off access to coarse bedload sediment supply in many areas thus restricting the ability of the stream to restabilize and adjust to altered hydrology.

The geomorphic stream reaches in the Small Lake Washington Tributaries Watershed were defined during the citywide OSCA surveys (Bellevue 2021a), which were completed for the Yarrow Creek Subbasin, Meydenbauer Creek Subbasin, and Lakehurst Area. The specific morphologic reach types and channel types for each of these reaches are described further in Appendix B. In general, the channel morphology transitions from source to transport to response in the downstream direction. However, in the Small Lake Washington Tributaries Watershed, many of the reaches are so highly modified that the geomorphic functioning is forced. Further, a good portion of the drainage in the upper watershed, where source and transport morphologic reach types would be located, is instead piped. Therefore, the OSCA surveys assessed a greater portion of the lower gradient, response morphologic reach types.

The reach-scale geomorphic character of the Yarrow Creek Subbasin is highly variable and altered by local and subbasin scale urban development and land use. The average gradient for the surveyed reaches in the subbasin is 3.2 percent, which is about average for streams across the City of Bellevue. The stream generally has a plane-bed morphology with a wetland at its confluence with Lake Washington and a beaver-created wetland located just upstream of the SR 520 crossing. Sediment transport patterns are strongly influenced by flashy stream flows with the general pattern of streambank erosion in the upper portion of the subbasin and channel incision throughout the subbasin, resulting in sediment accumulation in the lower reaches. Issues with erosion in Yarrow Creek have been evident for decades. A 1971 study by the Bellevue Utilities Department highlighted Yarrow Creek as having moderate to severe erosion potential (as cited in Kerwin 2001). Sedimentation issues were observed around several culverts that were not sized to support geomorphic processes. Approximately 25 percent of the stream channel within the City of Bellevue is piped, which is higher than average for streams in the City of Bellevue.

The reach-scale morphology of Meydenbauer Creek is also severely altered. Approximately 37 percent of the stream channel is piped and the subbasin has the highest frequency of culverts observed in the City of Bellevue at 18.4 culverts per mile. The remaining open channel is generally low gradient and strongly influenced by stormwater discharge. Outfalls into the stream channel are numerous; the OSCA surveys documented an average of 16.1 outfalls per mile, which is much higher than average for streams across the City of Bellevue. Because the headwaters are now contained in the storm drainage network, channel incision and streambank erosion are the primary sources of sediment entering the stream. Overall, the stream gradient is 2.3 percent, which is slightly lower than average for streams in the City of Bellevue. When there are strong westerly winds in Meydenbauer Bay, water can be pushed upstream, influencing water depth and reversing streamflow for most of the surveyed stream length. The predominant channel type is plane-bed, although the lower portion of the stream could be considered dune-ripple or lacustrine.

Lakehurst Creek is one of the smaller creeks evaluated during the OSCA surveys, and it has three distinct areas that yield different geomorphic characteristics: a piped portion, a well-vegetated ravine, and a lower gradient residential area (Map B-5 and Table B-7 of Appendix B). Approximately 24 percent of the stream is piped. Aside from the small wetland area at the upstream end of the open stream channel, the channel type is predominantly plane-bed due to numerous weirs that control the grade in the ravine. Overall, the average stream gradient for the stream reach upstream of I-405 is 4.6 percent which is greater than that seen in the other tributaries in the Small Lake Washington Tributaries Watershed and slightly above average for streams across the City of Bellevue.

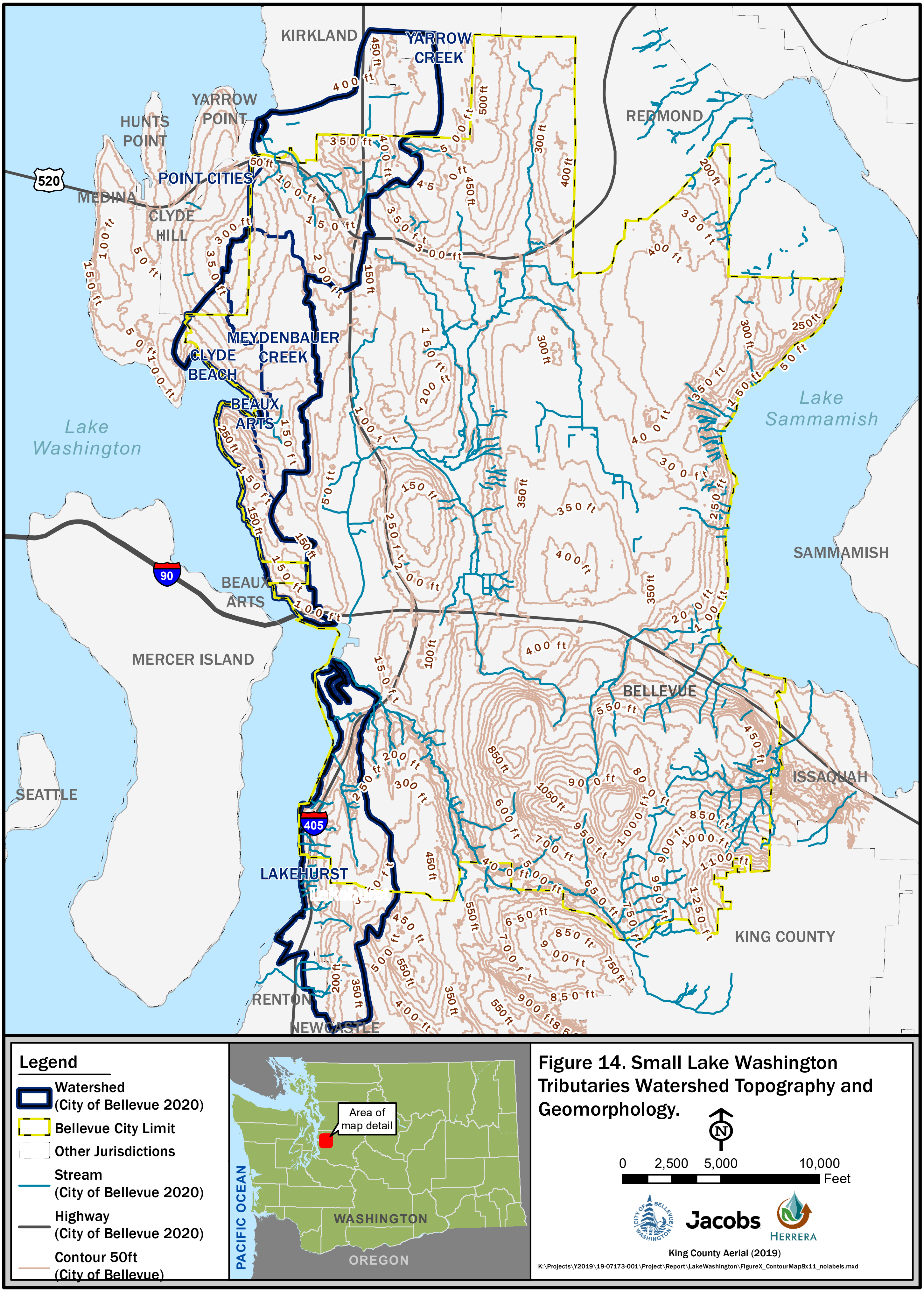

Figure 14. Small Lake Washington Tributaries Watershed Topography and Geomorphology.

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.

There are two major and three minor tributaries to Lake Washington in the City of Bellevue (Figure 3). The two major tributaries, the Greater Kelsey Creek Watershed and the Coal Creek Watershed, are each discussed independently in separate Watershed ARs. The Small Lake Washington Tributaries Watershed is comprised of the remaining drainage features and areas within the City of Bellevue that drain to Lake Washington, including Lakehurst Area, Meydenbauer Creek, Yarrow Creek, and associated tributaries. In addition to fluvial channels and tributaries, surface water features in Small Lake Washington Tributaries Watershed include floodplains and wetlands; however, much of the Small Lake Washington Tributaries Watershed is characterized by highly urbanized areas that do not support broad floodplains, pollute existing wetlands, and often limit the size and health of wetlands within the watershed.

As observed in other streams throughout the City of Bellevue, channel incision exacerbated by upland hydrologic changes coupled with streambank armoring and development that confine alluvial processes have separated the channels from their floodplains 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.

The Small Lake Washington Tributaries are described here, and detailed information from OSCA surveys of these creeks is available in Appendix B:

- Lakehurst Area's primary drainage feature is Lakehurst Creek. Lakehurst Creek consists of one channel; although several short tributaries have been mapped, none were included in the OSCA surveys. Overall, the subbasin has 6.8 miles of open channel, much of which are minor seasonal drainages, and 11.3 miles of storm drainage pipes within Bellevue city limits (Bellevue 2017). Lakehurst Creek is occasionally dry in the summer months during low precipitation years, with limited off-channel habitat opportunities due to the confined nature of the ravine and residential reaches.
- Lakehurst Area also has an unnamed fish-bearing channel that runs through Newcastle Beach Park with potential opportunities for public education and outreach. This drainage includes wetland and floodplain habitat that is otherwise lacking throughout the remaining Lakehurst Area.
- Meydenbauer Creek is predominantly piped and has a substantially urbanized stream corridor. The subbasin has only 0.4 miles of open channel and 31 miles of storm drainage pipes within City limits (Bellevue 2017). This is the highest proportion of storm drainage pipes relative to open channel of any subbasin in the City. Historical maps from 1950 indicate that the Meydenbauer Creek channel was open from its outlet all the way to NE 10th St (USGS 1950), but the current channel is very short, reduced by over approximately 67 percent of its historic length. There are two forks; the northern fork is considered the mainstem and carries the majority of base streamflow.
- Yarrow Creek Subbasin includes one mainstem channel (Yarrow Creek) with several significant tributaries, including Tributaries 0254 and 0256. Yarrow Creek headwaters are located in Bridle Trails State Park. The subbasin is characterized by predominantly residential and commercial development with water quality impacts from major roads (I-405, SR 520). Overall, the subbasin has 4.7 miles of open stream channel and 20.4 miles of storm drainage pipes within the City.

Figures 4-6 depict the mapped floodplains and wetlands present in the Small Lake Washington Tributaries Watershed. The widths of the alluvium and outwash deposits that underly the stream drainages and the topography of the lower lying areas adjacent to Lake Washington shown in Figures 4 through 6 suggest that the current floodplain widths have been severely reduced from what they were in natural, pre-development conditions. Figures 4-6 show wetlands that have been both delineated and mapped by the National Wetland Inventory (NWI, USFWS 2021) as well as King County (King County 2021a). In the Small Lake Washington Tributaries Watershed, there are 19 acres of wetlands, comprising 0.6 percent of the total watershed area (Table 3). The largest wetland areas are in the Yarrow Creek Subbasin:

- Yarrow Creek's outlet to Lake Washington has an extensive wetland area (Yarrow Bay Wetlands) located in the City of Kirkland. Although this area is outside the City of Bellevue, the unique lakeshore habitat is critically important to the Yarrow Creek Subbasin and to Lake Washington.
- At the Yarrow Creek confluence with Tributary 0254, there is a beaver-impounded wetland and extensive ponding in the Washington Department of Transportation (WSDOT) restoration area south of SR 520. See Section 2.1.6.1 for discussion of beavers.
- Wetlands are mapped along upper reaches of the stream where it crosses from the City of Bellevue back into Kirkland, and further north in the WSDOT right-of-way to the east of I-405, where there is a stretch of denser canopy. These smaller, unnamed wetland areas were not accessible for detailed survey and are currently privately owned, but there may be opportunities for property acquisition in the future. A culvert may be influencing altered hydrology in this area and will be further discussed as an opportunity later in this AR.

There are also notable shoreline associated wetland areas in other subbasins. These unmapped wetlands are not shown in Figure 4 or Figure 5, but were identified in the City's Shoreline Master Program update (Bellevue 2018a):

- At Newcastle Beach Park in the Lakehurst Area, a slow-moving portion of the low-gradient stream channel forms a wetland in the transitional area between the stream and Lake Washington. Flows may not be sufficient through the wetland and water temperatures may be too warm to attract fish from the lake; however, crayfish have been observed in the stream (Bellevue 2010).
- At Meydenbauer Bay Park in the Clyde Beach Area, a cluster of small slope wetlands was removed and mitigated for in the nearby restored stream drainage with lakeshore wetland enhancements, creating a ponded wetland that is not currently shown on Figure 5.

Table 3. Wetlands in the City of Bellevue Portion of the Small Lake Washington Tributaries Watershed by Subbasin / Area

Subbasin/Area	Wetland Area (acres)	NWI Wetlands AND Sensitive Area Ordinance King County Wetlands 2016 – percent
Lakehurst Area	5.3	0.80%
Meydenbauer Creek	-	-
Beaux Arts Area	-	-
Clyde Beach Area	0.7	0.30%
Yarrow Creek	12.7	1.40%
Point Cities Area	-	-

The Meydenbauer Creek Subbasin has no mapped wetlands. Floodplain areas are mapped along the lower reaches of Meydenbauer Creek, where there is substantial influence from lake levels in Meydenbauer Bay.

Flow patterns can also be influenced by strong winds that appear, per visual observations, to reverse stream flow up the channel for most of the surveyed stream length. This unique interaction with Lake Washington has a substantial influence on the lower reaches of Meydenbauer Creek and may contribute to capacity issues present in the system. It should be noted that there is one portion of lower Meydenbauer Creek that has a connected floodplain and intact riparian corridor between 101st and 102nd Ave. SE.

2.1.5 Groundwater

In areas that have not been disturbed by urbanization, very little precipitation contributes to direct surface flow. 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. Rainfall that does not flow laterally through the soils can slowly penetrate to deeper groundwater aquifers before eventually discharging at surface openings into the stream channel. Limited groundwater information is available for the Small Lake Washington Tributaries Watershed. An assessment of groundwater resources will be included, where necessary, to inform the siting and design of any infiltration facilities proposed as part of the Watershed Management Plan.

2.1.6 Wildlife and Human Interaction within the Small Lake Washington Tributaries Watershed

2.1.6.1 Beaver Activity

Several streams in the Small Lake Washington Tributaries 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 also restore and enhance habitat with substantial 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 result in cooler stream temperatures.

Beaver activity is substantial in the Yarrow Creek Subbasin. Extensive wetlands are present in Yarrow Bay at the stream mouth in Kirkland, which provides attractive habitat for beavers. After WSDOT completed a restoration project in 2014 at the SR 520 interchange, beaver activity increased and has moved upstream farther into the subbasin. Beaver dams have caused culvert blockages at several locations, including 108th Street (maintained by the City of Bellevue) and SR 520 (maintained by WSDOT), with extensive beaver-impounded ponding now present on the south side of SR 520. These are ongoing Beaver Management Areas and are being addressed under City of Bellevue Utilities Beaver Management actions.

In the Meydenbauer Creek Subbasin, beavers are active near the stream mouth and lower stream reaches,. An exclusion fence and beaver deceiver were installed at both ends of a long city-owned culvert under 101st Avenue SE to deter beaver activity, but this area (currently a beaver management site) presents an ongoing challenge for maintenance due to accessibility and safety concerns. This may be an opportunity for improvements to stream function. Concern over bank stabilization, sedimentation, and capacity issues at the downstream end of this culvert are amplified by known beaver and nutria activity.

Nutria is an invasive species and listed as a Prohibited (WDFW 2021a) and High Priority (WISC 2021) invasive mammal. They exhibit extensive tunneling behavior that is not characteristic of beavers and can threaten bank stabilization and increase sediment loading to the stream, reducing system capacity and increasing the need for maintenance activities such as dredging. Nutria are herbivores and feed primarily on wetland vegetation, targeting the base of plant stems and digging for roots and rhizomes in the winter. Their feeding activity destroys marsh and wetland vegetation, transforming marsh areas into open water and displacing native species. Nutria also hosts infectious diseases that affect humans, livestock, and wildlife.

Because of all the potential benefits and negative impacts of beaver activity depending on the associated location, the City should develop a Beaver Management Plan that would work in concert with the City of Bellevue's Beaver Maintenance Manual (currently being revised). This Beaver Management Plan should identify locations to attract beaver activity to maximize habitat benefits and identify locations to discourage beaver activity.

2.1.6.2 Human Interaction within the Small Lake Washington Tributaries Watershed

Like many communities in King County, the City is experiencing a large growth in population that contributes to environmental stressors. As the City becomes more urban, it is important to recognize the impact of human activity on the City of Bellevue's portion of the Small Lake Washington Tributaries 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. . As the City's population grows, resulting in greater stream and riparian area use by people, the greater the likelihood that human contaminants will enter the City of Bellevue's surface waters.

Creeks and tributaries in the Small Lake Washington Tributaries Watershed flow through residential and impervious areas, which are a potential source of pet waste and introduce other negative water quality impacts from nearby upland areas, including landscaping activities. Clearing of riparian vegetation reduces stream shading and beneficial filtration processes, while application of fertilizer or pesticides introduces pollutants to the stream.

Other notable impacts specific to Yarrow Creek Subbasin include illicit discharges and unauthorized encampments that have degraded the riparian corridor in portions of the mainstem and both tributaries by damaging vegetation and causing localized streambank erosion. Litter and human waste pose additional water quality concerns. Specific areas of concern include:

- Along Tributary 0256, unauthorized encampments were observed in riparian areas during OSCA surveys, and the City of Bellevue has previously engaged in cleanup activities as needed in this area. Generally, human impacts from social trails and litter are present in both tributaries and mainstem Yarrow Creek.
- Tributary 0254 is confined where it flows between a hillside and a large parking lot with historic illicit discharge incidents (for example, a leaking dumpster). There are no active illicit discharges known at this time, but the stream is subject to untreated stormwater runoff from this parking lot.
- WSDOT owns a maintenance yard near the 108th Street culvert. This site was used historically for salt stockpiling; current conditions are unknown, but historic sampling in this area demonstrated substantial copper loading to Yarrow Creek.
- Failing septic systems are also a potential issue that can have a negative impact on stream water quality. Failing septic systems have been identified in the past as an issue in the Yarrow Creek Subbasin by inspection staff at the City of Kirkland. For properties developed in 1980 and earlier, septic systems may be approaching their lifespan for providing treatment. The cities of Bellevue and Kirkland are coordinating regarding mutual concern for water quality related to these systems.

Meydenbauer Creek is uniquely influenced by human interaction in the CBD, which is a high-density commercial area with a large number of food establishments clustered on Main Street. The City responds to numerous illicit discharge complaints and violations in this area, and food waste has been observed downstream in Meydenbauer Creek. Education and outreach are needed to assist staff and business owners with making informed choices for disposal of food waste, dishwashing waste, floor cleaning washwater, etc. An increasing number of dogs in the CBD also poses a water quality concern related to pet waste disposal.

There are also human recreational activities and opportunities within the Small Lake Washington Tributaries Watershed, which provide valuable community assets:

- Newcastle Beach Park at 4400 Lake Washington Boulevard Southeast is located in the Lakehurst Area and is the largest beach park in Bellevue with a nature trail, picnic area, play area, and other features that draw many families for recreational use. A small, unnamed fish-bearing channel flows through the park and offers potential rearing habitat for juvenile Chinook and Coho salmon, similar to juvenile salmon usage observed in recently restored Mapes Creek in Seattle. This area presents a potential opportunity for interactive public education and outreach.
- In 2019, the Bellevue Parks Department acquired the 3.5 acre “Brick Property” in the Lakehurst Area, where Lakehurst Creek flows in a vegetated ravine.
- Meydenbauer Creek Subbasin may influence the water quality at the nearby Meydenbauer Bay Park swimming area. The swimming area was closed in August 2021 due to high bacteria levels. The swimming area was also closed in September 2003, July 2004, and in the summer of 2007. High bacteria levels were also recorded in 2008, 2011, and 2015, but did not result in beach closures (King County 2021b). Water quality impacts may continue to inhibit full use of the beach in the future.
- Clyde Beach Park is another community asset located in the Clyde Beach Area. The park includes a swimming area, but is not included in King County’s Lake Swimming Beach Bacteria sampling program. The Bellevue Parks Department has also acquired additional property in the Clyde Beach Area (separate from Clyde Beach Park) for habitat restoration efforts, which is discussed later in this Watershed AR.

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 Small Lake Washington Tributaries Watershed is typical of urban watersheds with a lower percentage of tree canopy and higher percentage of impervious surface. Existing land cover in the Small Lake Washington Tributaries Watershed is predominantly impervious surfaces (43 percent), with 35 percent urban tree canopy, and 19 percent non-canopy vegetation (Bellevue 2013, 2017) (Table 4). Bare soil, scrub/shrub, and water surface together comprise less than 4 percent of total land cover. Notably, the Beaux Arts Area and Lakehurst Area have greater amounts of urban tree canopy land cover than impervious surface cover. Yarrow Creek Subbasin has approximately equal urban tree canopy (38 percent) and impervious surface cover (40 percent). Although the entire watershed is largely urbanized, Meydenbauer Creek and Clyde Beach Area have noticeably higher percentages of impervious area at 60 percent and 48 percent, respectively. These calculations are specific to the portion of the subbasin or area within the City of Bellevue.

Figures 15 through 17 show the land cover and tree canopy of the Lakehurst Area; the Meydenbauer Creek Subbasin, Beaux Arts Area and Clyde Beach Area; and the Yarrow Creek Subbasin and Point Cities Area, respectively.

Table 4. Land Cover in the City of Bellevue Portion of the Small Lake Washington Tributaries Watershed

Subbasin/Area	Bare Soil and Dry Vegetation (%)	Impervious (%)	Non-Canopy Vegetation (%)	Scrub/ Shrub (%)	Urban Tree Canopy (%)	Water (%)
Lakehurst Area	6%	33%	21%	-	40%	-
Meydenbauer Creek	-	60%	14%	-	25%	-
Beaux Arts Area	-	30%	22%	-	47%	-
Clyde Beach Area	-	48%	22%	1%	29%	-
Yarrow Creek	2%	40%	19%	1%	38%	-
Point Cities Area	1%	36%	31%	-	32%	-

As shown in Figures 18 through 20, the land use of the subbasins of the Small Lake Washington Tributaries Watershed reflects land cover. The predominant land use types include single family residential (67 percent), multi-family (10 percent), mixed-use (9 percent), commercial/office (6 percent), highway (4 percent), parks (3 percent), industrial/medical (1 percent) (Table 5). The areas with developed land use types (e.g., commercial, industrial, mixed use, and single family or multi-family residential) within the watershed include approximately 80 miles of streets (mostly local access streets); I-405 and SR 520 are significant major roads in the Small Lake Washington Tributaries Watershed and account for 4 percent of the Lakehurst Area and 9 percent of the Yarrow Creek Subbasin. Highways, streets, industrial, and commercial land use have higher pollutant loading compared to residential land usage and parks.

Park spaces in the Small Lake Washington Tributaries Watershed are mostly located outside the stream corridors and do not provide substantial tree cover for riparian benefit. The largest park in the watershed is Bridle Trails State Park at Yarrow Creek headwaters, located in the City of Kirkland. Bellevue park areas include lakeshore beaches such as Clyde Beach Park, Newcastle Beach Park, and Meydenbauer Bay. Publicly-owned land (including parks and land owned by the City of Bellevue's Utilities Department) represent site opportunities to invest 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 5. Land Use in the City of Bellevue Portion of the Small Lake Washington Tributaries Watershed

Subbasin/Area	Commercial/ Office (%)	Highway (%)	Industrial (%)	Mixed-use (%)	Multi-Family (%)	Park (%)	Single-family (%)	Total (acres)
Lakehurst Area	-	4%	-	-	4%	5%	87%	650
Meydenbauer Creek	0.7%	-	-	33.8%	14.3%	1.2%	49.9%	800
Beaux Arts Area	-	2.0%	-	-	0.4%	7.1%	90.5%	370
Clyde Beach Area	1.3%	-	-	2.4%	19.9%	2.7%	73.7%	231
Yarrow Creek	17.9%	8.7%	3.9%	-	11.2%	2.5%	55.8%	917
Point Cities Area	-	-	-	-	-	-	100.0%	9.0

Table 6 compares the change in canopy cover and impervious surfaces between 2006 and 2017 for the six subbasins and watershed areas within the Small Lake Washington Tributaries Watershed (HRCD 2021). The Yarrow Creek Subbasin experienced the largest tree canopy loss, while the Meydenbauer Creek

Subbasin experienced the largest impervious surface increase out of all the Small Lake Washington Tributaries Watershed subbasins and areas.

Table 6. Change in Tree Canopy and Impervious Surfaces from 2006 to 2017 in the City of Bellevue Portion of the Small Lake Washington Tributaries Watershed

Subbasin/Area	Tree Canopy Loss (2006 – 2017)		Impervious Surfaces Increase (2006 – 2017)		Primary Agent of Change
	Change	Trend [a]	Change	Trend[a]	
Lakehurst Area	1.6 %		1.8 %		Development
Meydenbauer Creek	2.0 %		2.4 %		Development
Beaux Arts Area	0.9 %		1.9 %		Development
Clyde Beach Area	1.7 %		1.3 %		Redevelopment
Yarrow Creek	2.8 %		1.5 %		Development
Point Cities Area	0.1 %		0.9 %		Development
Total	2.0 % (93 acres)		1.8 % (83 acres)		Development

SOURCE: https://hrcd-wdfw.hub.arcgis.com (HRCD 2021)

[a] The Department of Fish and Wildlife High Resolution Change Detection (HRCD) data is based on aerial imagery collected in 2006, 2009, 2011, 2013, 2015, and 2017. Trend bars represent the change detected between those years.

Based on changes in tree canopy and impervious area data, since 2006 there has been development or redevelopment in all of the subbasins and areas within the Small Lake Washington Tributaries Watershed. Table 6 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 Small Lake Washington Tributaries Watershed, it is important to consider the impacts of the City's growth on water quality and habitat within the riparian corridor.

Within the City of Bellevue, ownership across all of the subbasins within the Small Lake Washington Tributaries Watershed is approximately 77 percent private property and 23 percent publicly owned. Developing stream improvement plans in collaboration with private property owners is essential for the Small Lake Washington Tributaries 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.

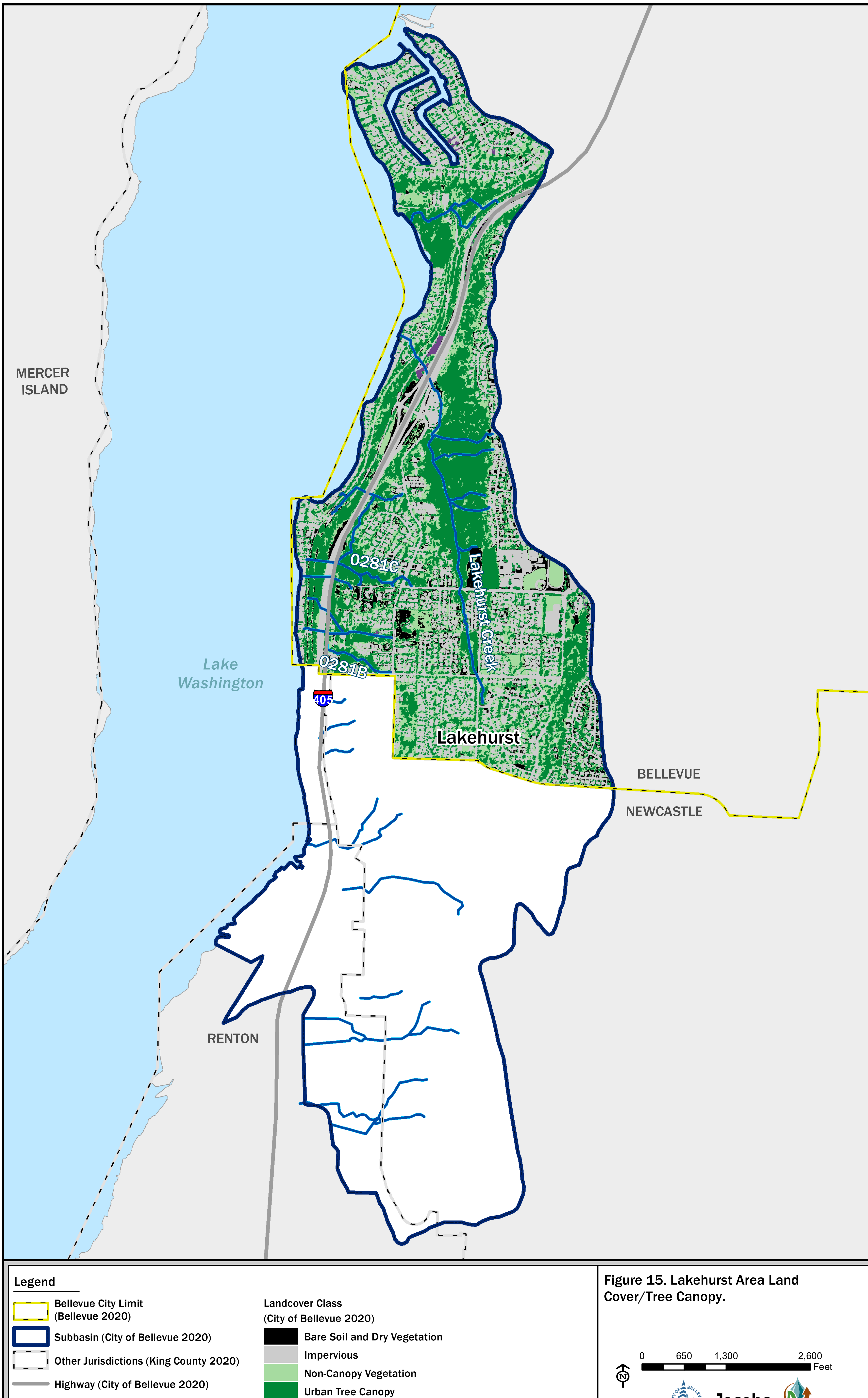

Figure 15. Lakehurst Area Land Cover/Tree Canopy.

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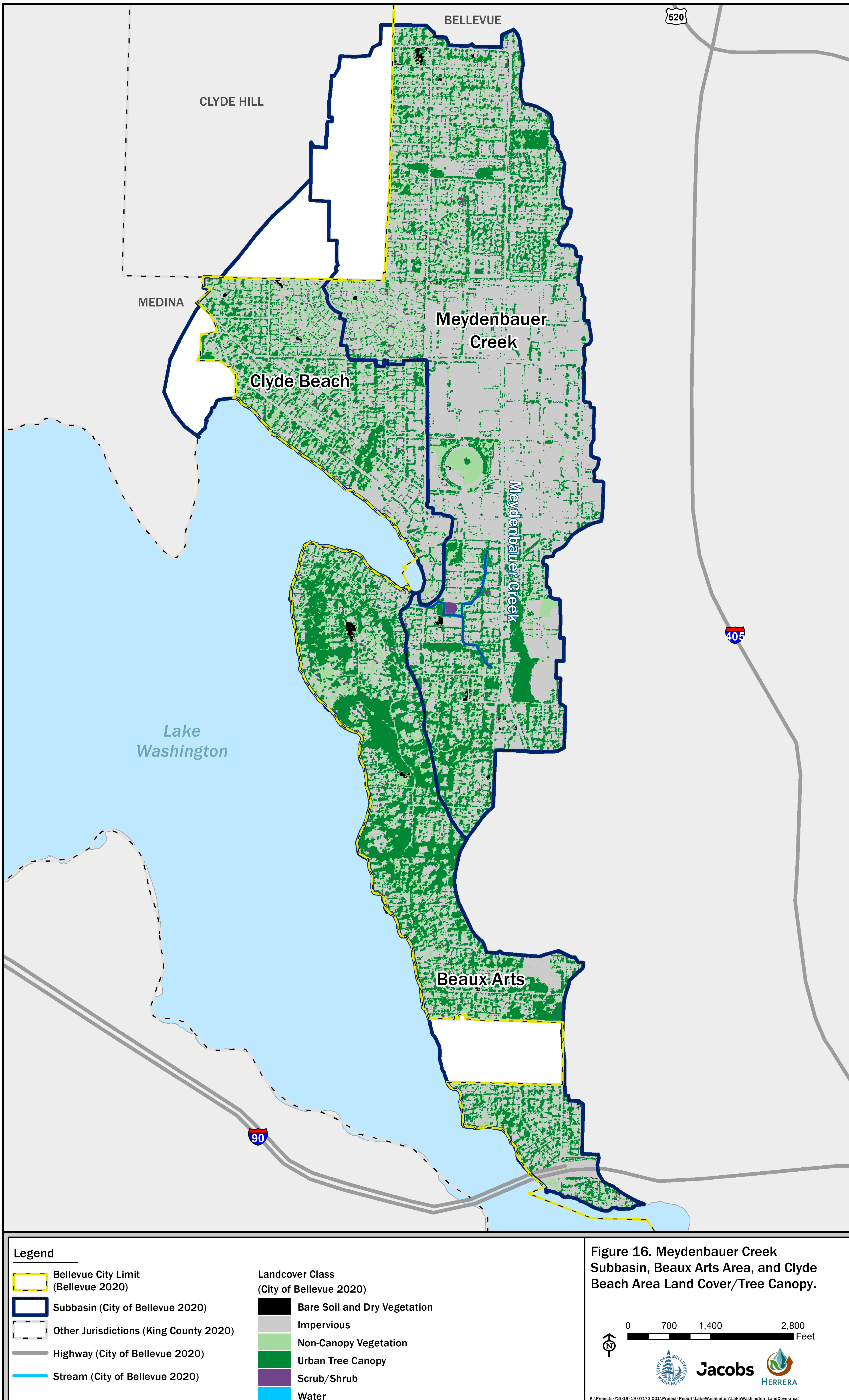
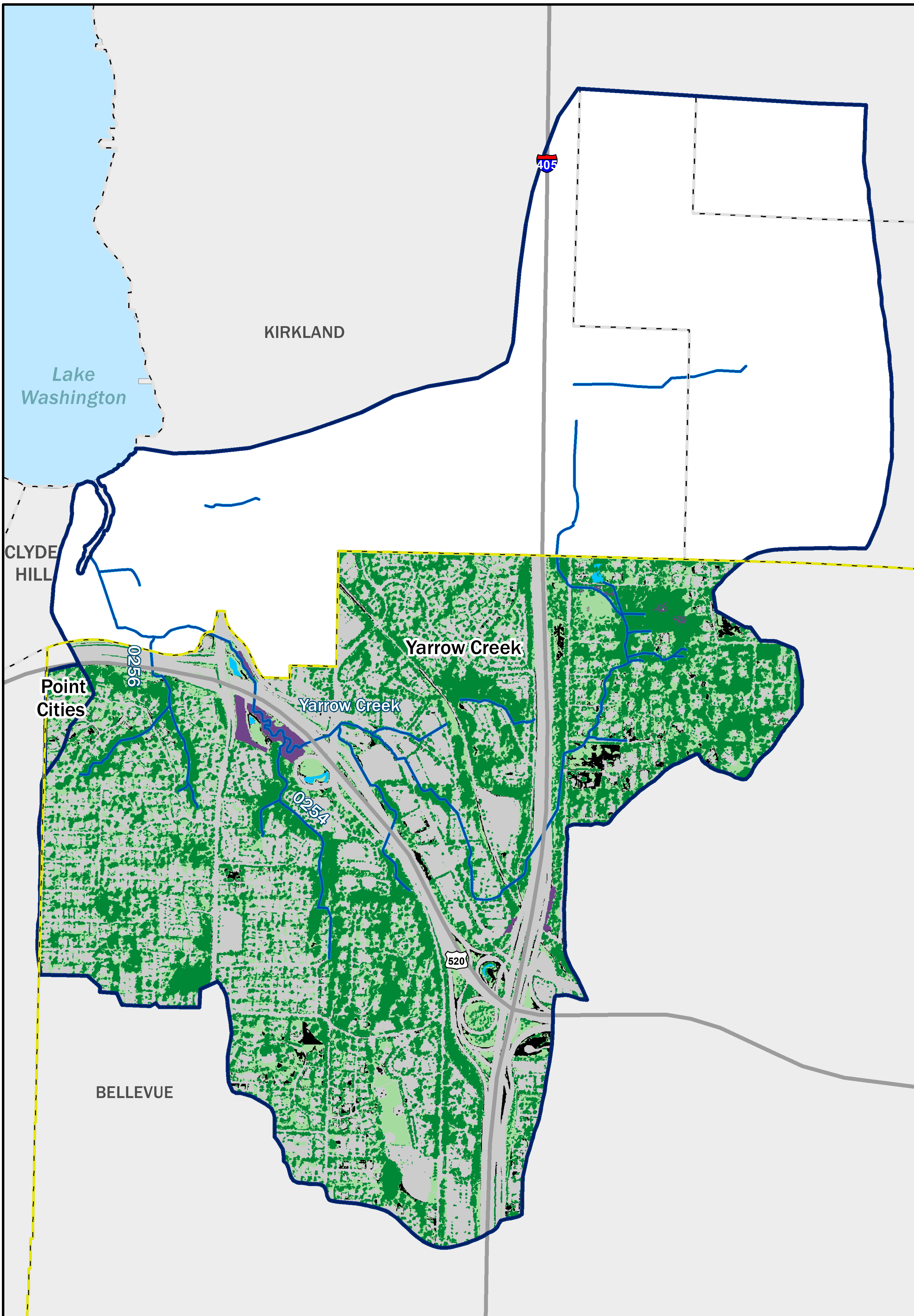


Figure 16. Meydenbauer Creek Subbasin, Beaux Arts Area, and Clyde Beach Area Land Cover/Tree Canopy.



Legend

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

Landcover Class (City of Bellevue 2020)

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

Figure 17. Yarrow Creek Subbasin and Point Cities Area Land Cover/Tree Canopy.

0 500 1,000 2,000 Feet

Jacobs

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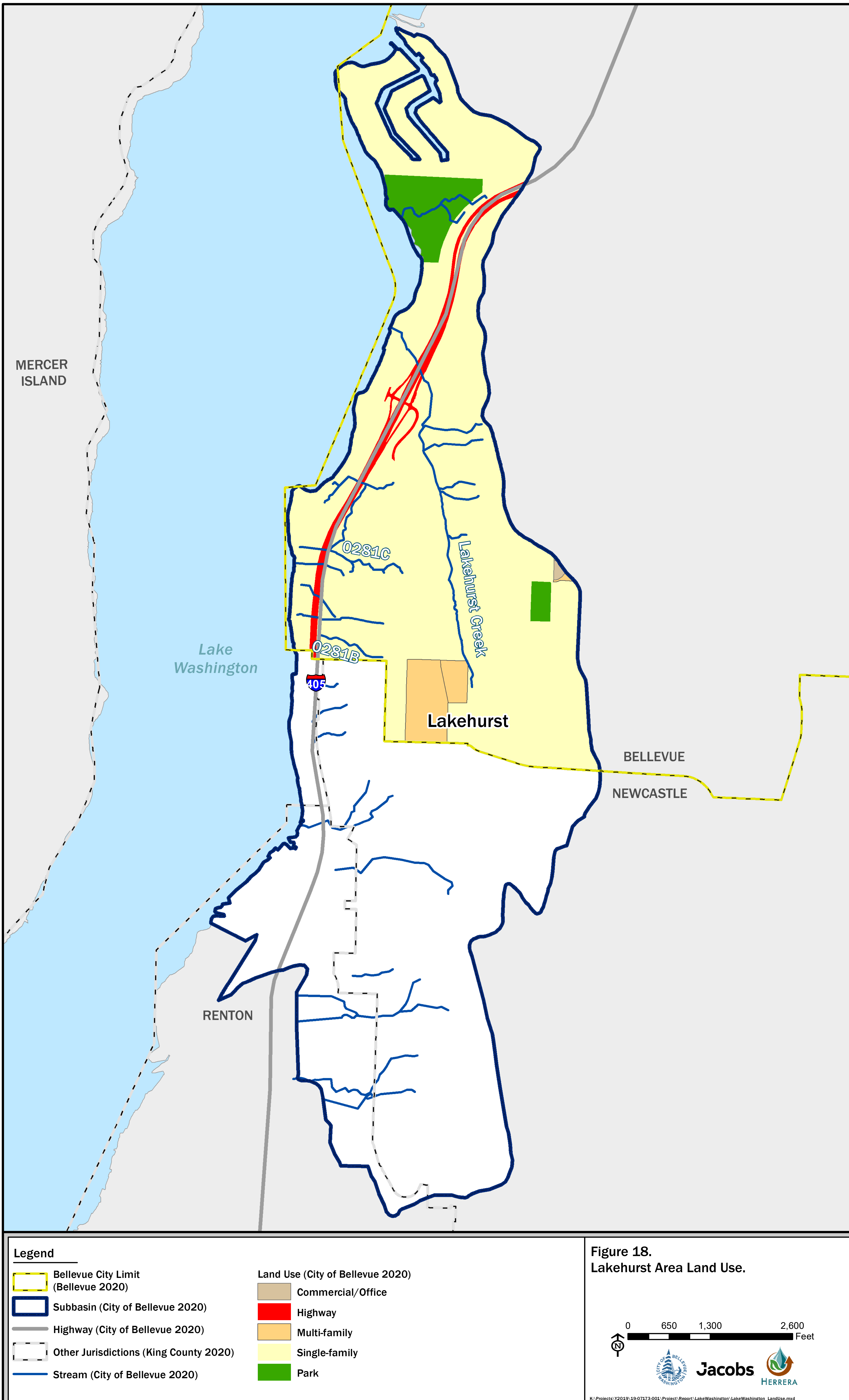

Figure 18.
Lakehurst Area Land Use.

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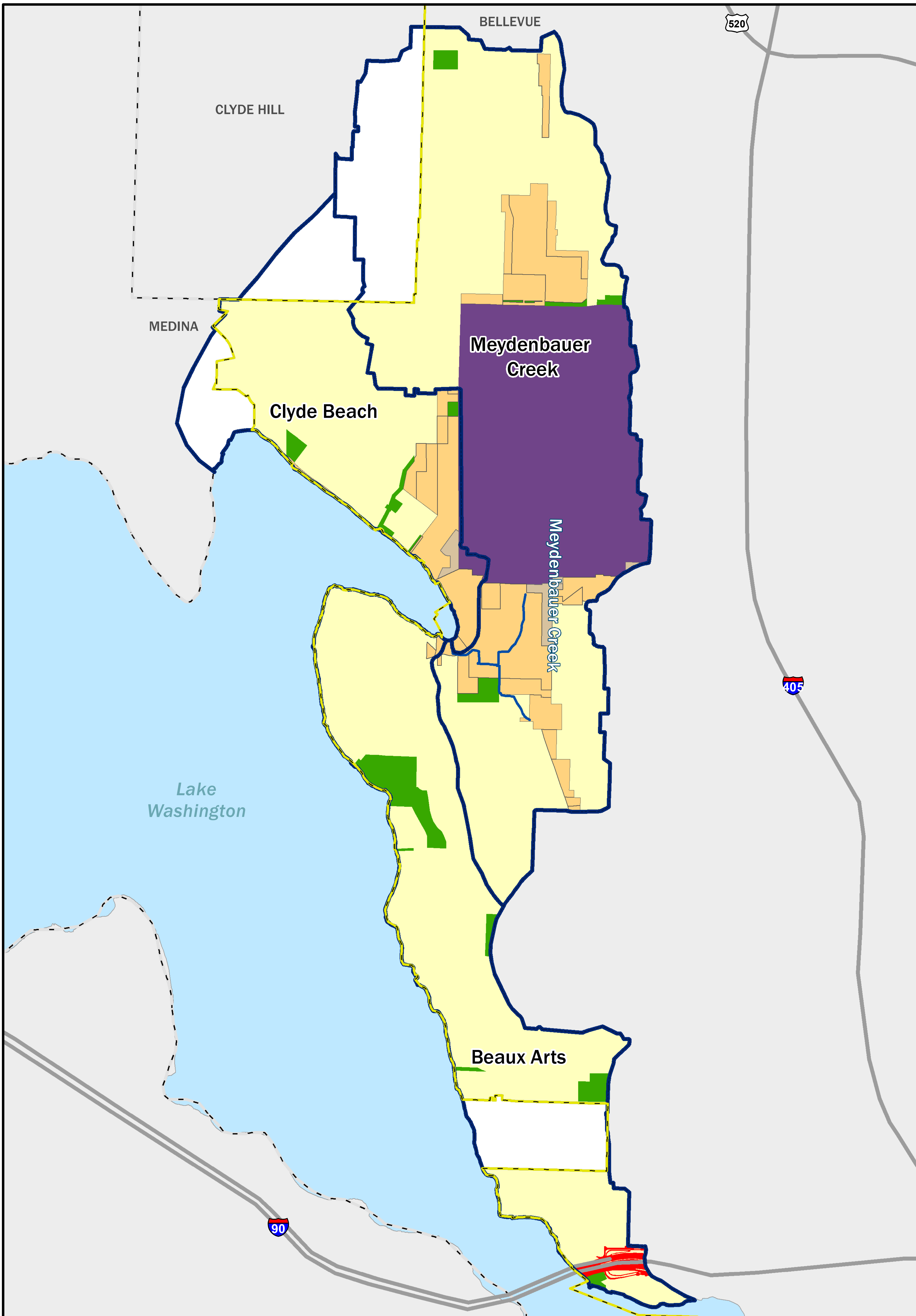

Legend

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

Land Use (City of Bellevue 2020)

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

Figure 19.
Meydenbauer Creek Subbasin, Beaux Arts Area, and Clyde Beach Area Land Use.

0 700 1,400 2,800 Feet

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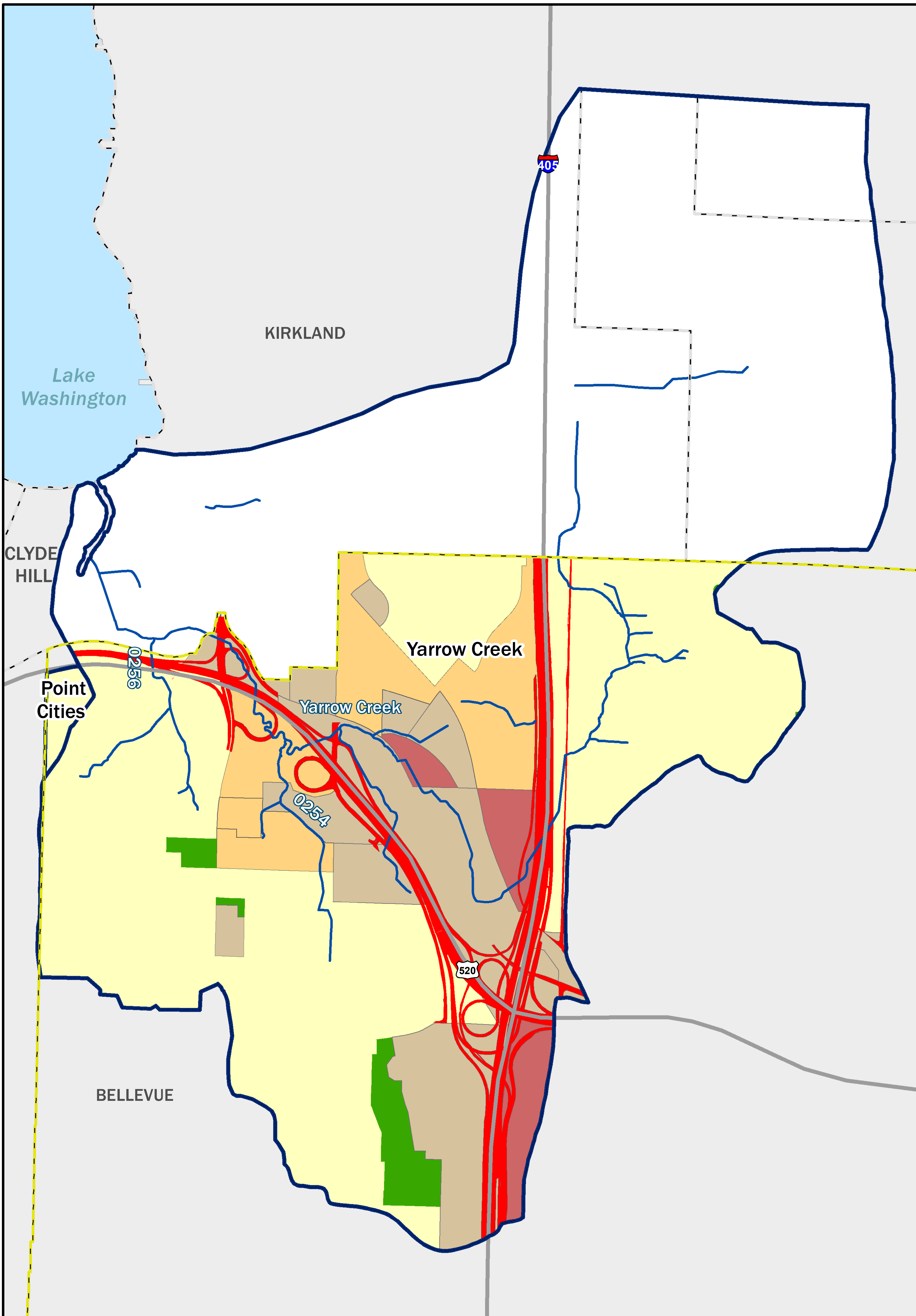

Legend

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

Land Use (City of Bellevue 2020)

- Commercial/Office
- Highway
- Industrial
- Multi-family
- Single-family
- Park

Figure 20.
Yarrow Creek Subbasin and Point Cities Area Land Use.

0 500 1,000 2,000 Feet

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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.

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 Small Lake Washington Tributaries 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 Lake Washington and its tributaries. Table 7 shows the percentage of the mapped stream channel that flows through pipes for each subbasin or area within the Small Lake Washington Tributaries Watershed. Meydenbauer Creek has the largest percentage of mapped stream channel in a pipe with 37 percent, followed by Yarrow Creek and Lakehurst Creek at approximately 25 percent.

Table 7. Piped Stream Channel Percent by Subbasin/Area in the City of Bellevue Portion of the Small Lake Washington Tributaries Watershed

Subbasin/Area	Percent of the Mapped Stream Channel that is Piped
Lakehurst Area	24%
Meydenbauer Creek	37%[a]
Beaux Arts Area	Not Applicable[b]
Clyde Beach Area	Not Applicable[b]
Yarrow Creek	25%
Point Cities Area	Not Applicable[b]

[a] This percentage is for the existing stream channel, not the historic stream channel.
[b] This Lake Washington area does not contain perennial open streams

The Small Lake Washington Tributaries Watershed has one major stormwater facility in the Lakehurst Area and two in the Meydenbauer Creek Subbasin, which includes a high-flow bypass and water quality treatment unit (Table 8). The water quality treatment unit in the Meydenbauer Creek Subbasin improves the quality of stormwater runoff off a portion of 100th Ave NE before being discharged to Lake Washington and was funded by a Washington State Department of Ecology (Ecology) grant in 2017. The Lakehurst Area facility is an in-stream sediment pond that reduces the sediment load sent downstream to Lake Washington.

High-flow bypasses are designed to divert excess streamflow out of the main stream channel and into storm drainage pipes during extreme flow events. The diversion structure and high-flow bypass in Meydenbauer Creek Subbasin was constructed in 1983 with an accompanying "No-Detention Zone" for the CBD, which has no flow control requirements. A "baseflow" always flows into the stream, but when the flow reaches a certain level, the diversion structure directs the "excess flow" into the 60 inch bypass line that discharges to Meydenbauer Bay near the Yacht Club (without treatment).

Table 8. Existing Stormwater Facilities in the in the City of Bellevue Portion of the Small Lake Washington Tributaries Watershed

Facility Type	Facility Name	Subbasin/Area	Location
In-stream sediment pond	Storm Drainage Structure 525034	Lakehurst Area	5200 Lake Washington Blvd SE Lat: 47.55594° N, Long: 122.18879° W Built by King County sometime before the area was annexed by Bellevue (1993) in response to complaints by lakeshore homeowners at the mouth of Lakehurst Creek about large sediment loads. City O&M staff clean it out approximately once every 5 years.
High Flow Bypass to Lake Washington: Diversion structure and Outfall adjacent to Yacht Club	Storm Drainage Structure 327485 Storm Discharge Point 316606	Meydenbauer Creek	In street (NE 2nd Ave St) adjacent to 200 105th Ave NE Lat: 47.61202° N, Long: 122.19985° W See Louis Berger 2016 report for detail on this diversion and the downtown trunk line. 9927 Meydenbauer Way SE Lat: 47.60825° N, Long: 122.20728° W Outfall area dredged approximately once every 5 years. City O&M staff take measurements quarterly to track accumulation.
Water quality treatment unit	Storm Drainage Structure 526517	Meydenbauer Creek	On the east site (off of 100th Ave NE) of the Park located at 10201 NE 4th St Lat: 47.61306° N, Long: 122.20676° W Water quality retrofit built in 2018 with Ecology grant – collects local runoff (KPFF 2016).

A portion of the southern part of the CBD, however, does not flow to the diversion structure yet is still within the "No-Detention Zone"; this area drains directly to Meydenbauer Creek without flow control protection. A re-evaluation of this policy for that portion of flow is warranted given the degraded condition of the Meydenbauer stream channel. Scour and erosion from unmitigated flows have negative impacts on Meydenbauer Creek and have caused historic and ongoing sediment accumulation downstream at the bypass outlet, which requires regular dredging maintenance every 2 to 3 years (KCM 1980; Entranco 1998; Louis Berger 2016). At the Meydenbauer Creek outlet, these sedimentation issues are further compounded by beaver and nutria activity, and concerns about streambank instability raised by private property owners.

The high flow bypass provides the open channel of Meydenbauer Creek some protection from the negative effects of high flows and benefits developers in the CBD by not having to install flow control facilities. Given that the bypass was installed almost 40 years ago, a reassessment of its benefits to the stream should be undertaken. In general, high-flow bypasses 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.

The City plans to evaluate the current condition, function, and benefits provided by the high flow bypass under existing conditions and may decide to alter code requirements or the system configuration to maximize benefits across a variety of objectives including both people and ecosystem function.

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 Small Lake Washington Tributaries 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 9). 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 runoff treatment was not required in the City until 2010. This means that runoff treatment facilities were not required for approximately 95 percent of the current *developed* area in the Bellevue portion of the Small Lake Washington Tributaries Watershed, including road projects.

Of the two major highways that impact the Small Lake Washington Tributaries Watershed, I-405 is older and does not have any flow control or treatment facilities. Some of SR 520 was widened in 2010 and expected to provide limited stormwater treatment. Highway runoff results in large volumes of water that contain pollutants of concern for ecosystem health.

More than 32 percent of the Small Lake Washington Tributaries Watershed was developed before 1974 with nearly half (47.9 percent) developed before the mid-1980s. All subbasins and areas in the watershed were developed to a similar extent (between 27 to 41 percent) before 1975. Yarrow Creek Subbasin was developed more heavily than other areas between 1975 and 1987. By 1996, over 60 percent of the land area within the Small Lake Washington Tributaries Watershed had been developed.

Figures 21 through 23 show the age of development for the Lakehurst Area; the Meydenbauer Creek Subbasin, Beaux Arts Area and Clyde Beach Area; and the Yarrow Creek Subbasin and Point Cities Area, respectively. Figure 24 shows the regional stormwater facilities in Small Lake Washington Tributaries Watershed.

Table 9. Development Age Categories for Assessing Stormwater Management Infrastructure Requirements

Category	Stormwater Management Requirements	Total, Small Lake Washington Tributaries Watershed	Lakehurst Area	Meydenbauer Creek	Beaux Arts Area	Clyde Beach Area	Yarrow Creek	Point Cities Area
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.	1.7%	1%	2%	3%	2%	1%	-
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.	3.0%	2%	3%	3%	5%	3%	3%
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	8.3%	6%	8%	16%	13%	6%	9%

Category	Stormwater Management Requirements	Total, Small Lake Washington Tributaries Watershed	Lakehurst Area	Meydenbauer Creek	Beaux Arts Area	Clyde Beach Area	Yarrow Creek	Point Cities Area
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	5.1%	5%	9%	5%	4%	3%	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”).	15.5%	12%	15%	9%	6%	24%	25%
Prior to 1975	No stormwater management required.	32.4%	27%	38%	39%	41%	26%	30%

LID: low impact development

cfs: cubic feet per second

Source: City of Bellevue Age of Development and Land Classifications (Bellevue 2013)

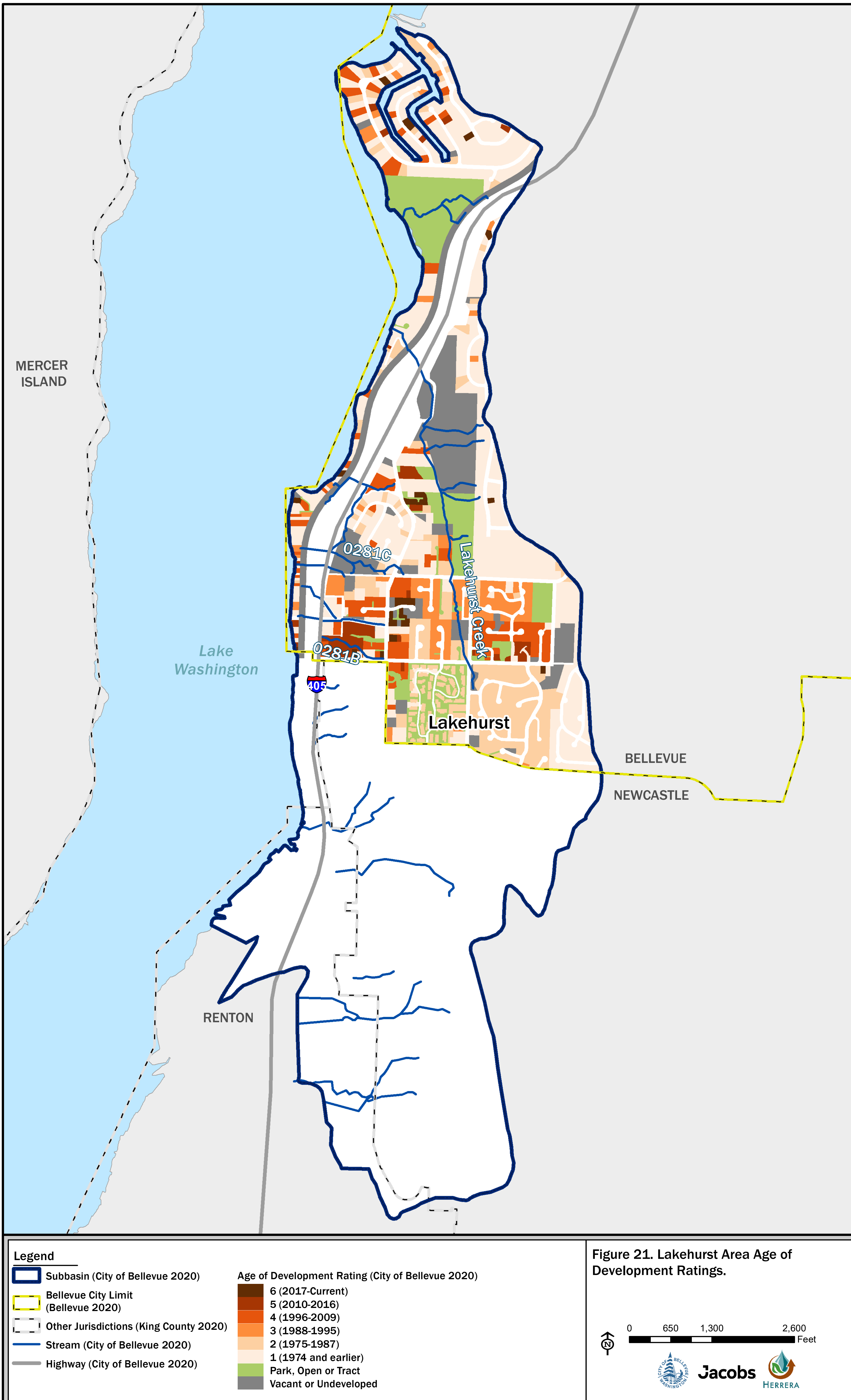


Figure 21. Lakehurst Area Age of Development Ratings.

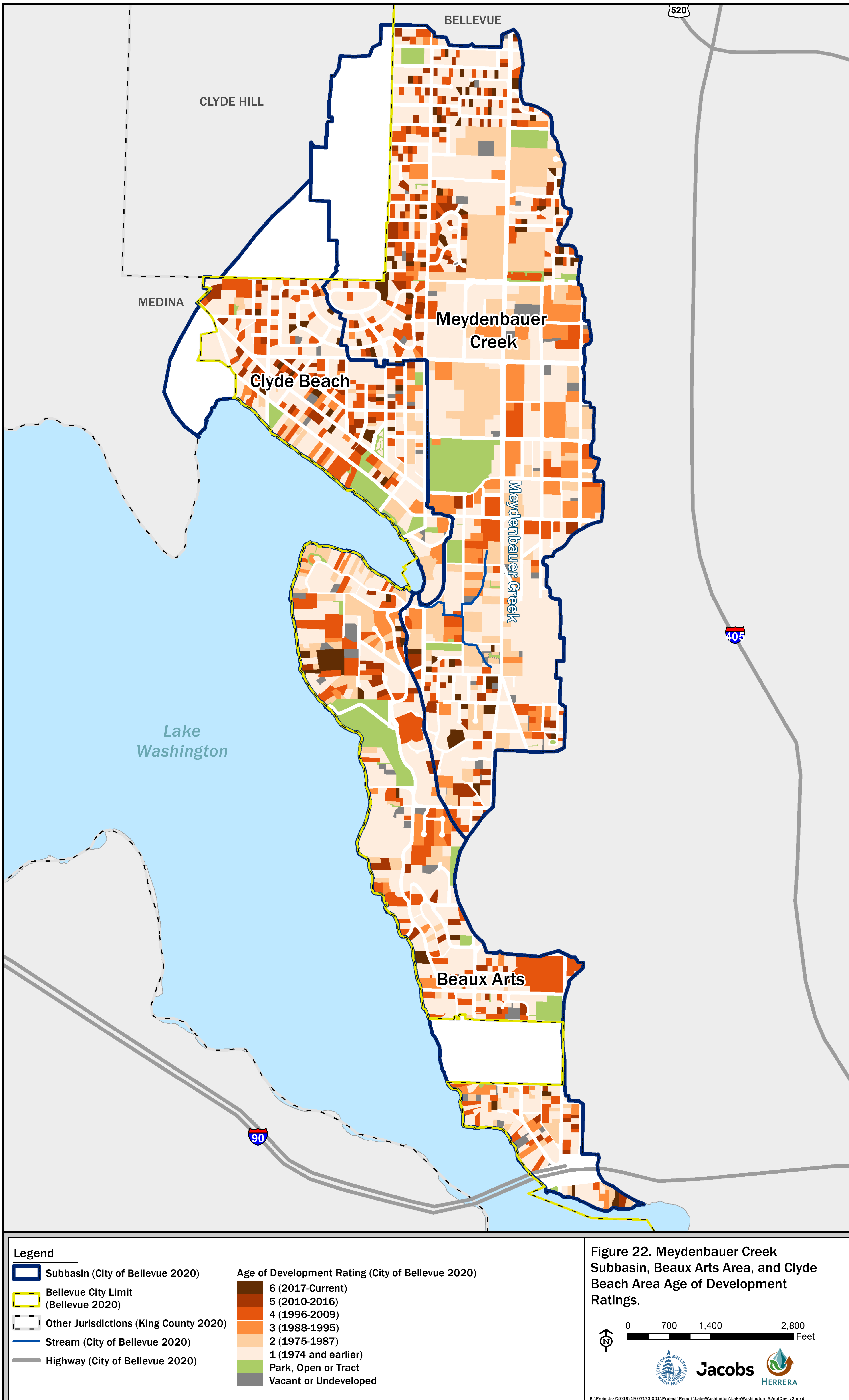


Figure 22. Meydenbauer Creek Subbasin, Beaux Arts Area, and Clyde Beach Area Age of Development Ratings.

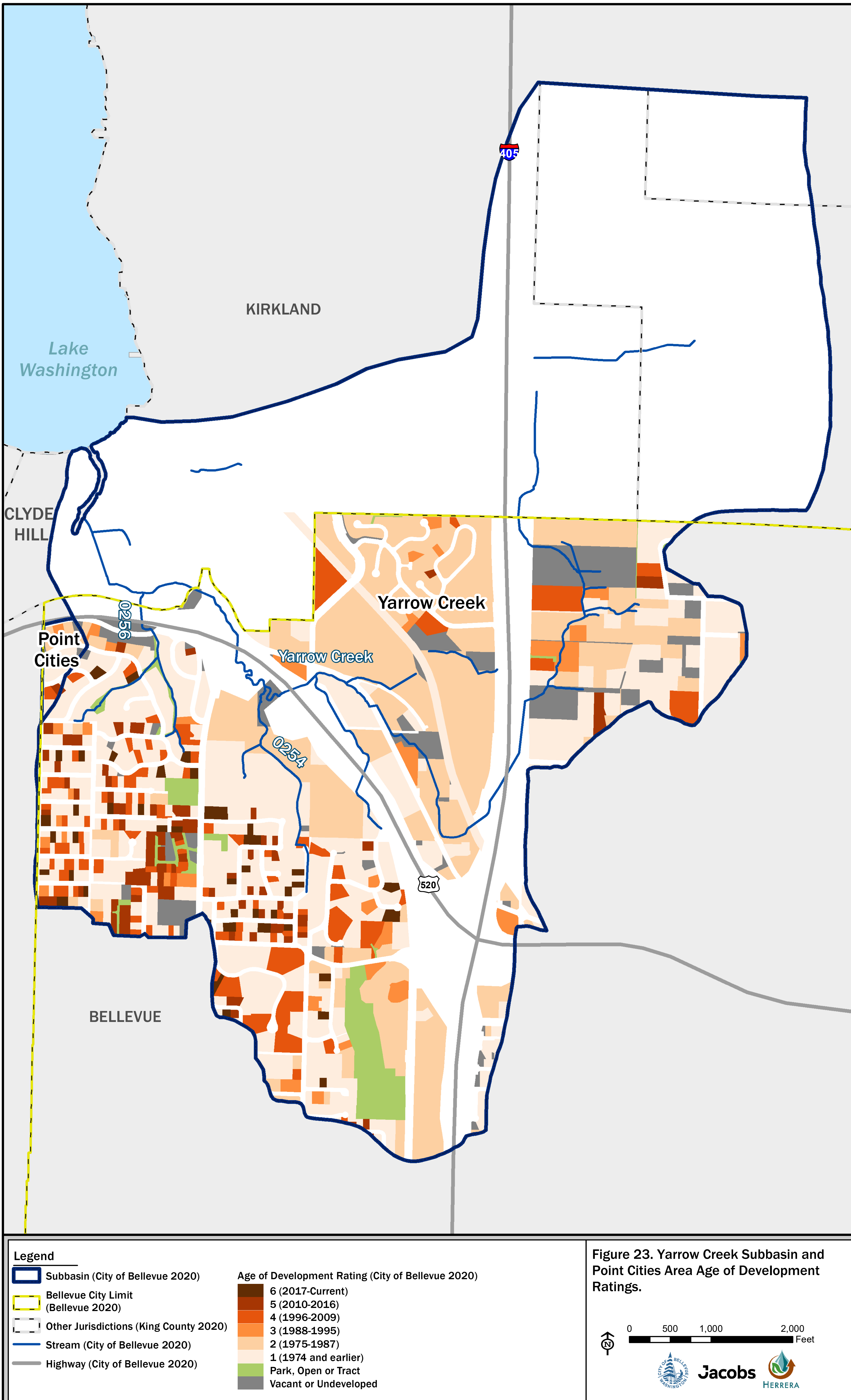
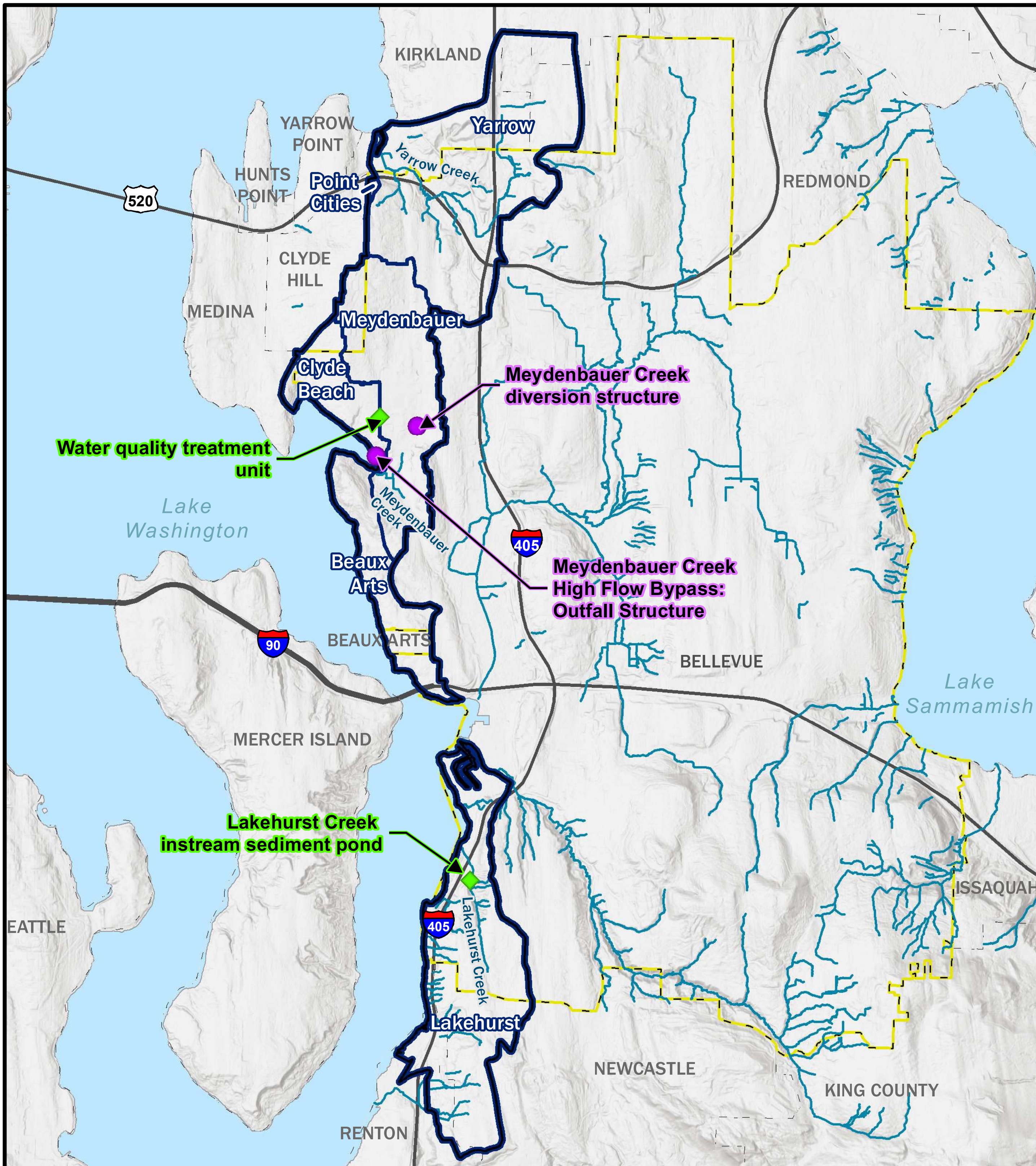


Figure 23. Yarrow Creek Subbasin and Point Cities Area Age of Development Ratings.



Legend

- Bypass Structures (City of Bellevue 2020)
- Major Stormwater Infrastructure (City of Bellevue 2020)
- Watershed (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (City of Bellevue 2020)
- Stream Reach (City of Bellevue 2020)
- Highway (City of Bellevue 2020)

*Note all data from City of Bellevue 2020

Figure 24. Regional Stormwater Facilities for the Small Lake Washington Tributaries Watershed.

N

0 3,125 6,250 12,500 Feet

CITY OF BELLEVUE WASHINGTON Jacobs HERRERA

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2.2.3 Other Non-Stormwater Built Infrastructure

As is true in all of Puget Sound, power lines, transportation corridors (e.g., roads, trails), sewer lines, and other types of infrastructure exist throughout the Small Lake Washington Tributaries Watershed and impact natural stream and hydrologic processes and function.

I-405 and SR 520 are major features of the Small Lake Washington Tributaries Watershed with historic stream modifications at crossings. WSDOT has invested in restoration efforts at the SR 520 Yarrow Creek Stream Compensatory Mitigation Site in the Yarrow Creek Subbasin, and now conducts monitoring and management activities (WSDOT 2020).

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

The hydrologic impacts of development on stream flow patterns are well understood. 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. Further, the compaction of soils and the replacement of natural drainage courses with piped drainage networks also contribute to the more “efficient” transport of stormwater runoff to downstream areas (Booth 1991; Konrad 2002). One consequence of these alterations is that, in comparison to a forested watershed, streamflow becomes increasingly “flashy” in response to rainfall but exhibits baseflow decreases following dry periods. Surface runoff volumes experience net increases, while groundwater recharge, evapotranspiration, and throughflow typically demonstrate net reductions (Imhof 1991). As shown in Figure 2, these and other related changes in streamflow characteristics can offset the physical equilibrium of channels and in turn, negatively impact stream physical habitat in several ways. For example, streamflow alterations contribute to channel degradation that can isolate streams from their floodplains or cause chronic bank erosion that results in the entrainment of fine sediment and increased sedimentation and embeddedness of spawning gravels downstream.

Streamflow data are not available for the Small Lake Washington Tributaries Watershed. However, streamflow characteristics of these small tributaries can be inferred from observations made in other urbanized watersheds in Bellevue and the Puget Sound Region over the past several decades (Alberti *et al.* 2007; Booth *et al.* 2004; Booth and Jackson 1997; May et al. 1997; Morley and Karr 2002). These studies clearly indicate that watersheds with the level of impervious surface present in the Small Lake Washington Tributaries Watershed (ranging from 33 percent in the Lakehurst Area to 60 percent in Meydenbauer Creek Subbasin), are associated with system-wide stream impairments.

At these high levels of impervious development, flashy streamflows are expected and were observed by City staff during OSCA surveys. For example, City staff have observed rapid increases in water level after light rain events in the Yarrow Creek Subbasin and Lakehurst Area; visible signs of erosive scour were also observed throughout the Yarrow Creek Subbasin. In the Meydenbauer Creek Subbasin, a portion of the highly impervious CBD drains directly to the stream without flow control. Maintenance activities include dredging at regular intervals downstream in Lake Washington near the high flow bypass outlet, which indicates substantial sediment transport in the system. Scour and bank stabilization issues have also prompted complaints from the condominium developments near the Meydenbauer Creek mouth. Many complex factors in the watershed are contributing to these issues, including nutria and beaver activity as discussed earlier in this report, but flashy streamflows are a known concern.

2.3.2 Surface Water Quality

Stormwater runoff from impervious surfaces that is untreated is a primary cause of pollutant transport to surface waters (See conceptual model shown in Figure 2). As described earlier in this report, the majority of the Small Lake Washington Tributaries Watershed was developed prior to the requirement for runoff treatment; hence, most runoff that enters Lakehurst, Meydenbauer, and Yarrow Creeks and their 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., copper, zinc), 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 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 cover approximately 43 percent of the Small Lake Washington Tributaries Watershed area and have increased by 1.8 percent over the period from 2006 to 2017.

Water quality data for the Small Lake Washington Tributaries 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.

One tributary to Yarrow Creek is identified as a Category 5 water body on the 303(d) list for dissolved oxygen and bacteria, but is located in the City of Kirkland, just downstream of the City of Bellevue. 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. As described in the next subsection, more recent water quality data collected by King County also indicates that dissolved oxygen concentrations in Yarrow Creek are at levels that warrant concern.

2.3.2.2 Water Quality Index

The water quality index (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 from 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.

WQI scores are only available for the Yarrow Creek Subbasin; no WQI data are available for other creeks in the Small Lake Washington Tributaries Watershed. King County (2021c) computed WQI scores for the Yarrow Creek Subbasin based on data from monthly grab samples that were collected at Site B499 from 2017 to 2021 and at Site A499 from 1975 to 2008 and from 2015 to 2020. Site B499 is located at a bridge on 101st Way Northeast along the mainstem of Yarrow Creek. Site B499 is located downstream of SR 520, therefore results from this sampling reflect potential influences on water quality from pollutants that are associated with highway runoff. Site A499 is located on Cochran Springs (a tributary to Yarrow Creek in the City of Kirkland) near the intersection of Points Drive and Lake Washington Blvd, approximately 25 feet downstream of the culvert crossing and downstream of the City of Bellevue. While Site A499 provides valuable information about the Yarrow Creek Subbasin, it is located outside the city limits.

Each monthly grab sample was analyzed for the suite of parameters used to calculate WQI scores. Average annual WQI scores from these stations (calculated on a water year basis [October through September]) are shown in Figure 25 for the period from 2017 to 2020 for Site B499 and from 2004 through 2020 for Site A499. The median value from these data (62 for Site B499 and 69 for Site A499) generally indicates water quality is a “moderate concern” in Yarrow Creek. As shown in Table 10, high fecal coliform bacteria concentrations, low concentrations of dissolved oxygen, and high total phosphorus concentrations (with a median WQI score of 71 for Site B499 and 64 for Site A499) were the primary factors driving the moderate score for the stream. Total nitrogen concentration varied widely between the two monitoring sites, ranging from extremely low (poor) scores at Site A499 to scores above 80 for Site B499, and all other parameters (pH, total suspended solids, temperature, turbidity) generally scored very near or above

90. Sources of fecal coliform bacteria in urban streams may 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 Yarrow 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 the Small Lake Washington Tributaries Watershed is slightly lower than the Puget Sound region relative to conditions in comparable streams located within the UGA from this study.

Table 10. Water Quality Index Scores by Year and Parameter for the Small Lake Washington Tributaries within the Yarrow Creek Subbasin

Station[a]	Water Year	WQI Score	WQ Concern	Fecal Coliform	DO	pH	TSS	Temperature	Turbidity	TP	TN
B499	2020	67	Moderate	67	61	97	97	74	91	71	99
B499	2019	56	Moderate	60	60	97	89	75	83	63	83
B499	2018	56	Moderate	56	68	97	93	73	89	71	89
B499	2017	70	Moderate	62	74	96	96	78	92	73	96
B499	Median	62	Moderate	61	65	97	95	75	90	71	93
A499	2020	82	Low	87	89	90	88	89	89	70	14
A499	2019	76	Moderate	75	88	91	79	89	86	68	12
A499	2018	80	Moderate	77	88	91	86	88	90	71	7
A499	2017	83	Low	84	89	90	88	89	92	72	11
A499	2016	49	Moderate	67	89	91	69	91	73	52	4
A499	2015	46	Moderate	43	85	90	81	90	89	56	3
A499	2008	82	Low	83	84	91	87	91	93	71	1
A499	2007	57	Moderate	61	79	91	72	90	81	64	1
A499	2006	60	Moderate	63	83	93	70	86	81	62	1
A499	2005	69	Moderate	81	80	88	86	90	91	46	2
A499	2004	41	Moderate	41	86	93	64	88	74	46	3
A499	Median	69	Moderate	75	86	91	81	89	89	64	3

SOURCE: King County Water Quality Index (2021c)

[a] Site A499 is located in the City of Kirkland, downstream of the City of Bellevue.

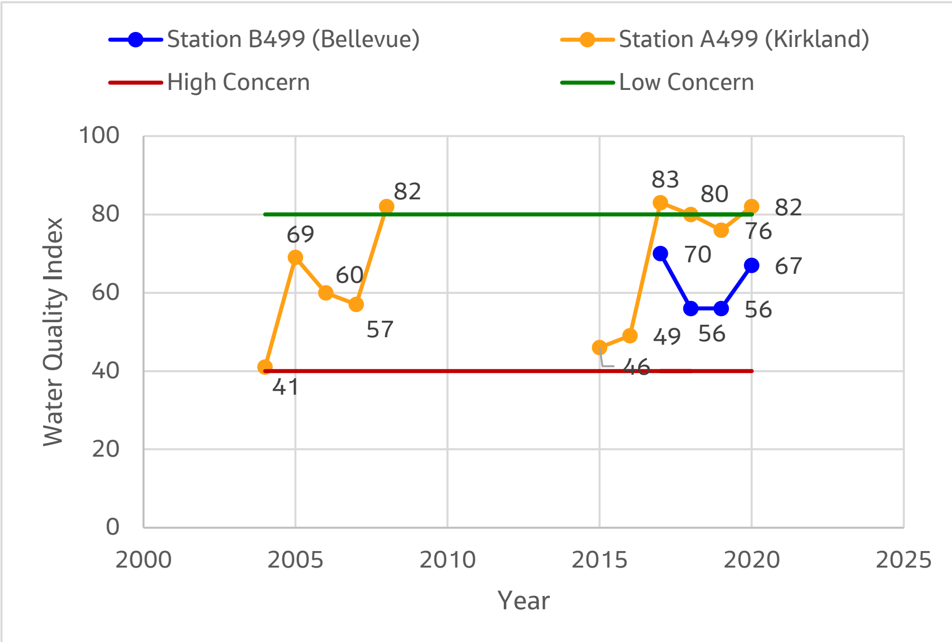


Figure 25. Water Quality Index Scores for Yarrow Creek

2.3.3 Groundwater Quality

The Small Lake Washington Tributaries Watershed includes two drinking water wells and associated wellhead protection areas located in the Beaux Arts Area. The Washington State Department of Health defines a Group A well as serving 15 or more connections, and a Group B well as serving fewer than 15 connections (and fewer than 25 people per day). The well located in Beaux Arts is Group A and the well located in Bellevue is Group B. No additional groundwater quality information was found to assess the quality of the groundwater of the Small Lake Washington Tributaries 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 Small Lake Washington Tributaries 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 2018b) for all open (or partially open) stream reaches that were assigned a SegmentID in the Lakehurst Area, Meydenbauer Creek Subbasin, and Yarrow Creek Subbasin. Within the Small Lake Washington Tributaries Watershed, riparian tree canopy cover across subbasins ranges from a low of 46 percent in Meydenbauer Creek Subbasin to a high of 66 percent in the Lakehurst Area (Table 11). In addition, riparian impervious cover across subbasins ranges from a low of 19 percent in the Lakehurst Area to a high of 38 percent in the Meydenbauer Creek Subbasin (Table 12). Overall riparian cover in the Small Lake Washington Tributaries Watershed is impaired and slightly below average for streams in the City of Bellevue. 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 11. Riparian Canopy Cover and Riparian Impervious Surface Cover in the City of Bellevue Portion of the Small Lake Washington Tributaries Watershed by Subbasin/Area

Subbasin/Area	Riparian Canopy Cover (%)	Riparian Impervious Surface Cover (%)
Lakehurst Area	66	19
Meydenbauer Creek	46	38
Beaux Arts Area	Not Applicable[a]	Not Applicable[a]
Clyde Beach Area	Not Applicable[a]	Not Applicable[a]
Yarrow Creek	50	27
Point Cities Area	Not Applicable[a]	Not Applicable[a]

SOURCE: OSCA Report summary calculations provided by City of Bellevue

[a] = This subbasin or area does not contain perennial open streams

As a comparison to the Small Lake Washington Tributaries Watershed, the upper range for riparian canopy cover in other subbasins in Bellevue is 82 to 86 percent in the Coal Creek Subbasin, Ardmore Area, and Newport Creek Subbasin. Generally, subbasins with excellent riparian cover are less urbanized and stream corridors are often located within public conservation lands and/ or parks. This is the case for Coal Creek Watershed, where 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, 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. Throughout the Small Lake Washington Tributaries Watershed, OSCA surveys note that stream reaches within residential areas generally exhibited less canopy cover. Riparian canopy in the Small Lake Washington Tributaries Watershed is composed of cedar and deciduous species, such as Red Alder (*Alnus rubra*) and Bigleaf Maple (*Acer macrophyllum*) (Bellevue 2021a).

Several invasive plant species are prevalent within the riparian corridor along streams in the Small Lake Washington Tributaries Watershed, including Himalayan blackberry (*Rubus armeniacus*), English ivy (*Hedera helix*), jewelweed (*Impatiens capensis*), and cherry laurel (*Prunus laurocerasus*), as the most frequently encountered. Knotweed species (*Persicaria wallichii* or *Fallopia* spp.), listed in King County as a Class B noxious weed, were also identified in the Small Lake Washington Tributaries Watershed (Bellevue 2021a) and have been identified in other City of Bellevue streams. If observed, immediate control is recommended to manage this aggressive and rapidly spreading noxious weed, which is already forming dense monoculture stands along portions of Bellevue streambanks. In areas where invasive plants are prevalent, with sparse canopy cover, increased coniferous species and riparian diversity are needed to reduce the extents of invasive and noxious vegetation. This would aid in maintaining a sustainable forest canopy and provide natural recruitment of large woody material to the stream channels.

2.3.5 Instream Habitat

Instream habitat conditions for three areas/subbasins (Lakehurst Area, Meydenbauer Creek Subbasin, and Yarrow Creek Subbasin) in the Small Lake Washington Tributaries 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.

During OSCA surveys, Lakehurst Creek was surveyed under the reduced Level 2 protocol due to limited fish habitat; therefore, habitat unit composition for the Lakehurst Area was not inventoried using the same protocol as the Yarrow Creek and Meydenbauer Creek subbasins, and thus the figures and statistics presented herein do not provide a similar level of detail for the Lakehurst Area. Additionally, portions of Lakehurst Creek were also not accessible for survey because of property access constraints. The data presented here are summarized at the watershed level. Stream- or subbasin-level summaries can be found in the OSCA subbasin summaries report (Appendix B).

2.3.5.1 Channel Morphology

Channel morphology, or the physical features and processes of a channel, is described by a variety of metrics, such as the channel slope and geometry (e.g., width and depth), the bed material size and overall bed form (e.g., pools, riffles, bars), floodplain height and characteristics, bank materials and stability, and channel patterns (e.g., sinuosity, multiple channel threads). A channel's morphologic conditions are the result of the interaction of three principal landscape drivers – hydrology (or transport capacity), sediment supply, and vegetation (Barnard *et al.* 2013). Native aquatic 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 Small Lake Washington Tributaries 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. Summary geomorphic observations collected during the OSCA surveys for the Lakehurst Area, Meydenbauer Creek Subbasin, and Yarrow Creek Subbasin are summarized in Table 12.

Human alterations in the Small Lake Washington Tributaries Watershed complicates the classification of the open channel reaches according to the Montgomery and Buffington (1997) morphologic reach types of Source, Transport, and Response. Source reaches are characterized by colluvial processes, where sediment supply largely originates from mass wasting (typically in steep, headwaters areas) and erosion. Transport reaches are supply-limited, morphologically resilient reaches (e.g., bedrock, cascade, step-pool channel types) which are capable of transporting the sediment supply delivered to them. Response reaches are lower gradient, transport-limited reaches (e.g., plane-bed, pool-riffle, dune-ripple channel types) where sediment supply and deposition drive the stream morphology and the channel adjusts in response (Montgomery and Buffington 1997).

Human alterations have created the need for a few additional morphologic reach type classifications in Bellevue, such as "Forced Transport", "Transport/Source", and simply "NA" to describe channels that would not fit into other typical categories. All categories are present in the Small Lake Washington Tributaries Watershed and vary based on topography. Reaches that would have been classified as Source or Transport prior to development have been converted to networks of ditches and culverts and thus were not assessed. Source reaches are rare in the Small Lake Washington Tributaries Watershed. Several reaches were identified as Transport/Source and Forced Transport due to a prevalence of intermittent piped conveyance and areas of high slope erosion. 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. The remaining open channel segments present in the downstream portions of the subbasins in the Small Lake Washington Tributaries Watershed are predominantly Response reaches.

The average gradients, based on the open channel reaches assessed by the OSCA surveys, were 4.6 percent slope (ft/ft) in the Lakehurst Area, 2.3 percent slope in Meydenbauer Creek Subbasin, and 3.2 percent slope in Yarrow Creek Subbasin. The predominant channel type in the watershed is plane-bed at 42 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 14 percent. A total of 37 percent of the Meydenbauer Creek channel is piped, 24 percent of the Lakehurst Creek channel is piped, and 25 percent of the Yarrow Creek channel is piped (see Table 7).

Riparian conditions, including large tree roots and understory vegetation, help shape channel morphology by stabilizing banks and slopes. As described in the Riparian Conditions Section (Section 2.3.4), the riparian conditions (i.e., conditions within 100 feet from the streambank) are highly variable, ranging from over 90 percent vegetated to over 75 percent impervious, with a median of about 56 percent vegetated and 26 percent impervious (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 and impaired riparian condition along several reaches have resulted in considerable streambank erosion within the Small Lake Washington Tributaries Watershed. Erosion and bank conditions are described further in the Streambank Conditions Section (Section 2.3.5.5).

Table 12. Geomorphic Characterizations by Subbasin/Area within the City of Bellevue portion of the Small Lake Washington Tributaries Watershed

Subbasin/Area	Geomorphology Characterization
Lakehurst Area	▪ Good riparian vegetation in subbasin, greatest in the ravine and less in residential areas.
	▪ Subbasin dominated by riffle habitat with below average pool frequency (9 pools per mile) compared to other subbasins in the City.
	▪ Higher than average LWM frequency (251 pieces per mile) compared to other subbasins in the City.
	▪ Streambed substrate primarily mix of fines and gravel.
	▪ Lower than average armoring across City subbasins with the 4th highest proportion of erosion.
Meydenbauer Creek	▪ Subbasin has the highest proportion of storm drainage pipes relative to open channel and the highest frequency of culverts present in the City.
	▪ Wetted width to depth ratio (10.4) is the second lowest score observed in the City, consistent with the confined and entrenched nature of the channel.
	▪ No off-channel habitat.
	▪ Pool habitat is limited (18 pools per mile), but average for streams in the City.
	▪ LWM is greatly lacking (44 pieces per mile).
	▪ Streambed substrate dominated by fines and gravels, and there are several instances of cobble and boulder presence originated from failing streambank armoring.
	▪ Armoring across subbasin is greater than average and the subbasin has the highest frequency of streambank erosion for subbasins across the City.
Yarrow Creek	▪ Riffle-dominated habitat with the third lowest proportion of pool habitat observed throughout OSCA-surveyed subbasins.
	▪ Channel has the second shallowest maximum depth observed in the City during OSCA surveys.
	▪ Beaver activity has converted the restored channel in OSCA Reach 3 (just upstream of the SR 520 crossing) to a large, ponded wetland.
	▪ LWM density (180 pieces per mile) is average for the subbasins across the City, but below that seen in similarly-sized reference streams.
	▪ Streambed substrate is predominantly fines and gravels.
	▪ The proportion of fines in the subbasin is higher than average for streams in the City, associated with the highest instance of undercut streambanks and second highest instance of erosion.
	▪ Less than average amount of streambank armoring.

2.3.5.2 Habitat Unit Composition and Off-Channel Habitat

This section presents summary habitat composition information based on the more detailed description presented in the OSCA report in Appendix B. Habitat unit composition by percent area and percent length, respectively, for the Meydenbauer Creek and Yarrow Creek subbasins is shown in Figures 26 and 27. As mentioned above, the Lakehurst Area was inventoried using a reduced Level 2 protocol, so the figures and statistics presented herein do not provide a similar level of detail for the Lakehurst Area; furthermore, several reaches within the Meydenbauer Creek and Yarrow Creek subbasins were also evaluated under different protocols that captured less detail.

The predominant stream habitat unit observed across all surveyed City of Bellevue stream reaches is riffle, or fast-water, habitat. Stream habitat unit composition in the Small Lake Washington Tributaries Watershed is no exception with riffles accounting for 62 percent of the surveyed stream area and 78 percent of the surveyed stream length. The Lakehurst Area is dominated by riffle habitat although habitat proportion data are not available. Although the percentages of riffle habitat in the Meydenbauer Creek Subbasin might appear moderate in comparison to those for other City of Bellevue creeks (e.g., Lewis Creek and Newport Creek with 83 and 91 percent riffle habitat, respectively, by area), riffle habitat is still the predominant habitat unit, accounting for 56 percent of the stream area and 40 percent of the stream length for the two stream reaches surveyed under a Level 1 protocol. Glide habitat comprises a close second for the Meydenbauer Creek Subbasin, with 39 percent of the stream area and 34 percent of the stream length. For the Yarrow Creek Subbasin reaches surveyed with a Level 1 protocol, riffle habitat accounts for 67 percent of the stream area and 82 percent of the stream length. This equates to the second highest proportion of riffle habitat (by length) in OSCA-surveyed subbasins throughout the City.

Conversely, pool habitat in the Small Lake Washington Tributaries Watershed is lacking and is generally below average for City of Bellevue streams, accounting for 10 percent of the surveyed stream area and 5 percent of the surveyed stream length. Low pool availability is considered a limiting factor for adult salmon migration and juvenile rearing habitat. The ratio of riffle to pool habitat area is 1.9 for the Meydenbauer Creek Subbasin and 10.4 for the Yarrow Creek Subbasin, which both exceed the target ratio of approximately 1.0 for juvenile salmonid productivity (Naman *et al*. 2018). The Meydenbauer Creek Subbasin has 21 percent pool habitat by area, and 10 percent by stream length, similar to several subbasins in the Greater Kelsey Creek Watershed. The Yarrow Creek Subbasin only has 6 percent pool habitat by area and 4 percent by length, which is the third lowest percentage of pool habitat found in OSCA-surveyed subbasins throughout the City. Pool depths in the Small Lake Washington Tributaries Watershed are also relatively shallow, with median depths of 1.1 feet, 1.1 feet, and 1.0 feet for the Lakehurst Area, Meydenbauer Creek Subbasin, and Yarrow Creek Subbasin, respectively. Although the shallower pool depths are sufficient for resident trout (Behnke 1992), salmon generally require a residual pool depth of three or more feet (Marcotte 1984, as cited in CDFG 1998; NOAA 1996).

Pool frequency in the Small Lake Washington Tributaries Watershed averages 12 pools per mile and is below average compared to other City of Bellevue watersheds. Pool frequencies for the Lakehurst Area (9 pools per mile), Meydenbauer Creek Subbasin (18 pools per mile), and Yarrow Creek Subbasin (11 pools per mile) are all well below the 96 (Meydenbauer) to 110 (Yarrow) pools per mile benchmarks needed to be considered “properly functioning” for their stream sizes (NOAA 1996). Off-channel habitat is absent or limited in each subbasin of the Small Lake Washington Tributaries Watershed and opportunities to enhance off-channel habitat are limited by confinement and the relatively high percentages of piped channel length. Confinement can be both natural as observed for the Lakehurst Area ravine, and anthropogenic, as evidenced by the overbank and floodplain development in the Meydenbauer Creek Subbasin.

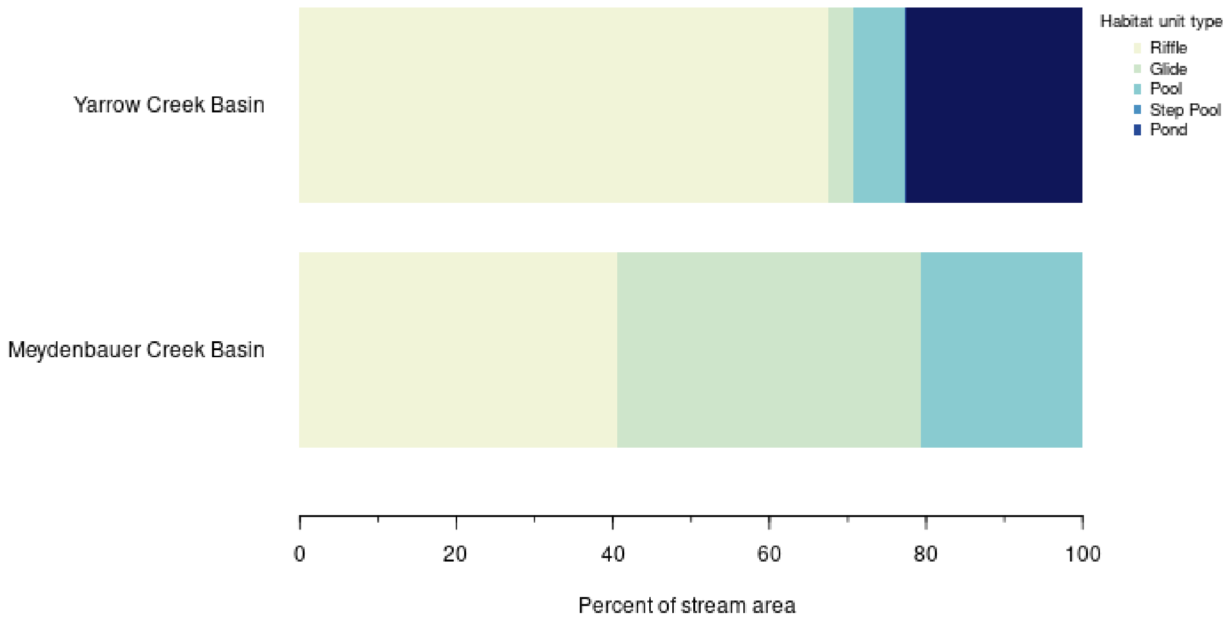


Figure 26. Habitat Unit Composition (by percent area) of the Subbasins in the Small Lake Washington Tributaries Watershed

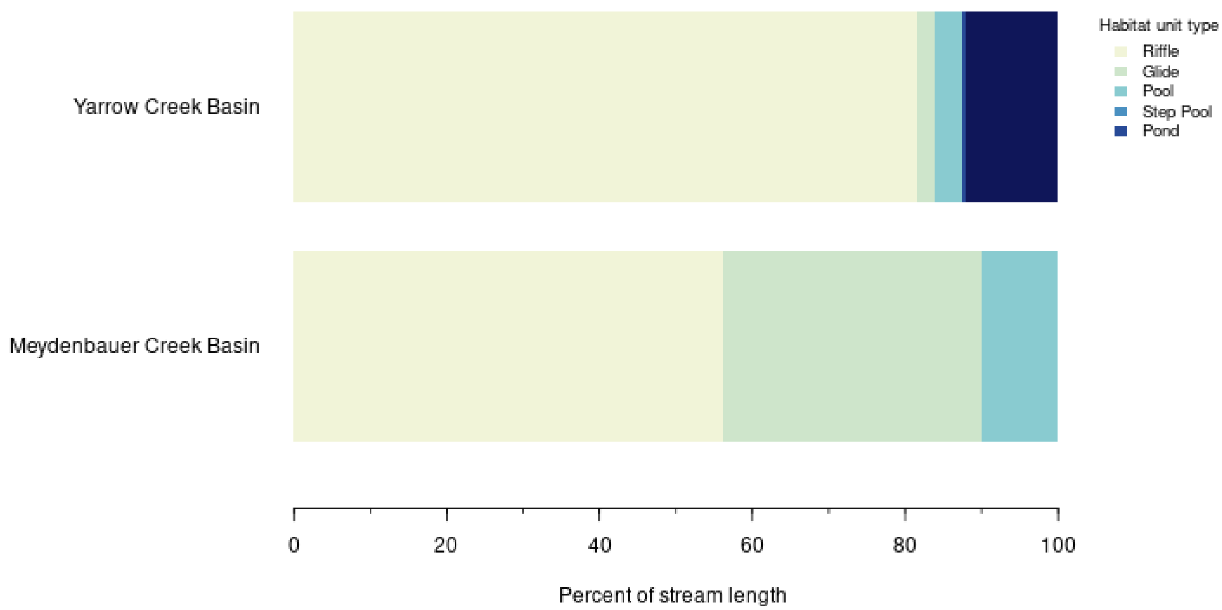


Figure 27. Habitat Unit Composition (by percent length) of the Subbasins in the Small Lake Washington Tributaries Watershed

Localized improvements in stream habitat complexity were noted in association with beaver activity in both the Meydenbauer Creek and Yarrow Creek subbasins. As a result of impoundment from beaver dams, the Yarrow Creek Subbasin has the highest percentage of pond habitat (23 percent by area) of all the City subbasins. 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.

2.3.5.3 Large Woody Material

The lack of large woody material (LWM) in the Small Lake Washington Tributaries Watershed limits habitat complexity, which in turn has a detrimental impact on salmonid rearing and migration. LWM levels in the watershed (averaging 171 pieces per mile) fall well below reference conditions of 467 pieces per mile for similarly sized streams (Fox and Bolton 2007), despite moderately high or similar frequencies of LWM found within some subbasins in comparison to the Greater Kelsey Creek Watershed. LWM frequency varies considerably by subbasin. For example, the Lakehurst Area has the highest concentration of 251 pieces per mile, higher than average for subbasins across City of Bellevue, whereas the Meydenbauer Creek Subbasin only had 19 pieces of wood for a frequency of 44 pieces per mile, one of the lowest across all City watersheds. The Yarrow Creek Subbasin had a LWM frequency of 180 pieces per mile, which is average for subbasins across the City of Bellevue.

LWM recruitment potential varies through the watershed but generally limits habitat complexity and stream functions. The OSCA surveys attributed a healthy riparian canopy in the portion of Lakehurst Creek that flows through a ravine, with the relatively higher LWM frequency noted and presumably good opportunities for future LWM recruitment there. Aside from the augmented natural recruitment potential along some restored reaches of Yarrow Creek Subbasin, both the Meydenbauer Creek and Yarrow Creek subbasins have sparse riparian canopy and severely limited opportunities for LWM recruitment. Using percent riparian tree canopy cover (based on OSCA summary and surveyed reaches, see Section 2.3.4) as a surrogate for recruitment potential, the Lakehurst Area (66 percent) has the highest recruitment potential, while the Meydenbauer Creek (46 percent) and Yarrow Creek (50 percent) subbasins have the lowest recruitment potential.

Figure 28 shows the frequency of large woody material in the Small Lake Washington Tributaries Watershed as compared to reference levels.

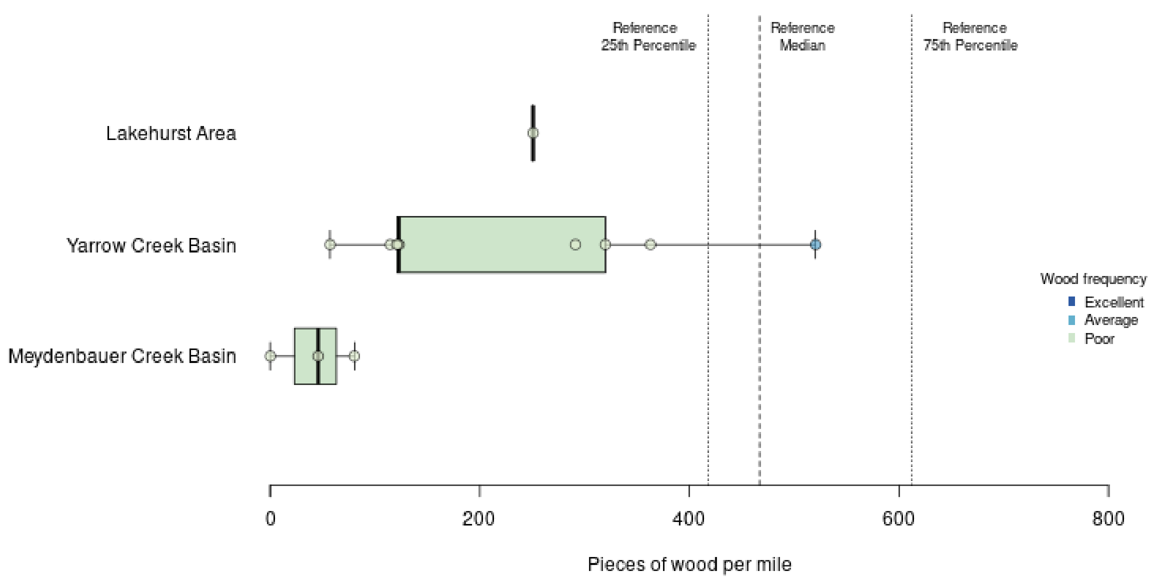


Figure 28. Large Woody Material Frequency in the Small Lake Washington Tributaries Watershed Subbasins compared to reference levels (Fox and Bolton 2007)

2.3.5.4 Substrate Conditions

Visual estimates of streambed surface substrate composition completed during OSCA surveys of the Small Lake Washington Tributaries Watershed indicate a predominance of fines and gravels (46 percent and 43 percent, respectively, in riffle habitat). Fines and gravels each comprised 41 percent of the substrate in Meydenbauer Creek Subbasin riffles, although cobbles, boulders, and a significant portion of exposed hardpan in one reach were also observed. The Yarrow Creek Subbasin is similarly comprised predominantly of fines (46 percent) and gravels (43 percent). Portions of the mainstem and tributary channels were observed with cement lining, classified as “Bedrock/Hardpan” in Figure 29. The Lakehurst Area was not surveyed at the same level of detail. At the representative cross-sectional profile, the substrate in Lakehurst Creek consisted of 75 percent fines and 25 percent gravels with occasional cobble and boulders.

The proportion of fines within the Small Lake Washington Tributaries Watershed were generally higher than average for City of Bellevue streams and unsuitably high for spawning salmonids. Excessive fines in the spawning gravels can also be detrimental to eggs incubating in gravel, which need water to flow through the gravel to bring in fresh oxygen. Although the range of preferred substrate size varies based on species (Kondolf and Wolman 1993), the WDFW Water Crossing Design Guidelines (Barnard *Et. al* 2013) recommend limiting fines in spawning material to no more than 10 percent. Figure 29 shows the substrate composition of riffle habitat for the Meydenbauer Creek and Yarrow Creek subbasins in the Small Lake Washington Tributaries Watershed, determined by visual observation.

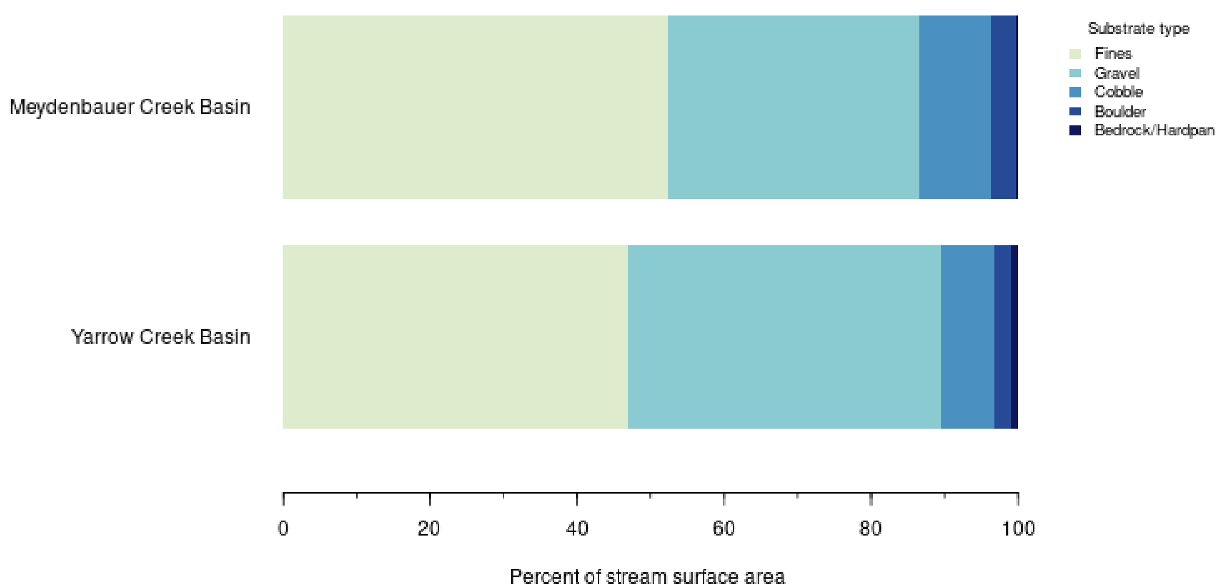


Figure 29. Substrate Composition of Riffle Habitat in the Small Lake Washington Tributaries Watershed

2.3.5.5 Streambank Conditions

The OSCA survey efforts assessed streambank conditions for the Lakehurst Area, Meydenbauer Creek Subbasin, and Yarrow Creek Subbasin (including Tributaries 0254 and 0256). These surveys gathered information related to the extents and composition of streambank armoring, as well as the nature and extents of streambank erosion, including undercutting. Conditions varied across the individual subbasins, but overall, the Small Lake Washington Tributaries Watershed has some of the highest instances of streambank erosion across the City. Across surveyed streams in the Small Lake Washington Tributaries Watershed, 29 percent of the streambanks are eroding, 20 percent are undercut, and 10 percent are armored.

The Lakehurst Area is similar in armoring prevalence (8 percent) to the Yarrow Creek Subbasin, which is slightly less than average for subbasins in the City. Streambank erosion is prevalent in this subbasin and one of the highest proportions in the City (23 percent of the surveyed reach). At 12 percent, undercutting in this subbasin is also greater than average for subbasins in the City. A failing culvert in the Lakehurst Creek ravine is causing substantial erosion and presents a potential opportunity for improvement.

The Meydenbauer Creek Subbasin also has prevalent armoring (19 percent of streambanks in surveyed reaches) and has the highest frequency of streambank erosion (31 percent) of all subbasins in the City, with 16 percent of the streambanks surveyed as undercut due to flashy streamflows.

Approximately 8 percent of the surveyed Yarrow Creek Subbasin streambank was observed as armored, which is slightly below the average armoring of other City of Bellevue subbasins. Erosion is also substantial in the Yarrow Creek Subbasin, at 30 percent of the surveyed streambank eroding. Undercutting was observed along 22 percent of the surveyed streambank along Yarrow Creek, more than any other creek in the City.

Most streambank erosion observed was toe scour with undercutting banks at the water line. Other areas, including two in the Yarrow Creek Subbasin, exhibited streambank erosion greater than 10 feet in height (both locations were associated with scour from stormwater outfalls). Such extensive erosion is often a major source of fine sediment in streams.

Figure 30 shows the proportion of armored streambank for the Small Lake Washington Tributaries Watershed. Figure 31 shows the percent of each Small Lake Washington Tributaries Watershed subbasin that is experiencing erosion.

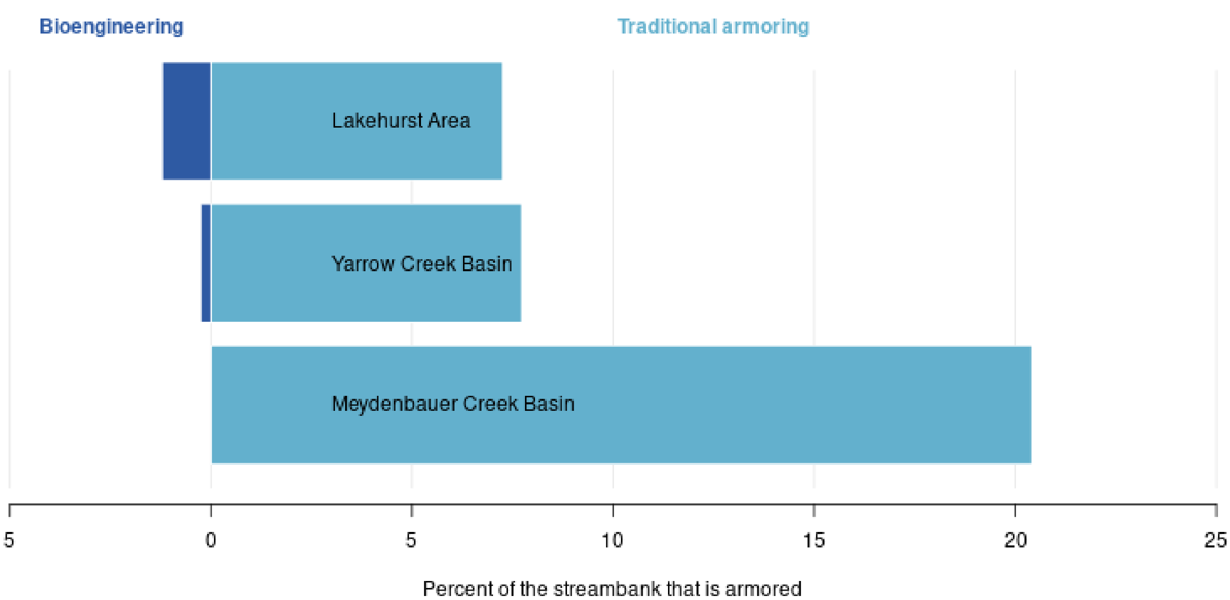


Figure 30. Diverging Bar Chart Showing the Proportion of Armored Streambank Using Traditional Materials (right) and Bioengineering (left) for Subbasins in the Small Lake Washington Tributaries Watershed

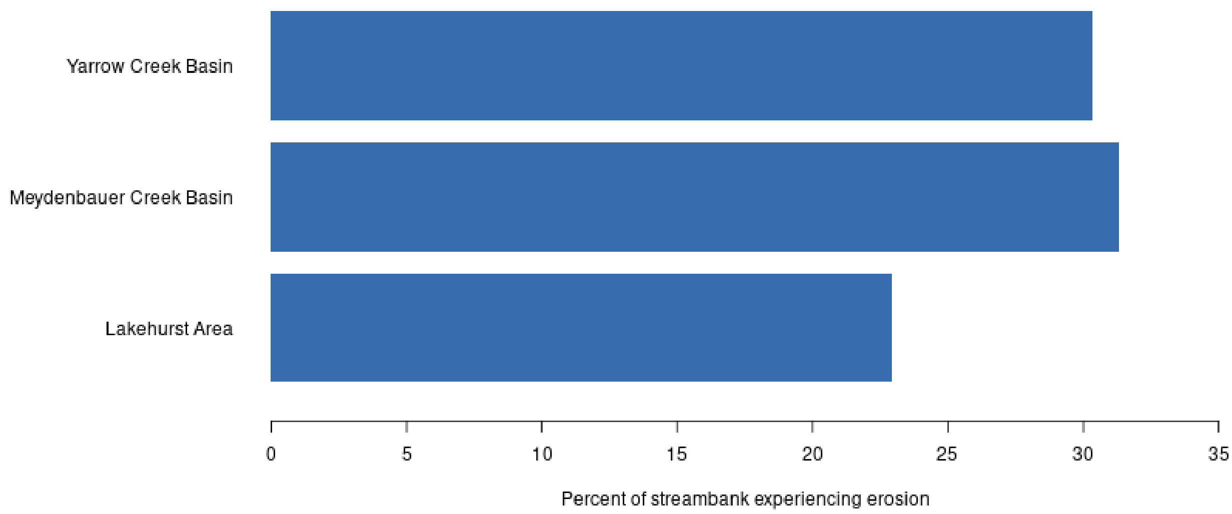


Figure 31. Percentage of Subbasins in the Small Lake Washington Tributaries Watershed that are Experiencing Erosion

2.3.5.6 Fish Habitat and Passage Barriers

The Small Lake Washington Tributaries Watershed includes streams and shoreline areas that provide (or historically provided) fish habitat. Sockeye Salmon have been known to spawn at Meydenbauer Bay Park and Clyde Beach Parks. Juvenile Chinook Salmon rear along the lake shoreline from January until June. Historic records indicate that local residents fished for trout (both resident and migratory Cutthroat) and salmon (likely Coho) in Meydenbauer Creek, which had more recent observations of adult Sockeye Salmon, Cutthroat Trout, sculpin and three-spine stickleback downstream of 101st Ave SE in 2000 and 2001 (Bellevue 2010). Yarrow Creek also historically supported Coho Salmon and Cutthroat Trout, and may have supported native Lake Washington kokanee (Bellevue 2010). For the Lakehurst Area, historic fish use is unknown.

These historic fish populations (described further in Section 2.3.6.1) have been significantly impacted by decreased quantity and quality of accessible fish habitat resulting from development. The conversion of open channel stream reaches to culverts, the development of both headwaters and floodplains, as well as other hydromodifications such as realigning, armoring, and straightening of remaining open channel reaches have significantly reduced the areas of open channel habitat and reduced the suitability of the habitat that remains. The high density of roadways and high frequency of road-stream crossings in the contributing area, not to mention the associated high number of outfalls conveying untreated stormwater, have had a demonstrable impact on habitat fragmentation and degradation (Alberti *et al.* 2007; May *et al.* 1997). Further challenges to fish habitat include the lack of channel complexity, including quality pool and edge habitat and instream cover.

Fish passage has been formally documented by WDFW (2021b) in the Small Lake Washington Tributaries Watershed, in addition to other undocumented barriers and potential impediments to fish passage, including weirs and habitat degradation associated with regional infrastructure. A total of 67 barriers to fish passage (23 partial barriers and 44 total barriers) have been identified by WDFW in the Small Lake Washington Tributaries Watershed. These are summarized by subbasin in Table 13 and shown in Figures 32 through 34. See Appendix D of this report for a complete inventory of the WDFW documented fish passage barriers in the watershed. Additionally, beaver dams in the Small Lake Washington Tributaries Watershed may temporarily impede fish passage during particular flow conditions.

The Small Lake Washington Tributaries Watershed has been heavily altered by urban development and land use, reducing suitable fish habitat despite aquatic and riparian restoration efforts. The majority of fish passage barriers in the Small Lake Washington Tributaries Watershed are associated with built infrastructure, several of which are located near the mouths of the streams emptying to Lake Washington that limit access to a substantial amount of the watershed. Several reaches within the Small Lake Washington Tributaries Watershed are piped, further limiting available fish habitat. While portions of the watershed have been restored, reconnecting the channel with adjacent wetlands and floodplain, much of the watershed is confined within the channel and has little adjacent habitat connectivity. Fish habitat is further limited by the lack of large pools with suitable depth to provide cold water refugia or holding areas.

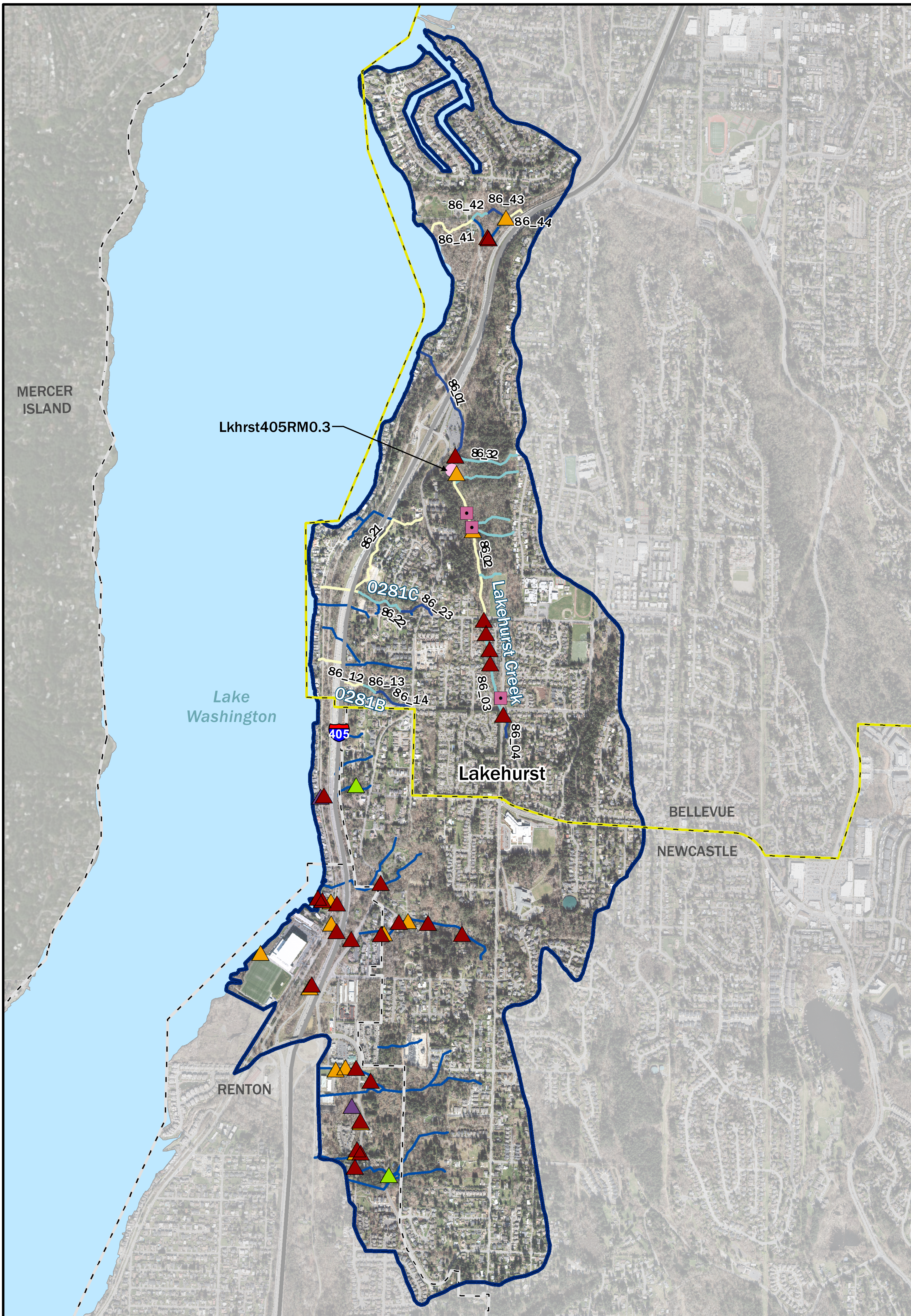
Table 13. Partial and Complete Fish Passage Barriers Documented by WDFW within the City of Bellevue Portion of the Small Lake Washington Tributaries Watershed

Subbasin/Area	**Barrier Type (WDFW Classifications)**		
	Partial Fish Passage Barrier	Complete Fish Passage Barrier	Total Documented by WDFW[b]
Lakehurst Area	13	27	40
Meydenbauer Creek	1	0	1
Beaux Arts Area	Not Applicable[a]	Not Applicable[a]	Not Applicable[a]
Clyde Beach Area	Not Applicable[a]	Not Applicable[a]	Not Applicable[a]
Yarrow Creek	9	17	26
Point Cities Area	Not Applicable[a]	Not Applicable[a]	Not Applicable[a]
Small Lake Washington Tributaries Watershed, Total	23	44	67

SOURCE: Retrieved from Washington State Fish Passage web map on Feb. 24, 2021 (WDFW 2021b).

[a] This subbasin or area does not contain perennial open streams

[b] Excludes natural barriers and barriers with unknown percent passable. See Figures 32 to 34.



Legend

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

Fish Passage Barrier (WDFW 2020)

- Unknown Percent Passage Barrier
- Natural Barrier
- Partial Fish Passage Barrier
- Total Fish Passage Barrier

Approximate Stream Reaches

- 86_01, 86_04, 86_14, 86_23, 86_43
- 86_02, 86_12, 86_21, 86_41, 86_44
- 86_03, 86_13, 86_22, 86_32, 86_42

Note: Washington Department of Fish and Wildlife (WDFW), Benthic Index of Biotic Integrity (B-IBI), Open Streams Condition Assessment Database (OSCA). Fish Passage Barrier WDFW retrieved Feb. 24, 2021

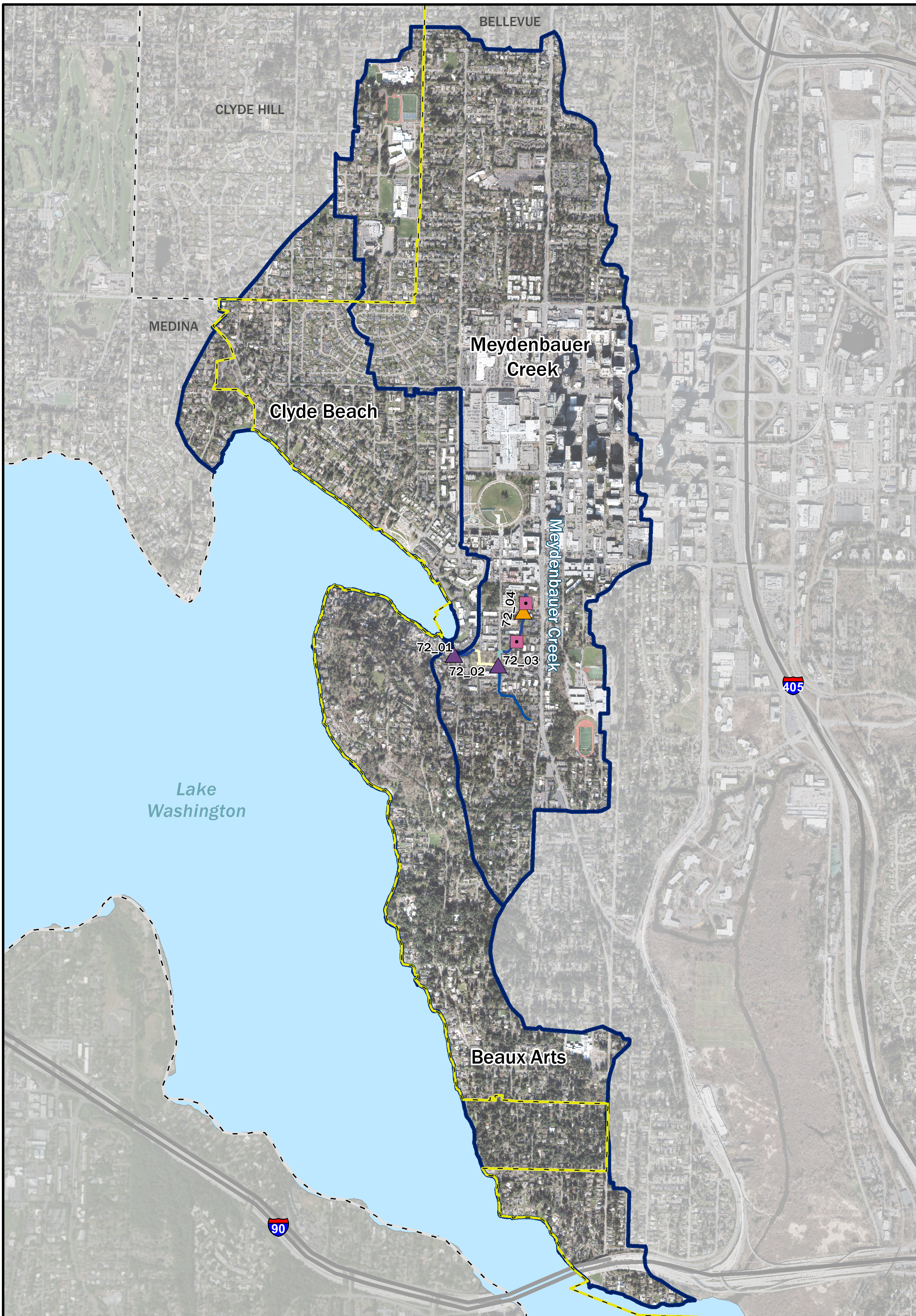
Figure 32. Lakehurst Area Fish Passage Barriers and B-IBI sampling.

N

0 650 1,300 2,600 Feet

Jacobs

HERRERA



Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Stream (City of Bellevue 2020)
- Highway (City of Bellevue 2020)
- OSCA observed knotweed location (City of Bellevue 2020)

Fish Passage Barrier (WDFW 2020)

- Unknown Percent Passage Barrier
- Partial Fish Passage Barrier

Approximate Stream Reaches

- 72_01, 72_04
- 72_02
- 72_03

Note: Washington Department of Fish and Wildlife (WDFW), Benthic Index of Biotic Integrity (B-IBI), Open Streams Condition Assessment Database (OSCA). Fish Passage Barrier WDFW retrieved Feb. 24, 2021.

Figure 33. Meydenbauer Creek Subbasin, Beaux Arts Area, and Clyde Beach Area Fish Passage Barriers.

0 700 1,400 2,800 Feet

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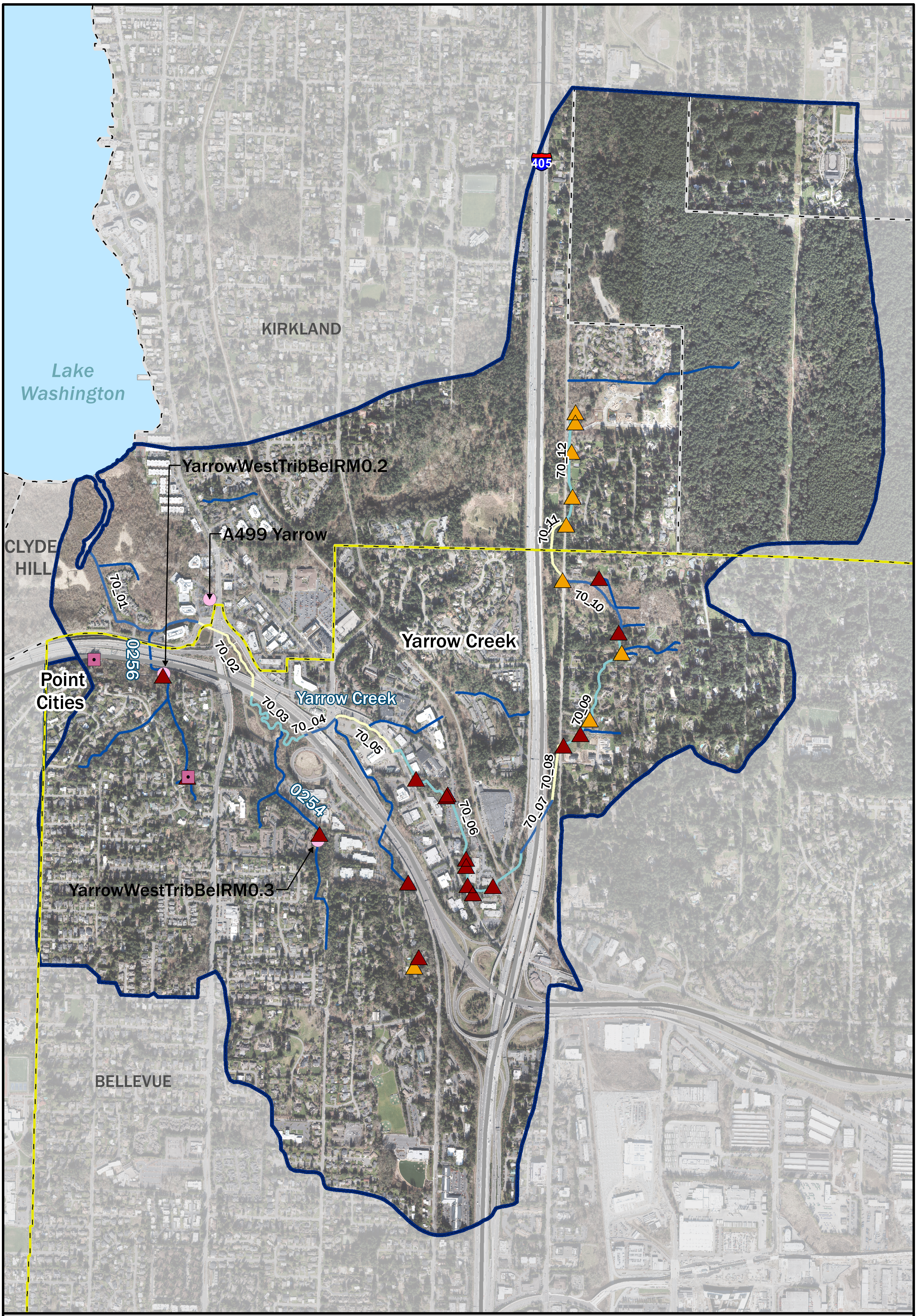

Legend

- Subbasin (City of Bellevue 2020)
- Bellevue City Limit (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

- 70_01, 70_04, 70_07, 70_10
- 70_02, 70_05, 70_08, 70_11
- 70_03, 70_06, 70_09, 70_12

Note: Washington Department of Fish and Wildlife (WDFW), Benthic Index of Biotic Integrity (B-IBI), Open Streams Condition Assessment Database (OSCA).
Fish Passage Barrier WDFW retrieved Feb. 24, 2021.

Figure 34. Yarrow Creek Subbasin Fish Passage Barriers and B-IBI Sampling Locations.

0 500 1,000 2,000 Feet

Jacobs HERRERA

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2.3.6 Aquatic Species

There are some discrete areas within the Small Lake Washington Tributaries Watershed with designated priority aquatic species habitat (WDFW 2021c), including Yarrow Bay Wetlands, Yarrow Creek Watershed Park, and Bridle Trails State Park, all located within the Yarrow Creek Subbasin. Together, these areas have been identified as a biodiversity area and corridor, including freshwater emergent, scrub-shrub, and forested wetlands habitats (WDFW 2021c). More information about the aquatic species within the Small Lake Washington Tributaries Watershed that historically used or currently use the streams and these designated priority habitat areas are described herein under separate subsections for fish species, invasive species, and benthic macroinvertebrates.

2.3.6.1 Fish Species

Although some historic fish utilization of aquatic habitat within the Small Lake Washington Tributaries Watershed is documented (Kerwin 2001; WDFW 2021b), very little is known about current fish use. Of the specific subbasins and areas described in this report, only very limited information is available for the Yarrow Creek Subbasin and Meydenbauer Creek Subbasin, but nothing substantial for the other subbasins and areas.

Historically, the Yarrow Creek Subbasin supported several native fish species including Coho Salmon (Kerwin 2001), Cutthroat Trout, and kokanee, given historical records that a Native American village was located near the mouth of Yarrow Creek with Lake Washington (King County 2016). Recent fish barrier corrections and restoration actions in the lower reaches of Yarrow Creek have improved access for several species, with the potential to better support migrating and rearing salmonids. Priority fish species within Yarrow Creek, as designated by WDFW, include Coho Salmon and resident Cutthroat Trout (WDFW 2021c). Coho Salmon are a City of Bellevue Species of Local Importance, per Bellevue Land Use Code 20.25H.150A. In addition to resident Cutthroat Trout, other species observed include resident sculpin and adfluvial Cutthroat Trout (Appendix B).

The Meydenbauer Creek Subbasin also historically supported Coho Salmon and both resident and migratory Cutthroat Trout (Kerwin 2001). Meydenbauer Creek is designated as a fish bearing stream by Bellevue. More recent observations in 2000 and 2001 identified adult Sockeye Salmon, Cutthroat Trout, sculpin and three-spine stickleback downstream of 101st Ave SE (Appendix B). Observations made by the Salmon Watcher Program (a multi-jurisdictional effort to protect salmon health and educate) 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 Yarrow Creek Subbasin (Bellevue 2021a; King County 2018). Volunteers have observed fish in Yarrow Creek in 1997 through 2001; however, only one unidentified salmonid was observed in the stream by Salmon Watcher Program volunteers in 2000 and 2001.

As described above, the 303(d) list, which categorizes state impaired and threatened waters, indicates that the lower reaches of the Yarrow Creek Subbasin are classified as Category 5 for bacteria levels and dissolved oxygen concentrations that did not meet water quality standards for Washington State (WAC 173-201A). Yarrow Creek's impaired stream health contribute to potential spawning stresses including habitat limitations (i.e., gravel quantity and quality, as well as inadequate vegetative cover), low stream flow, and high temperatures in the early spawning season. Recent improvements to the lower reaches of Yarrow Creek may help improve water quality over time. Additional impacts on spawning and juvenile rearing success related to urbanization include human infrastructure (such as artificial light) and human harassment/disturbance.

Historic fish-use of the Lakehurst Area is unknown, and this area is not likely to support fish populations currently due to downstream fish barriers and limited suitable fish habitat (Appendix B). Limited information is available for about the remaining areas of the Small Lake Washington Tributaries Watershed; however, several shoreline areas may provide (or historically provided) fish habitat. Sockeye Salmon have been known to spawn at Meydenbauer Bay Park and Clyde Beach Parks, and juvenile Chinook Salmon rear along the lake shoreline from January until June (Bellevue 2010). A recent restoration project by the Bellevue Parks Department restored a formerly piped stream reach in the Clyde Beach Area near the lakeshore and mouth at Lake Washington that was historically used for Sockeye Salmon spawning habitat. The restoration plan indicates open channel is accessible to juvenile Coho Salmon approximately 100 to 200 feet upstream from the mouth, but a fish barrier was intentionally added to prevent access further upstream into the piped system.

Information on the priority fish species in the Small Lake Washington Tributaries Watershed is provided below.

Sockeye Salmon (*Oncorhynchus nerka*)

Sockeye Salmon that use Lake Washington are part of the Baker River Evolutionary Significant Unit (ESU) but are not listed under the Endangered Species Act (ESA-listed) by the National Marine Fisheries Service (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). Sockeye Salmon adults migrate into Lake Washington streams in early/mid-September and spawn from early October to mid-November (WDFW & NWIFC 2011). The last documented Sockeye Salmon in the Small Lake Washington Tributaries Watershed was in 2000 and 2001 in lower Meydenbauer Creek (Bellevue 2010).

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 Small Lake Washington Tributaries Watershed and they have not been identified by electrofishing surveys (Hart Crowser 2017) or by volunteers in the Salmon Watcher Program (King County 2018).

Coho Salmon (*Oncorhynchus kisutch*)

Coho Salmon found in the Small Lake Washington Tributaries 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. Coho Salmon in the Small Lake Washington Tributaries Watershed are likely 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 adults migrate into Lake Washington streams around mid-October and spawn between mid-November and early-December (WDFW & NWIFC 2011). Coho Salmon possess the advantage of migrating into the system in mid to late October, when stream flows are higher, enabling them to bypass physical barriers (like the lower Yarrow Creek beaver wetland complex) more easily (WDFW 2018). Coho Salmon presence in Yarrow Creek is currently unknown and were not identified by electrofishing surveys (Hart Crowser 2017) or volunteers in the Salmon Watcher Program (King County 2018).

Cutthroat Trout (*Oncorhynchus clarkia*)

Cutthroat Trout found in the Small Lake Washington Tributaries Watershed are part of the Puget Sound ESU and are not an ESA-listed species under NMFS. Small resident Cutthroat Trout likely inhabit Yarrow Creek 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 Cutthroat Trout migration begins in early-December, with spawning occurring in mid-December likely extending through the end of March (WDFW 2018).

In 2017, the City of Bellevue conducted electrofishing at RM 0.1 on the Yarrow Creek Tributary 0256 and at RM 0.25 on Tributary 0254 as part of an annual status and trends monitoring. Cutthroat Trout were the only fish captured at both tributaries at densities of 0.24 and 1.86 fish per linear foot, respectively (Hart Crowser 2017).

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. Documented occurrences of invasive aquatic species within the City of Bellevue 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 of Bellevue waters include Zebra Mussels (*Dreissena polymorpha*) and the African Clawed Frog (*Xenopus laevis*).

New Zealand Mudsnail (*Potamopyrgus antipodarum*)

New Zealand Mudsnails have not been observed or documented within the Small Lake Washington Tributaries Watershed; however, due to the life history of NZMS and their presence in the nearby Greater Kelsey Creek watershed, infestation is a real threat to Lake Washington tributaries. As such, further information on NZMS and infestation preventative measures are described below.

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 fish species food sources (such as terrestrial and aquatic insects, fish, amphipods, crustaceans, and other invertebrates) due to their low nutritional value. NZMS can pass through the digestive tract of a fish without injury (WDFW 2021d).

Once NZMS have infested an ecosystem, there is no effective method to remove them. Prevention will help mitigate the damaging impact of NZMS on not yet infested 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 2021b). Preventative actions are important to mitigate the spread (and harmful effects) of NZMS to the Small Lake Washington Tributaries Watershed.

Chinese Mystery Snails (*Cipangopaludina chinesis*)

Chinese Mystery Snails are a relatively large snail species which are commonly used in aquariums (USFWS 2018). 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 Larson Lake in the nearby Greater Kelsey Creek Watershed. To prevent further infestation of CMS, aquarium waters and specimens should not be released into the wild and care should be taken to prevent the spread of CMS 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.”

Studies comparing B-IBI scores across various ranges of development in other urbanized watersheds in Bellevue and the Puget Sound Region over the past several decades (Alberti et al. 2007; Booth et al. 2004; Booth and Jackson 1997; May et al.1997; Morley and Karr 2002) indicate declining B-IBI trends and system-wide stream impairments for watersheds with the level of impervious surface present in the Small Lake Washington Tributaries Watershed (ranging from 33 percent in the Lakehurst Area to 60 percent in the Meydenbauer Creek Subbasin).

One drawback of the B-IBI is that 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.

In 2010 and 2021, macroinvertebrate samples were collected at one location (Figure 32) in the Lakehurst Area by the City of Bellevue (PSBD 2021). In Yarrow Creek, macroinvertebrate samples were collected at three locations (Figure 34) in the Yarrow Creek Subbasin in 2013 (one location sampled), 2016 (one location sampled), and 2021 (two locations sampled) by City of Bellevue and King County. As shown in Table 14, these data indicate stream health in the Small Lake Washington Tributaries Watershed is “very poor” or “poor”, with a median score of 5.3 (n=2) in the Lakehurst Creek Subbasin and 27.4 (n=4) in the Yarrow Creek Subbasin (see Table 14; Appendix C). No data were available for the Meydenbauer Creek Subbasin.

Table 14. Median B-IBI Scores in the City of Bellevue Portion of the Small Lake Washington Tributaries Watershed

Subbasin/Area	B-IBI Median Score (n=number of samples)	B-IBI Rating
Lakehurst Area	5.3 (n=2)	Very Poor
Yarrow Creek	27.4 (n=4)	Poor

SOURCE: Small Lake Washington Tributaries Watershed Benthic Index of Biotic Integrity Scores (included in Appendix C)

In connection with Ecology's Stormwater Action Monitoring (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 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 Yarrow Creek Subbasin and Lakehurst Area 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 Small Lake Washington Tributaries Watershed is degraded (Lakehurst Area median score 5.3; Yarrow Creek Subbasin median score 27.4), relative to comparable streams located within the UGA.

3. Limiting Factors

The information presented in the previous sections was evaluated to identify potential factors limiting aquatic health in the Small Lake Washington Tributaries Watershed and discussed with City staff during a working session on December 15, 2021. The goal of the working session was to obtain input on potential limiting factors from City staff in departments overseeing resource management in the 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 35).

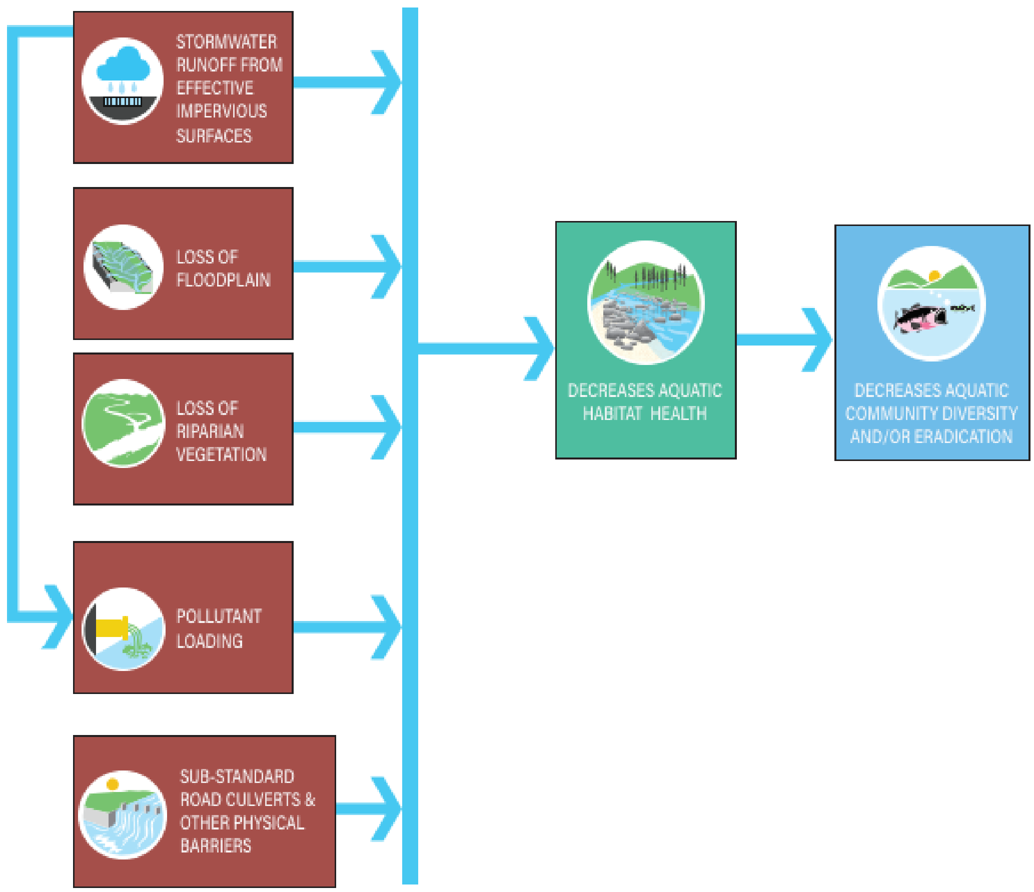

Figure 35. Source of Stressor Elements from the Conceptual Model.

Each of the individual subbasins and areas within the City’s portion of the Small Lake Washington Tributaries Watershed each has its own unique set of characteristics and therefore its own unique limiting factors. As expected for an urbanized watershed, each subbasin and area in the City’s portion of the Small Lake Washington Tributaries 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 this WMP, these limiting factors will be used to develop investments to promote ecological recovery and/or prevent continued degradation specific to each subbasin’s/area’s unique needs.

Table 15 summarizes the limiting factors for each of the subbasins and areas in the Small Lake Washington Tributaries Watershed. The rationale behind what’s shown in Table 15 is provided below.

Table 15. Limiting Factors by Subbasin/Area in the Small Lake Washington Tributaries Watershed

	Limiting Factors			
Subbasin/Area	**Stormwater Runoff from Effective Impervious Surfaces**	**Loss of Floodplain and Riparian Function**	**Pollutant Loading**	**Road Culverts and Other Physical Barriers**
Lakehurst Area	●			○
Meydenbauer Creek	●	○	●	○
Yarrow Creek	●	○	●	○

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

Note that no OSCA efforts were conducted in the Beaux Arts Area, Clyde Beach Area, or Point Cities Area, as these areas have few or no open stream channels. The limiting factors characterization in this section is based on the information provided in this assessment report, particularly land cover and land use information, data from the OSCA surveys, and WDFW fish passage inventories.

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

Lakehurst Area

- Stormwater Runoff from Effective Impervious Surfaces (evidence in support: 4th highest for percent of streambank experiencing erosion according to the OSCA survey)
- Road Culverts and Other Physical Barriers – Secondary (evidence in support: complete fish passage barrier at stream mouth, steep ravine is a physical barrier along with numerous weirs and grade control as Lakehurst Creek passes through the ravine, lower portion of the stream also includes failing weirs and an undersized private drive culvert)

Meydenbauer Creek Subbasin

- Stormwater Runoff from Effective Impervious Surfaces (evidence in support: 60 percent impervious (one of the highest in the City), drains the CBD, highest percent of streambank experiencing erosion according to the OSCA survey, issues with bank stabilization near the stream mouth)
- Pollutant Loading (evidence in support: mixed use and commercial development in the CBD, illicit discharge issues originating from Main Street)
- Loss of Floodplain and Riparian Function – Secondary (evidence in support: lack of tree canopy cover in the CBD, USGS map from 1950 shows open channel up past NE 10th Street that has been piped and filled in since that time)
- Road Culverts and Other Physical Barriers – Secondary (evidence in support: most of Meydenbauer Creek is piped; a City-owned culvert near the stream mouth attracts beavers and is a maintenance challenge)

Yarrow Creek Subbasin

- Stormwater Runoff from Effective Impervious Surfaces (evidence in support: 40 percent impervious area inside the City with higher intensity land use)

- Pollutant Loading (evidence in support: includes both SR 520 and I-405 which are older highways, also includes commercial/office/industrial and multi-family development, suspected failing septic systems in the cities of Bellevue and Kirkland, very low B-IBI scores)
- Loss of Floodplain and Riparian Function – Secondary (evidence in support: extensive wetland and mapped floodplain intact at the mouth of Yarrow Creek in the City of Kirkland, but impacted by road crossings upstream; some WSDOT restoration activities have occurred along SR 520)
- Road Culverts and Other Physical Barriers – Secondary (evidence in support: several highway crossings and beaver dams)

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 36 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.

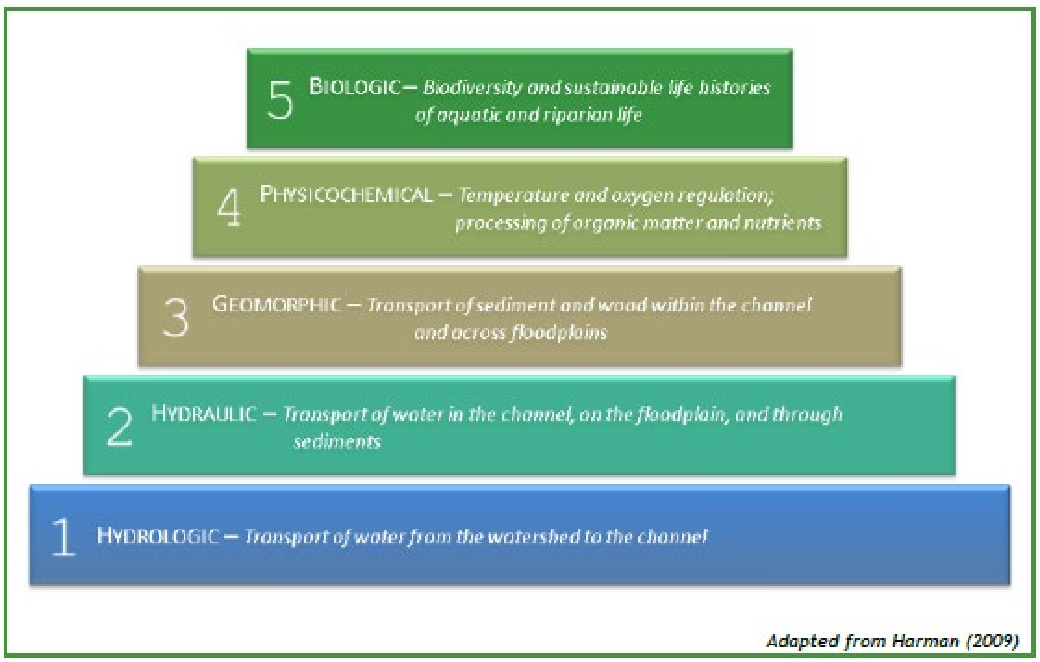

Figure 36. Stream Functions Pyramid.

4. Past and Present Investments

The City has implemented a number of projects to address stream health in the Small Lake Washington Tributaries Watershed. Table 16 outlines these past and present investments by category that have been made by the City (or else by King County, before areas were annexed into the City) in the Small Lake Washington Tributaries 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 16, the City has also invested in the following programmatic activities within the Small Lake Washington Tributaries Watershed:

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

There have also been investments made by others to benefit stream health in Bellevue, including WSDOT. In the Yarrow Creek Subbasin, the City of Kirkland has beaver management contracts and conducts other activities that may influence stream health in the Bellevue portion of the upper subbasin.

Table 16. Past and Present Investments for Stream Health in the City of Bellevue Portion of the Small Lake Washington Tributaries Watershed

Subbasin/Area	Description of Investment(s) by the City
Meydenbauer Creek	A diversion structure and high-flow bypass was constructed in 1983 with an accompanying "No-Detention Zone" for the Central Business District, which has no flow control requirements and now bypasses directly to Meydenbauer Bay; requires regular sediment dredging maintenance activities at outfall.
Meydenbauer Creek	Modeling study was completed for a flood control project along NE 100th street to address flooding concerns at Bellevue Square (along 100th Ave NE and NE 8th). Construction was recently completed, and flooding issues were resolved.
Meydenbauer Creek	Ongoing beaver management and monitoring activities.
Clyde Beach Area	Parks Department project to enhance stream mouth, opened portion of piped system as a stream channel with a restoration plan to improve fish habitat (targeting juvenile Chinook Salmon and lake spawning Sockeye Salmon). Aligns with WRIA 8 creek recovery goals to open piped stream mouths around Lake Washington.
Yarrow Creek (Tributary 0256)	City did a fish passage improvement project including a roughened channel, bridge replacement and walking path, as well as riparian restoration and ingravel "seeding" by King County with macroinvertebrates from Cedar River. Incorporated into long-term monitoring.
Yarrow Creek (Tributary 0254)	Recent Bellevue offsite mitigation included fish passage improvement and stream/riparian restoration.

5. Potential Opportunities

Table 17 presents observations for improving the stream health in the City's portion of the Small Lake Washington Tributaries Watershed based on observations made during the OSCA field work and/or by previous studies conducted by the City. These observations will be moved forward into the Watershed Improvement Plans (WIPs) where they will help identify potential investments for stream health improvement.

While the City has invested in stream restoration and other instream maintenance activities within the subbasins and areas of the Small Lake Washington Watershed, the City has not performed very many upland projects. Upland investments might include retrofits of existing stormwater 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 Small Lake Washington Watershed identified in this AR.

Table 17. Instream Observations for Improving Stream Health in the City of Bellevue Portion of the Small Lake Washington Tributaries Watershed

Subbasin/Area	Reach	Instream Opportunity
Lakehurst Area	General	Opportunities should focus on upland stormwater detention and streambed and streambank stability. The addition of LWM would aid in reducing flow velocity, while increasing sediment retention with the secondary benefit of increasing pool habitat that is valuable to fish as well as other wildlife.
Lakehurst Area	OSCA Reach 1	Address fish passage barrier and enhance stream mouth, remove pipe and restore the channel to allow for natural alluvial processes and habitat creation. Small stream mouth restoration is encouraged in the WRIA 8 Chinook Salmon Recovery Plan.
Lakehurst Area	OSCA Reach 2	Address failing weirs and grade control structures in this reach. Specific opportunity to remove failing culvert in ravine (property owned by Parks), followed by stream channel stabilization and restoration. Due to steep gradient and low base streamflow, this action would not necessarily improve fish access.
Lakehurst Area	OSCA Reach 3	Riparian vegetation enhancement, community awareness, and incentive programs would be highly beneficial for the residential areas.
Lakehurst Area	OSCA Reach 4	City-owned parcel and maintained swale at the very upstream end of the open channel offers an opportunity to re-vegetate or create a wetland for improved stormwater management.
Meydenbauer Creek	General	Projects focusing on upland detention and treatment of stormwater runoff would greatly benefit this system by reducing erosion, pollutant input, and flooding risk. Projects targeting these issues should be prioritized before stream habitat enhancement.
Meydenbauer Creek	General	Riparian enhancements are recommended, particularly the control of invasive plants and the maintenance and planting of native vegetation
Meydenbauer Creek	South Fork (general)	South Fork channel stabilization needed due to severe incision and scour. Streambed and streambank stability projects should include placing large woody material to help retain and sort sediment, attenuate flow velocities, and increase channel complexity and habitat.
Meydenbauer Creek	North Fork (general)	Implement energy dissipation and consider adding treatment at North Fork storm outfall

Subbasin/Area	Reach	Instream Opportunity
Meydenbauer Creek	OSCA Reach 1	Replace101st Street culvert to address fish passage barrier and capacity constraint. This culvert is also currently a monitoring site for beaver management and presents an ongoing challenge for maintenance due to accessibility and safety of cleanout operations.
Meydenbauer Creek	OSCA Reach 2	Land acquisition of OSCA Reach 2 may provide opportunities for the creation of off-channel habitat and the use of process-based restoration to combat flooding and sedimentation issues.
Yarrow Creek	General	Projects targeting bank stability, particularly around high-discharge stormwater outfalls are also recommended. Need for streambed and bank stabilization. Large number of culverts have filled with sediment, causing capacity and fish passage constraints.
Yarrow Creek	General	Projects promoting the upland detention and treatment of stormwater to improve water quality and reduce the impact of highly erosive and flashy stream flows.
Yarrow Creek	General	Stream would benefit from the installation of rounded boulders and LWM to retain and sort sediment, attenuate flow velocities, and increase channel complexity, pool habitat, and instream cover.
Yarrow Creek	General	Numerous fish passage barriers should be corrected, which may require private-public partnerships as many of the barriers are on private property.
Yarrow Creek	General	Projects and programs for controlling invasive plants and planting native species in the riparian corridor is also recommended to increase stream shading and provide a natural source of LWM recruitment into the future.
Yarrow Creek	OSCA Reach 6	Multiple opportunities to address channel modifications in this reach, including stream flow under concrete and concrete structure that creates waterfall.
Yarrow Creek	OSCA Reach 10	Backwatered wetland area caused by relic structure (fish-passage barrier) on private property. Supporting wetland function could be beneficial to stormwater management, but limited access.
Yarrow Creek	Upper portion of the subbasin	Potential for failing septic systems (primarily located in City of Kirkland, but some suspected systems in the City of Bellevue as well).

6. Data Gaps

Missing or incomplete information that were not available to inform this Small Lake Washington Tributaries Watershed AR or future phases of WMP development are as follows:

- Water level and streamflow information are 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 limited to Yarrow Creek and absent from the other subbasins or areas
- Resident fish population and health information is not available for any of the subbasins and areas except Yarrow Creek Subbasin, for which the data is limited
- Macroinvertebrate data is unavailable for Meydenbauer Creek Subbasin
- 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.

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

Appendix A. Small Lake Washington Tributaries Watershed Assessment Report: Data Sources and Methods Used to Summarize Geospatial Watershed Attributes

1.1 Introduction

This appendix to the Small Lake Washington Tributaries Watershed Assessment Report 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 (City); additional spatial data sources are also listed at the end of this appendix. Calculations were generally derived by intersecting spatial data within specific boundaries (Small Lake Washington Tributaries Watershed subbasins and areas, city limits, Greater Kelsey Creek Watershed). 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 8-10) and Soils (Table 2; Figures 11-13)

Geology and soil data were intersected within the city and subbasin boundaries, only area falling in the city limits was counted towards the total area. For geology, the total area of each geologic type was calculated using United States Geological Survey (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 4-6)

Wetland area within each subbasin was calculated by merging King County Sensitive Ordinance wetlands and National Wetland Inventory (NWI) wetlands (2020) data and intersecting wetland boundaries with subbasin boundaries and the city boundary. Subbasin area falling outside of the city limits was excluded, as were wetlands falling outside of city limits.

1.3 Built Infrastructure

1.3.1 Landcover/Tree Canopy (Tables 4 and 6; Figures 15-17; Tables B-4 to B-7)

Landcover analysis was performed using a raster mosaic of the 2017 and 2013 landcover. These data were provided by the City in tag image file format (TIF) files. The more recent (2017) landcover only contained data from within the 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 extent in order to exclude area falling outside the city limits from analysis and reporting.

1.3.2 Land Use (Table 5; Figures 18-20)

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 City's impervious surface polygon dataset (2013) 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 city boundary).

1.3.3 Change in Tree Canopy and Impervious Surfaces (Table 6)

Land use change data was downloaded from the Washington State Department of Fish and Wildlife (WDFW) 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 7)

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 limits or those with an empty SDPIPE field were omitted.

1.3.5 Regional Stormwater Detention Facilities (Table 8; Figure 24)

The regional stormwater detention facilities data was gathered using the City's Storm Inlets layer with focused FACILITYID definition query.

1.3.6 Age of Development Ratings (Table 9; Figures 21-23)

To evaluate the adequacy of stormwater management in the Small Lake Washington Tributaries 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) provided by the City.

1.4 Natural Systems

1.4.1 Riparian Impervious Surface Cover and Riparian Tree Canopy Cover (Table 11; Tables B-4 to B-7)

To calculate the riparian impervious surface cover, a 100-foot 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.

1.4.2 Subbasin Fish Passage Barriers and B-IBI Sample Locations (Tables 13 and 14; Figures 32-34)

Benthic Index of Biotic Integrity (B-IBI) location data was downloaded from the Puget Sound Stream Benthos website and intersected with subbasin boundaries. Fish passage barrier data was downloaded from the WDFW SalmonScape website and intersected with subbasin boundaries.

1.4.3 Stream Gradient (Tables B-4 to B-7)

The stream gradient was calculated as follows:

- Used Dissolve tool to group stream segments by SegmentID (reach number)
- Used Feature Vertices to Points tool to create points at each end of each reach

- Used Extract Values to Points tool to obtain the elevation at the end of each reach
- Exported data to R. Computed stream gradient as the difference between the maximum and minimum elevation divided by the stream length.

1.5 Data Sources Table

See Table A-1.

1.6 Geospatial Data Sources

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

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Table A-1 GIS Data Sources used in Preparation of the Small Lake Washington Tributaries Watershed Assessment Report

Figure / Table subject	Figure number(s)	Table number(s)	Source Data	Source	Year accessed	Notes
All	All	All	Watershed boundaries	City of Bellevue	2020	
			Subbasin Boundaries (Carta.UTIL.SD_Basin)	City of Bellevue		
			Bellevue City Limit (CITYBDY)	City of Bellevue		City of Bellevue boundary isolated from 2020 CITYBDY polygons
			Highways (lines) (SR500KLRSLinesSPS)	WSDOT		
			Streams (Utilities.UTIL.envStreams)	City of Bellevue		
Vicinity map; Surface water features and monitoring sites; Fish passage barriers and B-IBI sampling locations	3-7, 39-42	--	GeoTIFF aerial orthophotos (2020)	City of Bellevue	2020	
Surface water features and monitoring sites	4-8	--	FEMA 100 year floodplain	FEMA	2020	
		3	King County Sensitive Area Ordinance Wetlands	King County		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 City limits.
		3	NWI Wetlands	US FWS National Wetlands Inventory		
Geology	9-12	1	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	13-16	2	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.
Topography	17	--	Contours (Contour50Ft_2016)	City of Bellevue	2020	
Land Cover/Tree Canopy	21-25	4, 6, B-4 to B-8	2017 Land Cover tif (Rasta.ENVIRO.TreeCanopyComposite_2016)	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, 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.
			2013 Land Cover tif (Rasta.ENVIRO.Bellevue_CompositeClass_2014)			
Land Use	22-25	5	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. 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).
			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	
Age of Development Ratings	27-30	9	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.
Regional Stormwater Detention Facilities	26	8	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	
Subbasin Fish Passage Barriers and B-IBI Sample Locations	39-42	16	Fish Passage Barriers	WDFW	2020	
		18	B-IBI Locations	Puget Sound Stream Benthos	2021	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.
		--	OSCA observed knotweed locations (Utilities.UTIL.envKnotweed)	City of Bellevue	2020	
Change in tree canopy and impervious surfaces	--	6	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	--	7	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.
Stream gradient	--	B-4 to B-8	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.
Riparian tree canopy cover	--	B-4 to B-8; 14	2017 Land Cover tif (Rasta.ENVIRO.TreeCanopyComposite_2016)	City of Bellevue	2021	To calculate the riparian tree canopy 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 tree canopy cover for each reach and the subbasin as a whole.
Riparian impervious surface cover	--	B-4 to B-8; 14	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.
Stream flow and hydrologic metric scores	--	10,11	King County stream flow gauge data (Hydrologic information center)	King County	2020	
Category 5 waters	--	12	303(d) list (2014)	Washington Department of Ecology	2020	
Fish species	--	17		King County	2021	

Appendix B
Open Streams Condition Assessment Subbasin Summaries for the Small Lake Washington Tributaries Watershed

Appendix B

Open Streams Condition Assessment Subbasin Summaries for the Small Lake Washington Watershed

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November 2021

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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 the functioning of the City's storm and surface water systems. This appendix summarizes data and qualitative observations gathered during OSCA surveys for three lessor subbasins in the Lake Washington Watershed: Yarrow Creek Subbasin, Meydenbauer Creek Subbasin, and Lakehurst Creek Subbasin. The Coal Creek Watershed and Greater Kelsey Creek Watershed are discussed in their respective Assessment Reports (Bellevue 2021a, Bellevue 2021b).

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.

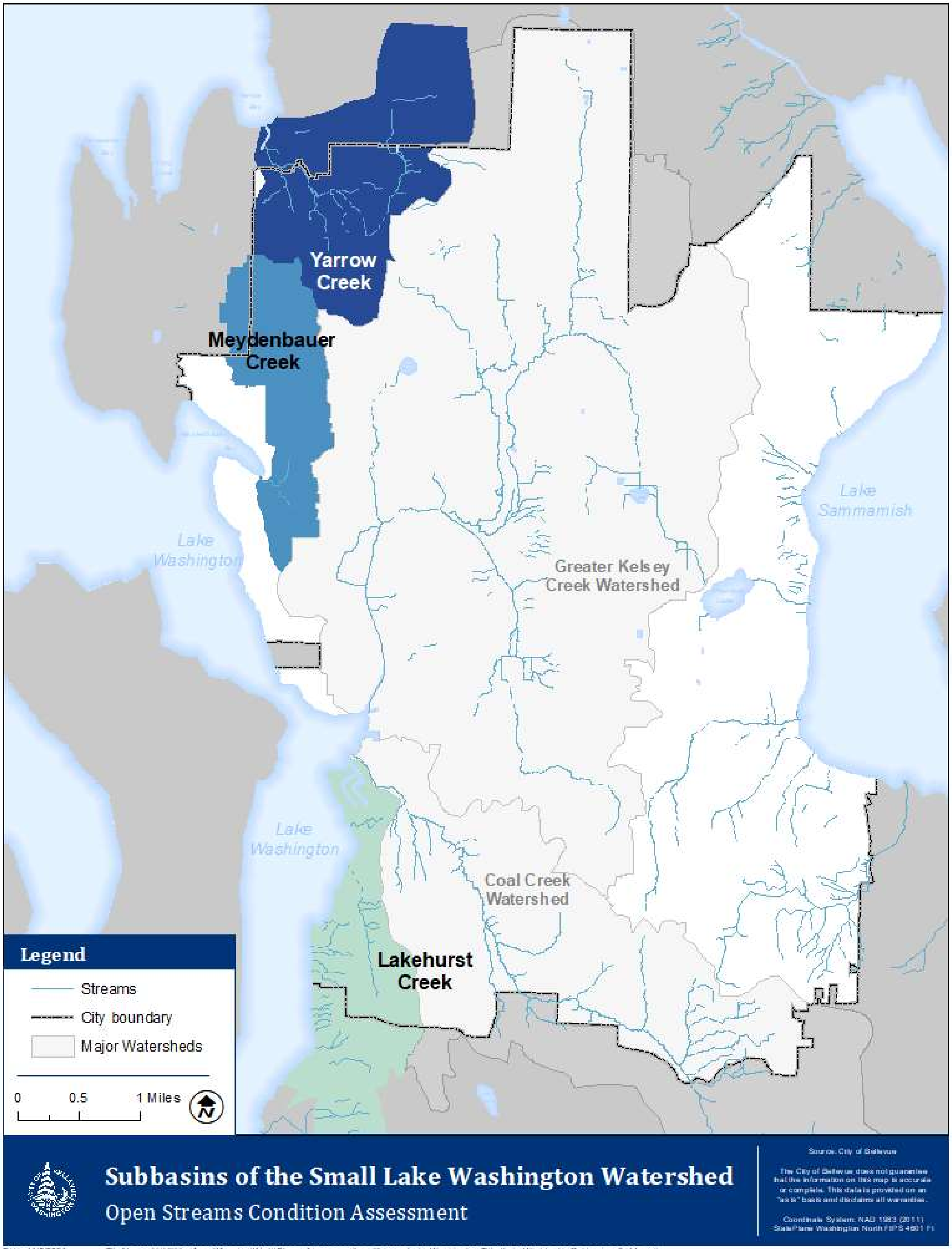
- *Channel type*: Classification given to each stream reach based on its bedform characteristics. These classifications are based on those established by Montgomery and Buffington (1998). However, due to the topography and highly modified environment throughout the City, additional channel types are 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.
- *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 that is covered by tree canopy.
- *Riparian impervious surfaces*: Proportion of the area within 100 ft of the stream that is covered by impervious surfaces.
- *Reach length*: Total length of each stream reach, derived from GIS stream stationing.

B.3 Summary of Results

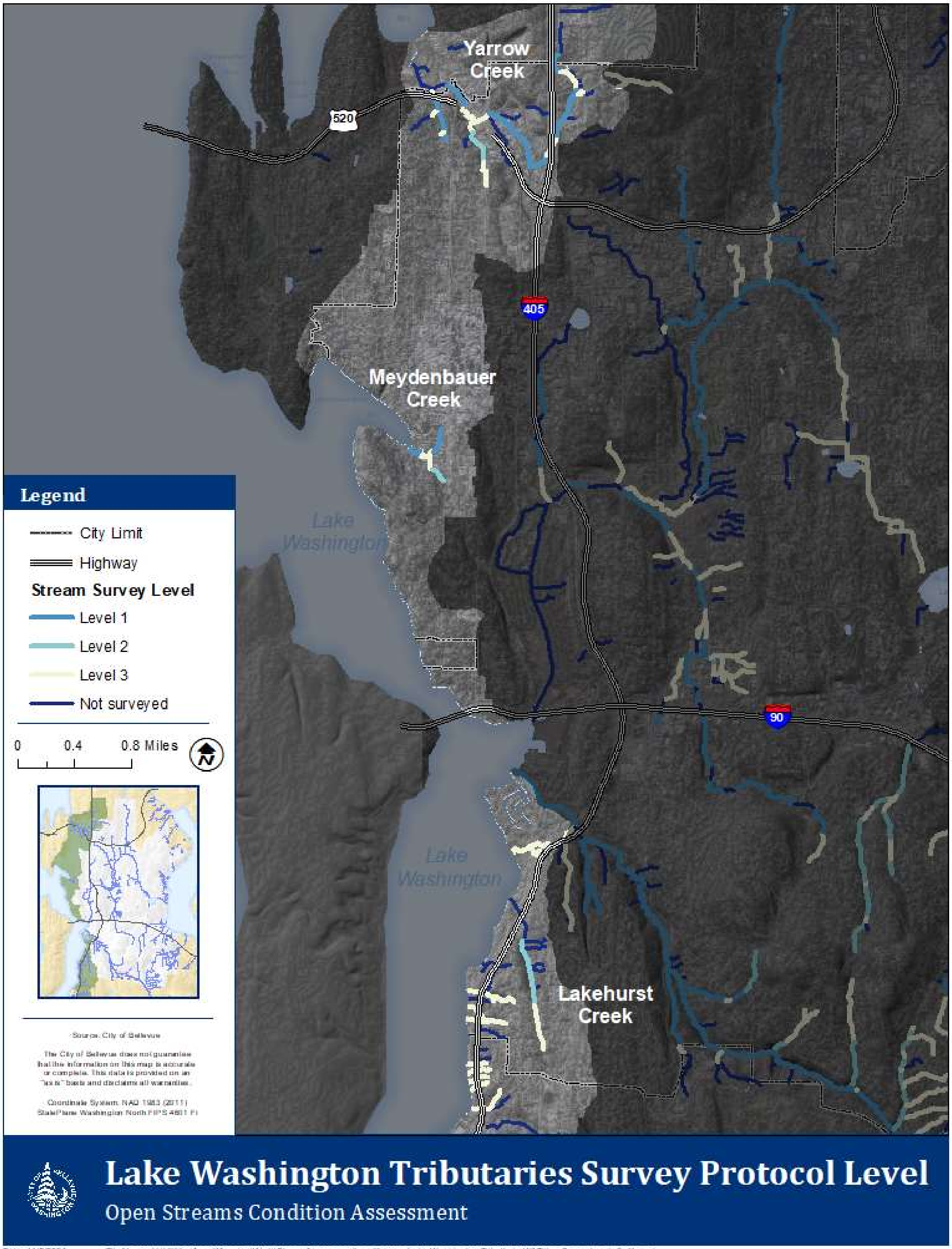
Within the City of Bellevue, there are two major and three minor tributaries to Lake Washington. The two major tributaries, the Greater Kelsey Creek Watershed and the Coal Creek Watershed, are each discussed independently (Bellevue 2021a, Bellevue 2021b). This report will consider the three lesser tributaries that comprise the Small Lake Washington Watershed: Yarrow Creek Subbasin, Meydenbauer Creek Subbasin, and Lakehurst Area (**Map B-1**). (In the City's stormwater basin delineation, the term "Area" is applied when the small basins surrounding multiple minor independent streams or drainages are grouped together and is thus not a true subbasin).

The lesser tributaries to Lake Washington are highly varied in condition and strongly impacted by urban development. In terms of stream gradient and riparian conditions, they most closely resemble urbanized subbasins in the Kelsey Creek Watershed. In general, these subbasins have average to below average riparian tree canopy cover and worse than average riparian impervious surface cover when compared to other subbasins in the City. The channels have also been modified resulting in a greater than average proportion of the stream being piped.

The primary channels in the Small Lake Washington Watershed were surveyed as part of the Open Streams Condition Assessment (OSCA) in the summer and fall of 2020. Yarrow Creek and Meydenbauer Creek were primarily surveyed under a Level 1 protocol, while Lakehurst Creek and the smaller tributaries to Yarrow and Meydenbauer creeks were surveyed under a Level 2 protocol (**Map B-2)**. Additionally, several of the minor drainages in the Lakehurst Area were surveyed with Level 3 "hot spot" checks in the fall of 2019; these minor drainages, which do not maintain year-round flow, will not be discussed in this report. **Map B-2** and **Table B-3** present the surveyed streams within the lesser subbasins of Lake Washington and the survey level used for each.



Map B-1. The three surveyed subbasins of the Small Lake Washington Watershed.



Map B-2. Map showing the survey protocol level used for the lesser tributaries to Lake Washington.

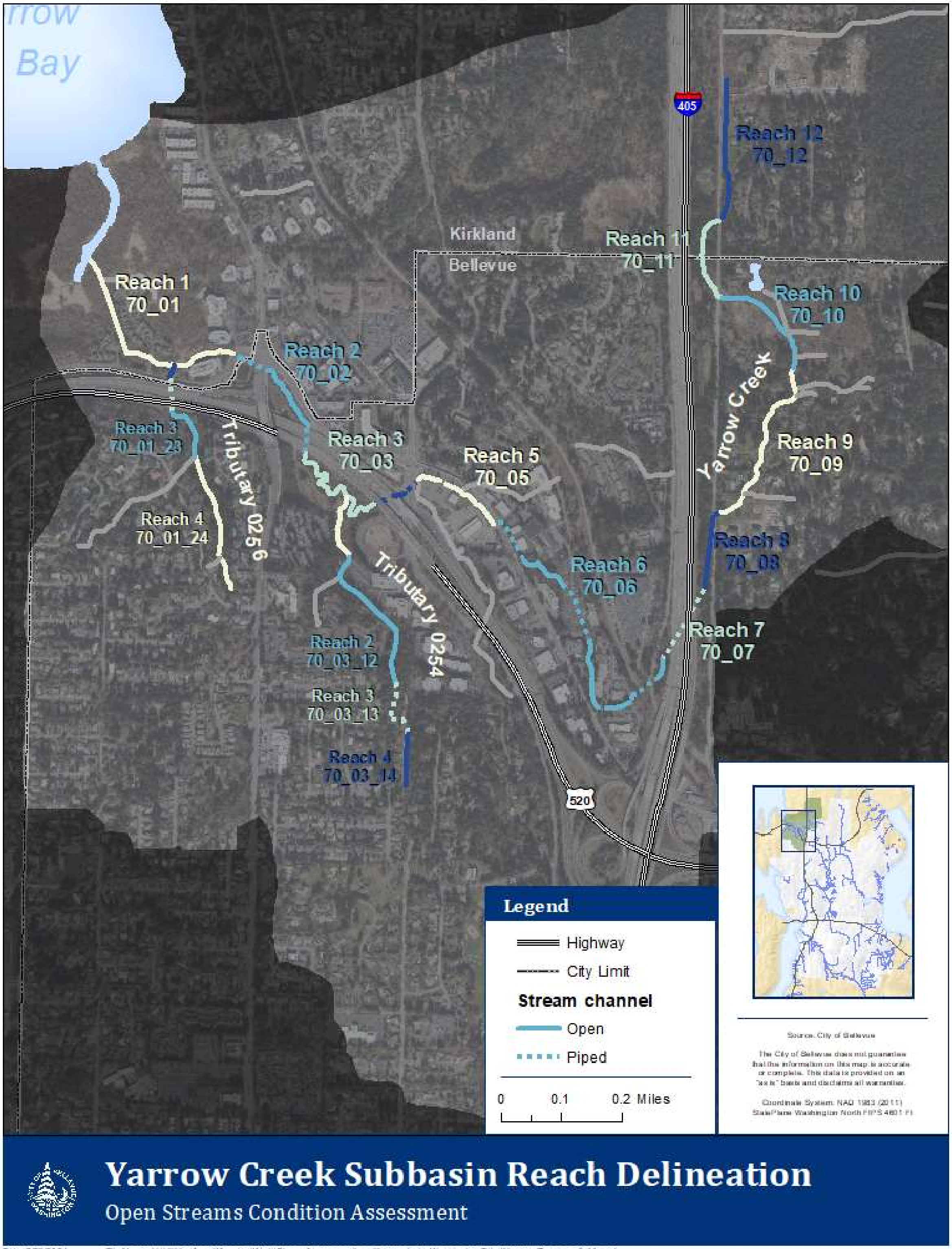
Table B-3. List of inventoried Bellevue streams, including Bellevue Stream Segment number and Water Resource Inventory Area (WRIA) number, organized from north to south and downstream to upstream.

Bellevue Subbasin	Stream Name	WRIA #	Stream Reach	Bellevue Segment ID	Assessment Level
Yarrow Creek Subbasin	Yarrow Creek	08.0252	Reach 2	70_02	1
			Reach 5	70_05	1
			Reach 6	70_06	1
			Reach 8	70_08	1
			Reach 9	70_09	1
	Yarrow Tributary 0256	08.0256	Reach 3	70_01_23	1
			Reach 4	70_01_24	1
	Yarrow Tributary 0254	08.0254	Reach 2	70_03_12	2
Meydenbauer Creek Subbasin	Meydenbauer Creek	08.0258	Reach 1	72_01	1
			Reach 4	72_04	1
	South Fork Meydenbauer Creek	-	Reach 2	72_02_12	2
Lakehurst Creek Area	Lakehurst Creek	08.0281	Reach 2	86_02	1

B.3.1 Yarrow Creek Subbasin

The Yarrow Creek Subbasin encompasses 1,654 acres and passes through the Northwest Bellevue neighborhood. Only a little over half of the subbasin is within the City of Bellevue; the rest, including the stream mouth at Lake Washington, is in the City of Kirkland or unincorporated King County. Within the City of Bellevue, over 60% of the land use is public right of way and includes Interstate 405 (I-405), State Route 520 (SR-520), and large arterials including Northup Way and Bellevue Way NE. The rest of the land use is residential or commercial and mixed use. Park and open space accounts for about 1% of the land area within the City but 25% of the entire subbasin and includes Bridle Trails State Park near the headwaters and Yarrow Bay Wetlands at the mouth. Elevation ranges from 15 ft to 537 ft. Overall, the subbasin has 4.7 miles of open stream channel and 20.4 miles of storm drainage pipes within the City (Bellevue 2017).

The Yarrow Creek Subbasin includes one mainstem channel with several significant tributaries, including Tributaries 0254 and 0256 (**Map B-3**). The present-day headwaters are in a neighborhood around the southern end of Bridle Trails State Park. The upper portion of Yarrow Creek passes through residential properties and crosses under 116th Avenue NE multiple times. Middle Yarrow Creek is highly altered by urban development. The stream is piped under I-405 and then enters a commercial office complex where it is intermittently piped and there are numerous channel modifications that create sluggish backwatered areas and large hydraulic drops. The stream is then confined as it parallels Northup Way with minimal canopy cover. Lower Yarrow Creek has been improved by Washington State Department of Transportation (WSDOT) mitigation work. The stream passes under 108th Avenue NE and SR-520 in large box culverts and then enters the WSDOT restoration area south of SR-520 where it confluences with Tributary 0254. At the time of the OSCA surveys in 2020, this reach has been converted into a large beaver-impounded wetland. The stream crosses back under SR-520 and, although it is confined by major roads, WSDOT restoration in this area has greatly benefited the stream and riparian area. The stream flows through another large box culvert under Lake Washington Boulevard NE and crosses into the City of Kirkland, where it confluences with Tributary 0256, passes through a multifamily residential area, and enters an extensive wetland at its outlet into Lake Washington.



Map B-3. Stream reaches of the mainstem and surveyed tributaries of Yarrow Creek.

B.3.1.1 Channel Morphology and Riparian Corridor

The stream corridor in the Yarrow Creek Subbasin is highly variable and altered by urban development and land use. The average gradient for surveyed reaches in the subbasin is 3.2% (**Table B-4** and **Table B-5**) which is about average for streams across the City. The stream generally has a plane-bed morphology with a wetland at its confluence with Lake Washington as well as a beaver-created wetland in Reach 3. Sediment dynamics are strongly influenced by flashy stream flows with the general pattern of streambank erosion in the upper portion of the subbasin and channel incision throughout the subbasin resulting in sediment accumulation in the lower reaches. Issues with erosion in Yarrow Creek have been evident for decades. A 1971 study by the Bellevue Utilities Department highlighted Yarrow Creek as having moderate to severe erosion potential (as cited in Kerwin 2001). Because the channel is altered and confined, this has resulted in sedimentation issues around several culverts. Approximately 25% of the stream channel within the City is piped, which is higher than average for streams in the City.

The Yarrow Creek Subbasin has an impaired riparian corridor, although stream restoration and aquatic enhancement efforts have benefited portions of the mainstem as well as Tributary 0254. Although land use in the upper portions of the subbasin is primarily residential, the lower subbasin has a rather high proportion of impervious surfaces. Across all surveyed reaches within City limits, the subbasin has 50% riparian tree canopy cover (but see canopy cover footnote in **Table B-4**) and 26% impervious surfaces within 100 ft of the stream which is worse than average for subbasins across the City. The canopy is variable and generally consists of alder, big leaf maple, and cedar with an understory of vine maple, salmonberry, and Himalayan blackberry. Invasive plant species are intermittently prevalent and occasionally quite dense, particularly Himalayan blackberry and English ivy throughout the subbasin as well as jewel weed in the wetland Reach 3. Impacts from human activities and unauthorized encampments have degraded the riparian corridor in portions of the mainstem and both tributaries by damaging vegetation and causing localized streambank erosion. Litter and human waste pose additional water quality concerns.

Yarrow Creek is about average in width although shallow compared to other streams in the City. Across all surveyed reaches, the median wetted and bankfull widths are 7.3 ft and 8.9 ft, respectively (**Figure B-1**). The median minimum, representative, and maximum depths are 0.3 ft, 0.4 ft, and 0.6 ft, respectively. This is the second shallowest maximum depth observed in the City during OSCA surveys. Beaver dams are responsible for the greater wetted depths observed in mainstem Reaches 2 and 5 (**Figure B-2**).

Table B-4. Yarrow Creek mainstem reach attributes.

	Reach 1*	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Reach Segment ID	70_01	70_02	70_03	70_04	70_05	70_06
River Mile Boundaries	0.00 – 0.36	0.36 – 0.59	0.59 – 0.77	0.77 – 0.87	0.87 – 1.03	1.03 – 1.57
Sediment Dynamics	-	Response	-	Response	Response	Highly altered
Channel Type	Wetland	Plane-bed	Wetland	Plane-bed	Forced plane-bed§	Highly altered
Stream Gradient (%)	Unknown*	< 0.5	1.0	2.2	1.1	3.8
Riparian Canopy Cover (%)	Unknown*	3.2†	2.1†	3.4	21.4	44.5
Riparian Impervious Surface Cover (%)	20.2	53.3	10.5	61.0	62.5	44.5
Reach Length (ft)	1,900	1,200	950	550	860	2,840
	Reach 7	**Reach 8**	**Reach 9**	**Reach 10**	**Reach 11***	**Reach 12***
Reach Segment ID	70_07	70_08	70_09	70_10	70_11	70_12
River Mile Boundaries	1.57 – 1.70	1.70 – 1.83	1.83 – 2.13	2.13 – 2.33	2.33 – 2.48	2.48 – 2.73
Sediment Dynamics	Forced transport	Transport/ Source‡	Response	-	Response/ Source‡	Unknown*
Channel Type	Piped conveyance	Cascade	Plane-bed	Ditched wetland	Plane-bed	Unknown*
Stream Gradient (%)	6.2	5.9	3.2	1.0	*	*
Riparian Canopy Cover (%)	-	56.7	51.2	63.2	66.6¥	*
Riparian Impervious Surface Cover (%)	64.4	25.6	19.8	5.4	7.0	21.9
Reach Length (ft)	650	725	1,575	1,050	800	1,300

* Reaches 1 and 12 and the upstream half of Reach 11 are outside the City of Bellevue.

† Restoration plantings were very young at the time the canopy data were collected (2016). Canopy coverage is now much higher, although inundation from beaver ponds has subsequently killed some of the canopy gained in Reach 3.

§ The channel is forced to take on a plane-bed morphology due to confinement but would likely adopt a pool-riffle morphology if unconfined. Additionally, the downstream half of the reach is backwatered from beaver dams.

‡ Streambank erosion and channel incision is an active source of sediment that is accumulating downstream.

¥ Within Bellevue city limits only.

Table B-5. Reach attributes for Yarrow Tributaries 0256 and 0254.

	Yarrow Tributary 0256			
	Reach 1*	**Reach 2**	**Reach 3**	**Reach 4**
Reach Segment ID	70_01_21	70_01_22	70_01_23	70_01_24
River Mile Boundaries	0.00 – 0.02	0.02 – 0.08	0.08 – 0.17	0.17 – 0.41
Sediment Dynamics	Unknown*	Response	Response	Transport/Source‡
Channel Type	Unknown*	Plane-bed	Plane-bed	Cascade
Stream Gradient (%)	Unknown*	3.2†	2.8	5.9
Riparian Canopy Cover (%)	Unknown*	1.1	62.0	73.4
Riparian Impervious Surface Cover (%)	19.0	58.3	9.3	9.0
Reach Length (ft)	123	293	497	1,238
	Yarrow Tributary 0254			
	Reach 1	**Reach 2**	**Reach 3**	**Reach 4**
Reach Segment ID	70_03_11	70_03_12	70_03_13	70_03_14
River Mile Boundaries	0.00 – 0.12	0.12 – 0.37	0.37 – 0.48	0.48 – 0.57
Sediment Dynamics	-	Response	Forced transport	NA¥
Channel Type	Wetland	Plane-bed	Piped conveyance	NA¥
Stream Gradient (%)	2.2	3.8	11.2	3.0
Riparian Canopy Cover (%)	57.1	75.9	-	57.2
Riparian Impervious Surface Cover (%)	7.2	21.3	13.3	27.8
Reach Length (ft)	625	1,340	560	460

* Reach 1 of Tributary 0256 is outside the City of Bellevue.

† Stream gradient calculated manually from the digital elevation model as the generated value was clearly incorrect.

‡ Streambank erosion and channel incision is an active source of sediment.

¥ Mapped channel is a roadside ditch that was dry and lined with leaves and other organic litter; not a true stream channel.

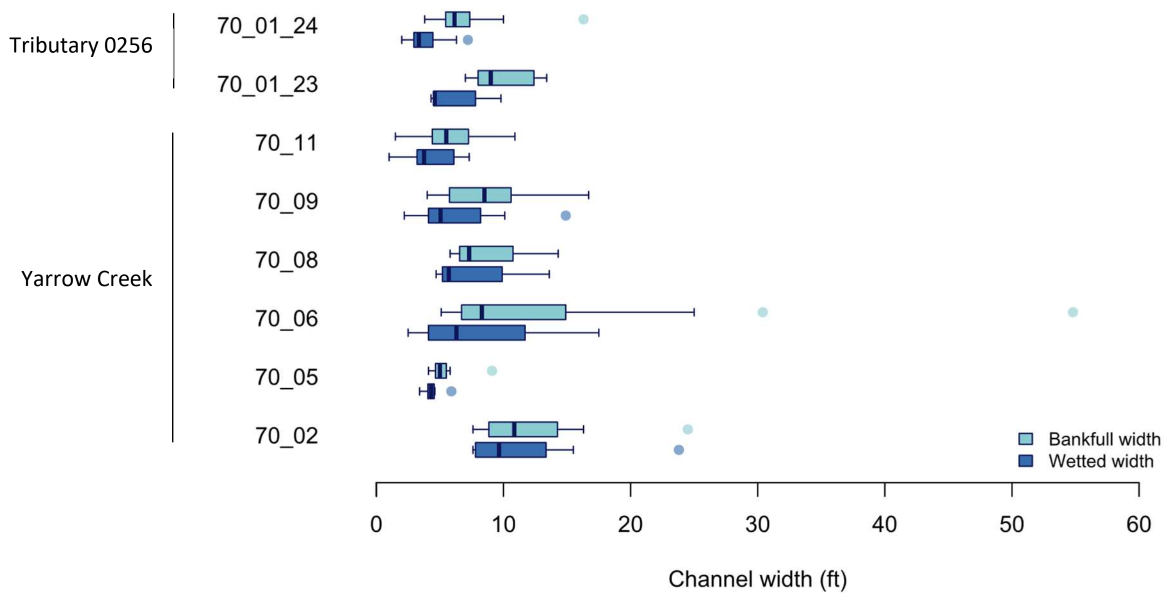


Figure B-1. Boxplot of the wetted and bankfull channel widths for stream reaches in the Yarrow Creek Subbasin that were surveyed under a Level 1 protocol.

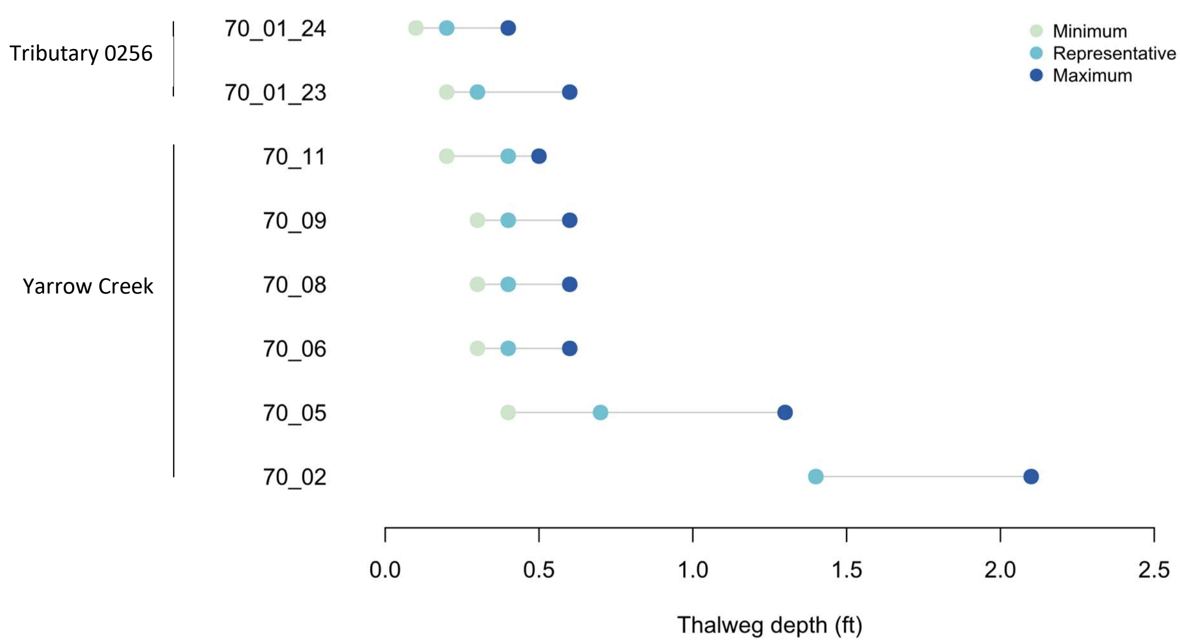


Figure B-2. Dumbbell plot of wetted stream depths for stream reaches in the Yarrow Creek Subbasin surveyed under a Level 1 protocol. Points represent the median value for the minimum, representative, and maximum depth for each reach. The minimum and representative depths are the same for Reach 70_02.

B.3.1.2 Habitat Unit Composition and Off-Channel Habitat

The Yarrow Creek Subbasin is strongly dominated by riffle habitat, although beavers create additional habitat complexity in the downstream reaches (**Figure B-3** and **Figure B-4**). For all stream reaches surveyed under a Level 1 protocol, riffle habitat accounts for 67% of the stream area and 82% of the stream length, followed by pond habitat which is mostly created by beaver activity and comprises 23% of the stream area and 12% of the stream length. The area comprised by pond habitat is an underestimate because a large pond habitat unit had to be omitted from the area analysis because widths could not be safely measured; this habitat unit is included in the length analysis. Pool habitat accounts for only 6% of the stream area (4% by length) while glide habitat accounts for the remaining 3% of the stream area (2% by length). By stream length, the Yarrow Creek Subbasin has the 2nd highest proportion of riffle habitat and 3rd lowest proportion of pool habitat found in OSCA-surveyed subbasins throughout the City.

Pool habitat in the Yarrow Creek Subbasin is lacking in both quantity and quality. Across all surveyed reaches, there is an average of 11 pools per mile (approximately 54 bankfull channel widths per pool), which is well below average for streams in the City and far below the approximately 110 pools per mile expected in similarly sized, "properly functioning" streams (NOAA 1996). When present, pools are generally not very deep, and at the time of the survey, no pool in the subbasin exceeded 2 ft maximum depth. The median residual pool depth is 1.0 ft (**Figure B-5**). Although this depth is sufficient for resident trout (Behnke 1992), salmon are generally considered to require a residual pool depth of three or more feet (Marcotte 1984 as cited in CDFG 1998, NOAA 1996).

There is very little off-channel habitat in the Yarrow Creek Subbasin. Beaver activity in Reach 3 has converted the restored channel into a large, ponded wetland. This provides many of the same benefits as off-channel habitat including stormwater and sediment retention and deep, slow water habitat. Reach 10 appears to be a mix of pasture and wetland and may provide similar benefits but could not be surveyed. Much of the rest of the subbasin is altered and confined by urban and residential land use and disconnected from the historic floodplain.

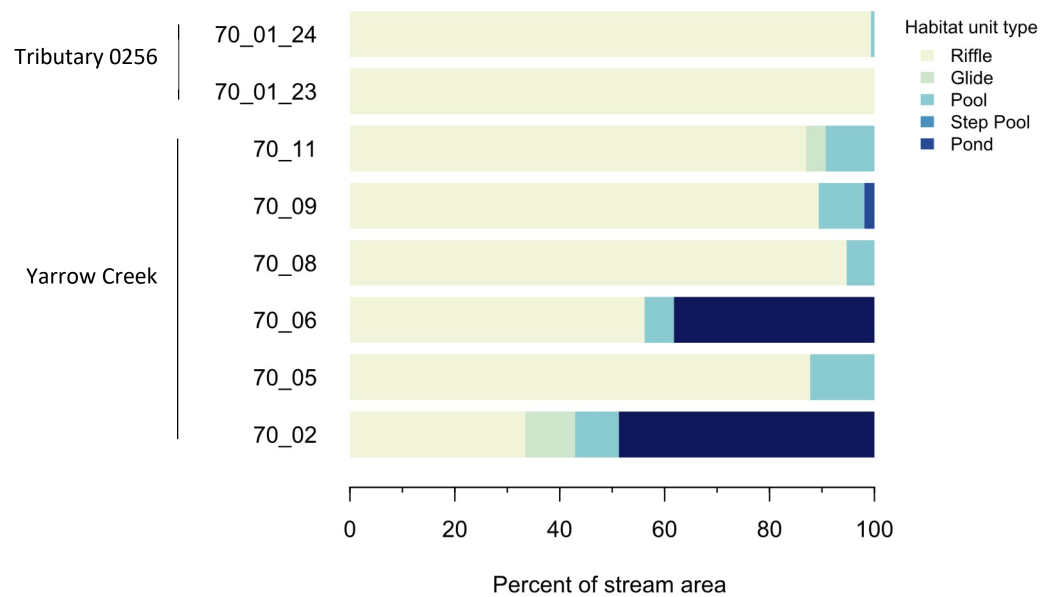


Figure B-3. Habitat unit composition (by percent area) for stream reaches in the Yarrow Creek Subbasin surveyed under a Level 1 protocol. Pond habitat is omitted in Reach 70_05 because widths could not be safely measured.

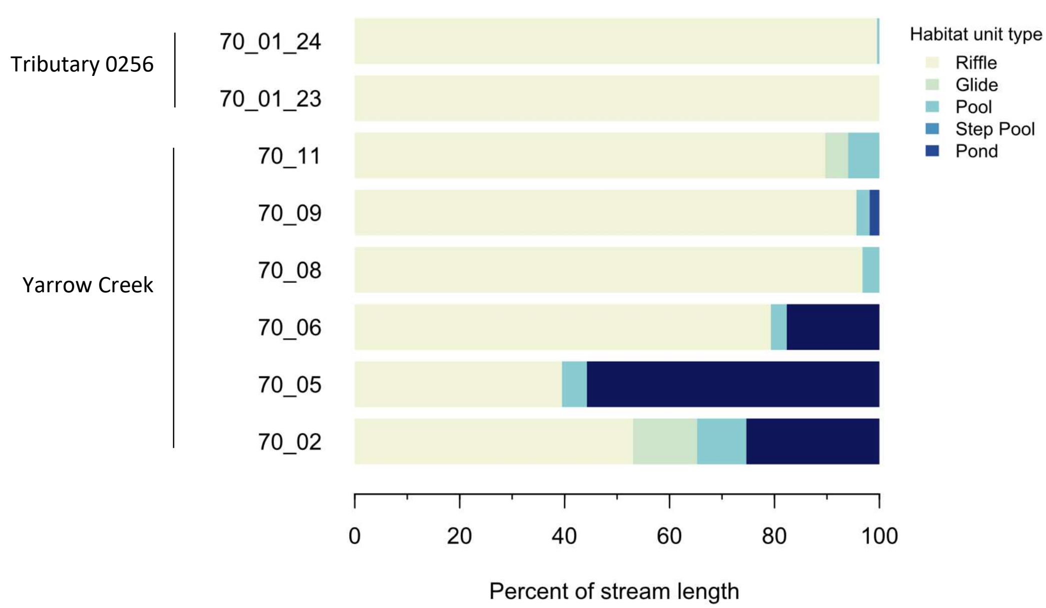


Figure B-4. Habitat unit composition (by percent length) for stream reaches in the Yarrow Creek Subbasin surveyed under a Level 1 protocol.

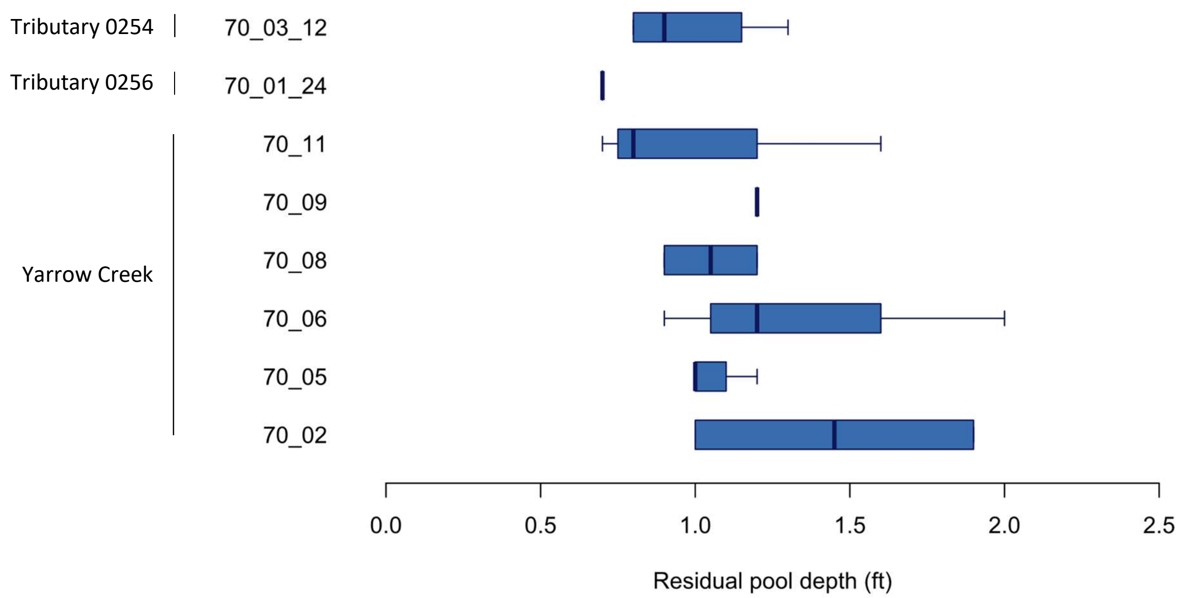


Figure B-5. Boxplot of residual pool depths observed in surveyed stream reaches of the Yarrow Creek Subbasin. Reach 70_01_23 is omitted as it did not contain pool habitat.

B.3.1.3 Large Woody Material

Large woody material (LWM) is lacking in the Yarrow Creek Subbasin. The overall LWM density for surveyed reaches is 180 pieces per mile (11 pieces per 100 m), which is about average for subbasins across the City but far below that seen in similarly-sized reference streams (Fox and Bolton 2007). Only one short reach, Reach 3 of Tributary 0256, has LWM levels comparable to that seen in unimpacted streams (**Figure B-6)**. The majority of LWM in the Yarrow Creek Subbasin is of natural origin, although restoration activities have augmented natural recruitment, particularly in the lower mainstem reaches. Beavers have also facilitated natural LWM recruitment in the lower reaches. Overall, 14% of the LWM in the subbasin was placed. LWM is influential in the creation and maintenance of pool habitat. A total of 51% of all LWM is associated with pool habitat, yet pool habitat accounts for only 6% of the stream area.

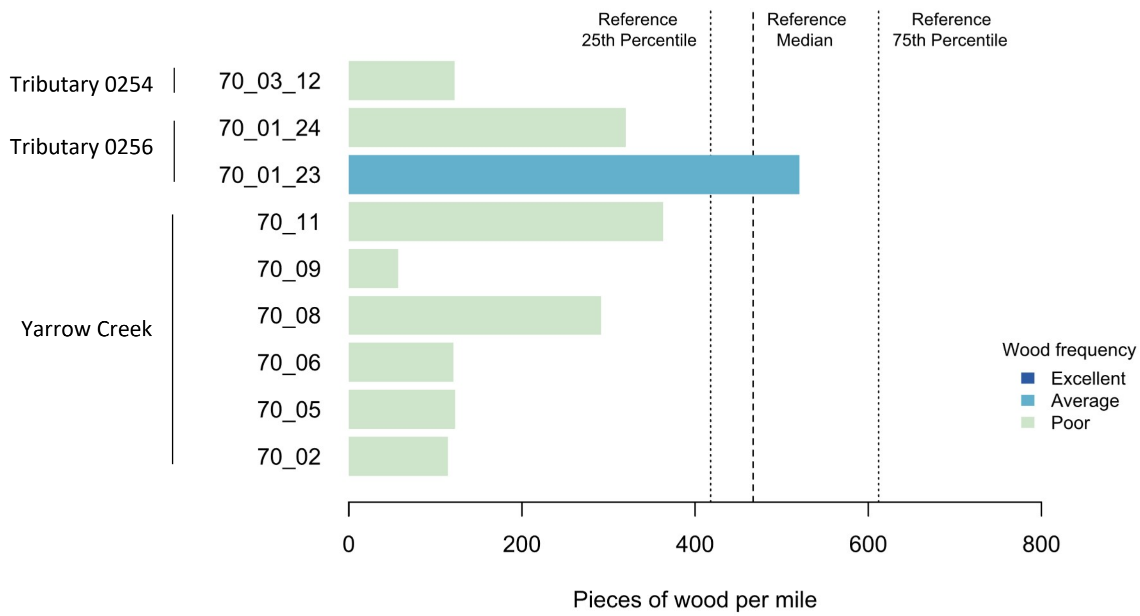


Figure B-6. Large woody material frequency in surveyed stream reaches of the Yarrow Creek Subbasin compared to reference levels (Fox and Bolton 2007).

B.3.1.4 Streambed Substrate

Streambed substrate in the Yarrow Creek Subbasin is predominantly fines and gravels. Across all riffle habitat surveyed under a Level 1 protocol, the substrate is composed of fines (46%), gravel (43%), cobble (7%), boulders (2%), and "bedrock" (1%). However, the substrate classified as bedrock consists almost entirely of cement that has been used to line the channel at multiple locations in mainstem Reach 6 and Tributary 0254 Reach 4 (**Figure B-7**). Additionally, the proportion of fines in the subbasin is higher than average for streams in the City and unsuitably high for spawning salmonids. There are only small, localized areas of acceptable spawning substrate scattered throughout the subbasin.

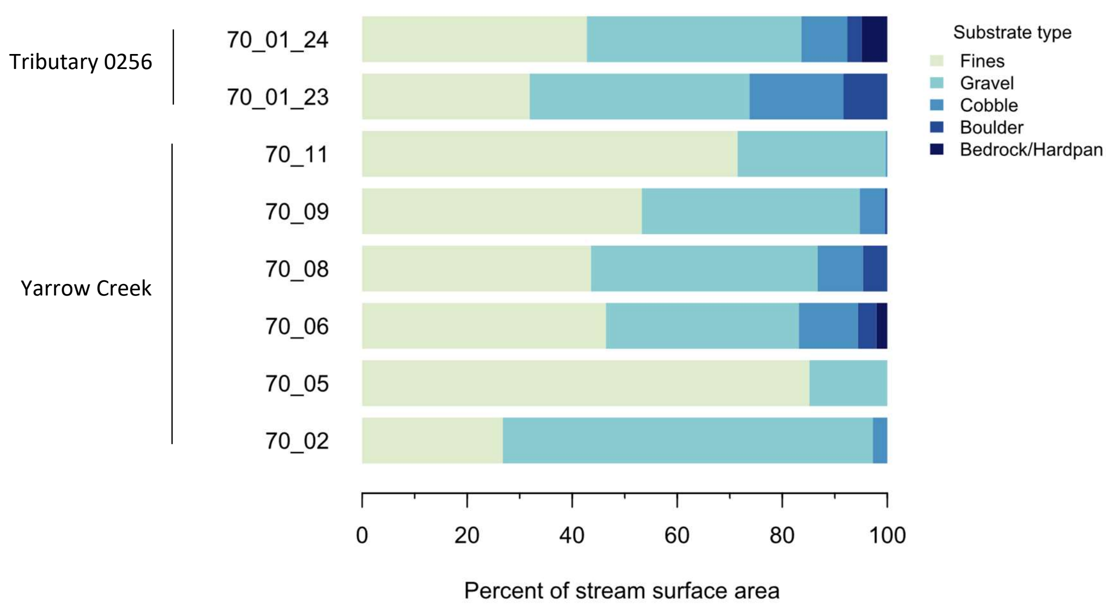


Figure B-7. Substrate composition of riffle habitat in surveyed stream reaches of the Yarrow Creek Subbasin, determined by visual estimation.

B.3.1.5 Streambank Conditions

The Yarrow Creek Subbasin has an approximately average proportion of armored streambanks for urban streams. Across all surveyed reaches, 8% of the streambanks are armored, which is slightly less than average for subbasins in the City. Streambank armoring varies considerably by stream reach (**Figure B-8**) and is most prevalent in mainstem Reach 9 where the stream passes through numerous residential properties. Nearly all (97%) streambank armoring is traditional or "hard" armoring and generally consists of large angular rock or concrete.

The Yarrow Creek Subbasin has considerable streambank erosion. Across all surveyed reaches, 30% of streambank shows signs of erosion and 22% of the streambank is undercut. This is the highest instance of undercut streambanks and second highest instance of erosion in subbasins across the City. Both erosion and undercutting vary considerably among stream reaches (**Figure B-9** and **Figure B-10**). Much of this streambank erosion is low in height (< 5 ft) and is likely the result of strong and flashy streamflow associated with urban development. There are a few locations in upper Reach 6 and Reach 8 where the streambank erosion is greater than 10 ft in height, and in two of these areas the erosion is associated with stormwater outfalls. Additionally, individual instances of streambank erosion generally extend further than in other subbasins in the City. The median length of streambank erosion is 33 ft, which is the second highest observed in the City, and some instances of erosion extend for over 200 ft along the streambank.

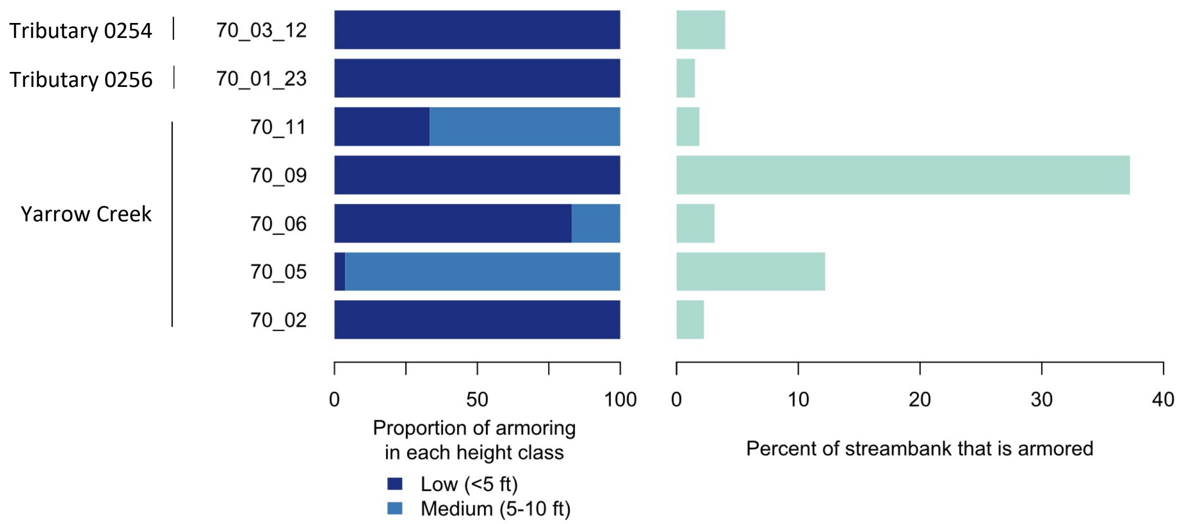


Figure B-8. Multi-panel bar charts showing the height and proportion of armoring in each surveyed stream reach in the Yarrow Creek Subbasin. Omitted reaches had no armoring.

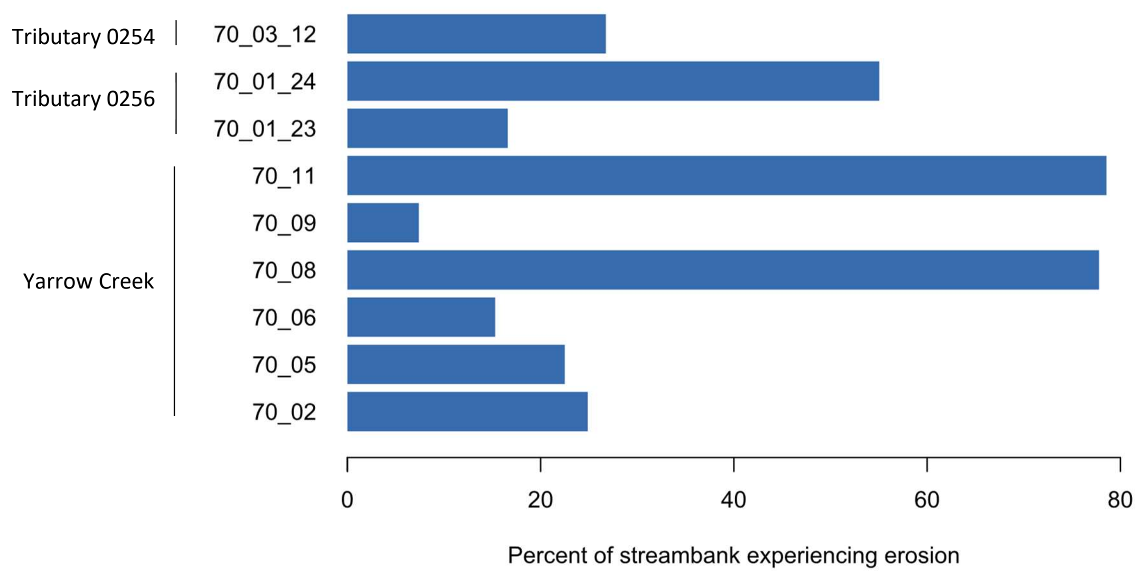


Figure B-9. Percent of each surveyed reach in the Yarrow Creek Subbasin that is experiencing erosion.

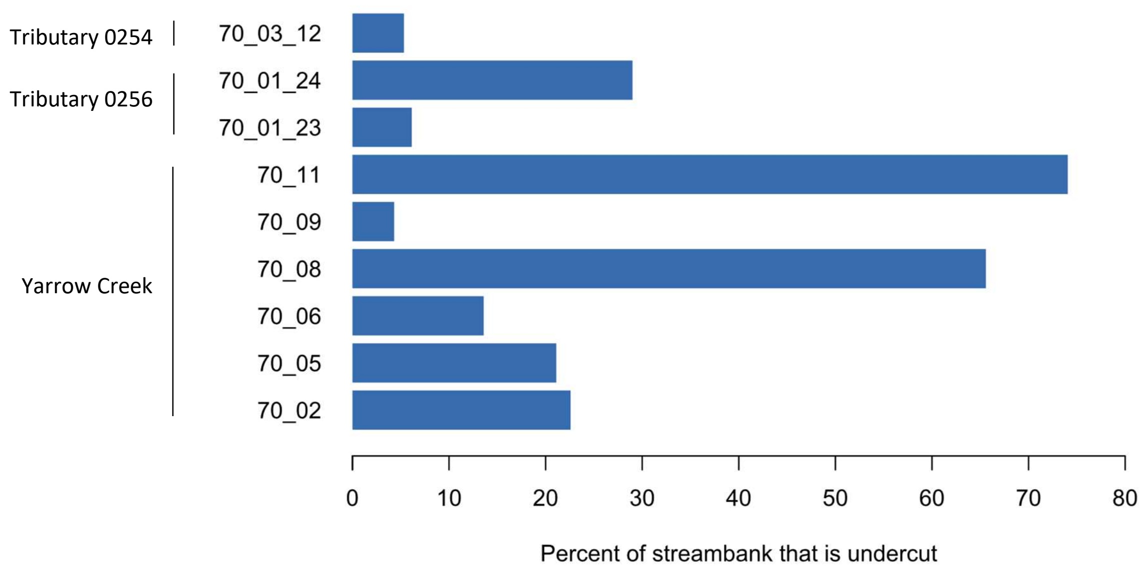


Figure B-10. Percent of each surveyed reach in the Yarrow Creek Subbasin with undercut streambanks.

B.3.1.6 Fish Habitat and Passage Barriers

All surveyed stream reaches in the Yarrow Creek Subbasin are fish-bearing or potentially fish-bearing. The subbasin historically supported spawning Coho Salmon and kokanee (Kerwin 2001). During the OSCA surveys, fish (primarily small trout) were observed throughout the mainstem of Yarrow Creek but not in either Tributary 0254 or Tributary 0256. In addition to resident sculpin and Cutthroat Trout, adfluvial Cutthroat Trout have also been observed spawning in Yarrow Creek. Water quality is a concern in this subbasin considering the high density of roadways directly adjacent to the stream, and illicit discharges are unfortunately common. Further challenges to fish habitat include a lack of channel complexity including quality pool and edge habitat and instream cover. The proportion of fines in the substrate also poses a challenge to spawning salmonids.

There are numerous barriers to fish passage in the Yarrow Creek Subbasin. WDFW (2021) has formally documented eleven complete and three partial fish passage barriers in the mainstem of Yarrow Creek within the City of Bellevue. Additionally, there is a complete fish passage barrier in Tributary 0256. The City is listed as owning three of the complete barriers and two of the partial barriers. Two additional barriers in Tributaries 0254 and 0256 are still listed in the WDFW database but are likely no longer barriers due to mitigation actions by the City and WSDOT, respectively. One privately-owned complete barrier in the mainstem is considered a dam with a concrete spillway that forms the break between Reaches 9 and 10. This relic structure has likely altered the hydrology of the stream, forming a backwatered wetland area in Reach 10. In addition to the formally documented barriers, issues with sedimentation and streambed aggradation presents additional challenges to fish passage and movement through the many culverts and piped stream conveyances in this subbasin. Extensive beaver dams in lower Yarrow Creek pose additional, temporary barriers, particularly during periods of low streamflow.

B.3.1.7 Opportunities

Yarrow Creek and its tributaries form a classic example of degraded urban streams and offer many opportunities to sustain and restore ecological functions in the subbasin. A high priority for this subbasin should be projects promoting the upland detention and treatment of stormwater to improve water quality and reduce the impact of highly erosive and flashy stream flows. Projects targeting bank stability, particularly around high-discharge stormwater outfalls are also recommended. Additionally, the stream would benefit from the installation of rounded boulders and LWM to retain and sort sediment, attenuate flow velocities, and increase channel complexity, pool habitat, and instream cover. Projects and programs for controlling invasive plants and planting native species in the riparian corridor is also recommended to increase stream shading and provide a natural source of LWM recruitment into the future. Restored portions of Yarrow Creek and its tributaries offer the opportunity to engage the community through stewardship activities and outreach (i.e., volunteer planting events, signage directed to behavior change, etc.), and promote general awareness of stream health and aquatic resources. Additionally, this subbasin should be included in City programs and initiatives to address the impact of human activities and encampments on water quality and riparian and stream health. Furthermore, the numerous fish passage barriers should be corrected, which may require private-public partnerships as many of the barriers are on private property.

B.3.2 Meydenbauer Creek Subbasin

Located in northwest Bellevue, the Meydenbauer Creek Subbasin encompasses 897 acres and includes portions of the Northwest Bellevue, Downtown/Bel-Red, and West Bellevue neighborhoods. Approximately 90% of the subbasin is within the City of Bellevue although the northwestern portion of the subbasin crosses into Clyde Hill. Land use in the subbasin is highly varied and includes a little over half of the Bellevue downtown area. Single family residential properties and public right of way each account for over a quarter of the land area within City limits, while commercial and office use is the next most common land use type. Elevation in the subbasin ranges from 18 ft to 392 ft. Overall, the subbasin has 0.4 miles of open channel and 31 miles of storm drainage pipes within City limits (Bellevue 2017). This is the highest proportion of storm drainage pipes relative to open channel present in the City.

Today, Meydenbauer Creek is rather short and branches into two forks (**Map B-4**). The northern fork is considered the mainstem and carries the majority of base streamflow. Its headwaters are now contained within the storm drainage network that outfalls into an open channel near Bellevue Way SE and Main Street. The stream passes through commercial and multi-family properties before being piped under and parallel to 102nd Avenue SE and outfalling at the confluence with the South Fork. There is a short section of potentially wetland habitat before the channel once again becomes confined and then passes through two short, piped sections before reaching the confluence with Lake Washington. The South Fork of Meydenbauer Creek is piped from its confluence with the mainstem to a ditch along SE 6th Street. The channel then passes through a few residential properties before reaching its outfall from the storm drainage network near Bellevue Way and SE 8th Street. At the time of the OSCA surveys in October of 2020, the South Forth of Meydenbauer Creek was dry, although substantial channel incision reveals that this channel is subject to flashy streamflow.

Map B-4. Stream reaches for Meydenbauer Creek and the South Fork of Meydenbauer Creek.

B.3.2.1 Channel Morphology and Riparian Corridor

Meydenbauer Creek is a highly altered stream. The remaining open channel is generally low gradient and strongly influenced by stormwater discharge. Outfalls into the stream channel are numerous; the OSCA surveys documented an average of 16.1 outfalls per mile which is much higher than average for streams across the City. Overall, the stream gradient is 2.3% which is slightly lower than average for streams in the City. When there are strong westerly winds in Meydenbauer Bay, water can be pushed upstream, influencing water depth and even apparently reversing streamflow up to the lower portion of Reach 4. The channel morphology is generally plane-bed although the lower portion of Reach 1 could be considered dune-ripple or lacustrine (**Table B-6**). Because the headwaters are now contained in the storm drainage network, channel incision and streambank erosion are the primary sources of sediment entering the stream. Additionally, 37% of the stream channel is piped and the subbasin has the highest frequency of culverts observed in the City at 18.4 culverts per mile.

The Meydenbauer Creek riparian corridor is in generally poor condition (**Table B-6**). The average riparian canopy cover is 46% which is below average for streams in the City. Across all surveyed reaches, the impervious surface cover within the 100 ft stream buffer is 38% which is worse than in most other subbasins in the City. Riparian canopy cover generally consists of cedar and deciduous trees. Invasive plant species are common and include English ivy, laurel, and especially Himalayan blackberry which has formed dense thickets.

In terms of channel width and depth, Meydenbauer Creek is slightly larger than most other streams in the City. The median wetted and bankfull depths are 8.0 ft and 10.0 ft, respectively, for reaches surveyed under a Level 1 protocol (**Figure B-11**). The median representative wetted thalweg depth is 0.7 ft (**Figure B-12**). This yields a wetted width to depth ratio of 10.4, which is the second lowest score observed in the City and likely results from confinement due to channel incision and streambank armoring.

Table B-6. Reach attributes for Meydenbauer Creek and its South Fork.

	Meydenbauer Creek				South Fork	
	Reach 1	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 1**	**Reach 2**
Reach Segment ID	72_01	72_02	72_03	72_04	72_02_11	72_02_12
River Mile Boundaries	0.01 – 0.12	0.12 – 0.23	0.23 – 0.27	0.27 – 0.47	0.00 – 0.10	0.10 - 23
Sediment Dynamics	Response	Unknown	Forced transport	Response	Forced transport	Source/ Transport
Channel Type	Dune-ripple/ Piped conveyances	Unknown	Piped conveyance	Plane-bed	Piped conveyance	NA*
Stream Gradient (%)	0.4	0.1	1.4	2.1	2.3	4.3
Riparian Canopy Cover (%)	36.8	32.8	-	51.4	-	57.9
Riparian Impervious Surface Cover (%)	60.6	28.1	54.9	33.7	75.1	36.3
Reach Length (ft)	600	575	225	1,040	540	658

* The channel was dry at the time of the survey.

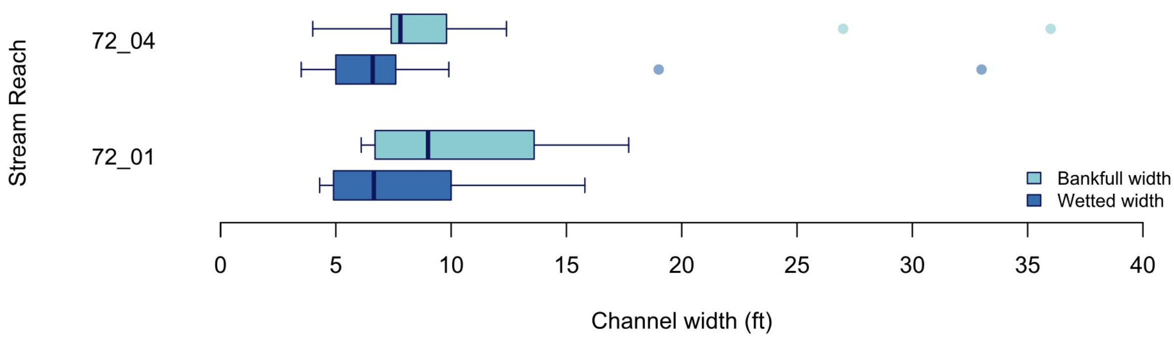


Figure B-11. Boxplot of the wetted and bankfull channel widths for stream reaches in the Meydenbauer Creek Subbasin that were surveyed under a Level 1 protocol.

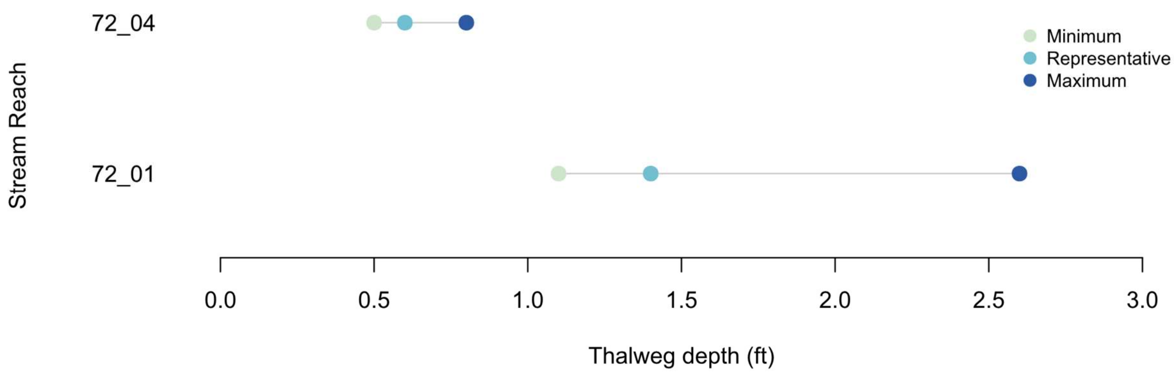


Figure B-12. Dumbbell plot of wetted stream depths for stream reaches in the Meydenbauer Creek Subbasin surveyed under a Level 1 protocol. Points represent the median value for the minimum, representative, and maximum depth for each reach.

B.3.2.2 Habitat Unit Composition and Off-Channel Habitat

Habitat unit composition in Meydenbauer Creek is dominated by glide habitat in the lower reach and riffle habitat in the upper reach (**Figure B-13** and **Figure B-14**). For all stream reaches surveyed under a Level 1 protocol, riffle habitat accounts for 56% of the stream area and 40% of the stream length, followed by glide habitat which accounts for 39% of the stream area and 34% of the stream length. This proportion of glide habitat area is the second highest in the City following Richards Creek. Pool habitat accounts for 21% of the stream area and 10% of the stream length.

Pool habitat is limited in Meydenbauer Creek and is primarily restricted to mainstem Reach 4. Across all surveyed reaches, there is an average of 18 pools per mile (approximately 29 bankfull channel widths per pool), which is approximately average for streams in the City but far below the approximately 96 pools per mile expected in similarly sized, “properly functioning” streams (NOAA 1996). When present, pool depth varies considerably (**Figure B-15**). In the South Fork Reach 2, there are only two small pocket pools in scoured glacial till. These were the only habitat units that retained water in this reach at the time of the survey. In Reach 4, pool depth is more variable; the deepest pool, with a residual depth of 4.2 ft, is associated with the stormwater outfall that forms the headwaters of the open stream channel. Overall, the median residual pool depth is 1.1 ft, which is approximately average for the City.

There is no off-channel habitat present in the Meydenbauer Creek Subbasin. The channel is generally confined by development that frequently encroaches upon the streambank. Channel incision further disconnects the stream from its floodplain. However, Reach 2 was not surveyed due to a lack of property access. This short reach is potentially wetland habitat and may provide limited off-channel habitat or the opportunity for off-channel habitat creation.

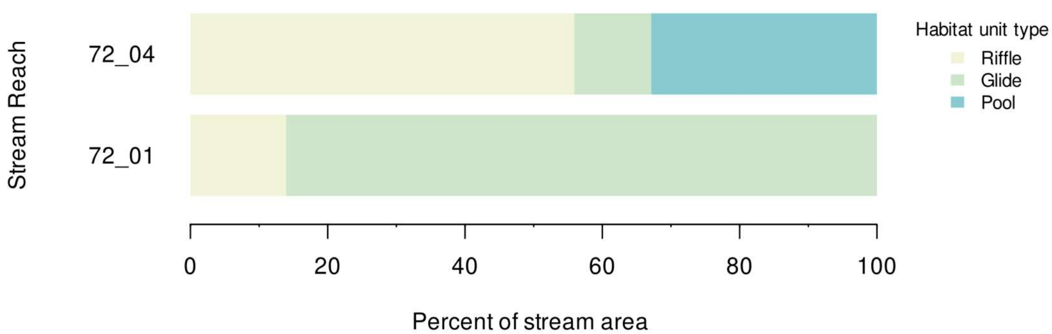


Figure B-13. Habitat unit composition (by percent area) for stream reaches in the Meydenbauer Creek Subbasin surveyed under a Level 1 protocol.

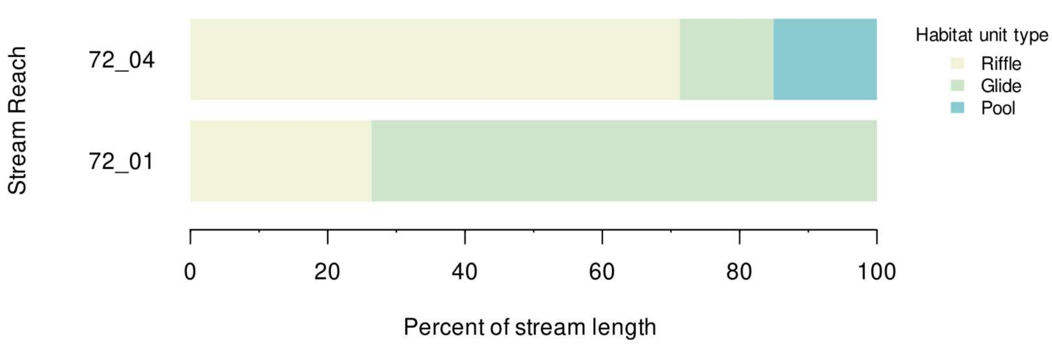


Figure B-14. Habitat unit composition (by percent length) for stream reaches in the Meydenbauer Creek Subbasin surveyed under a Level 1 protocol.

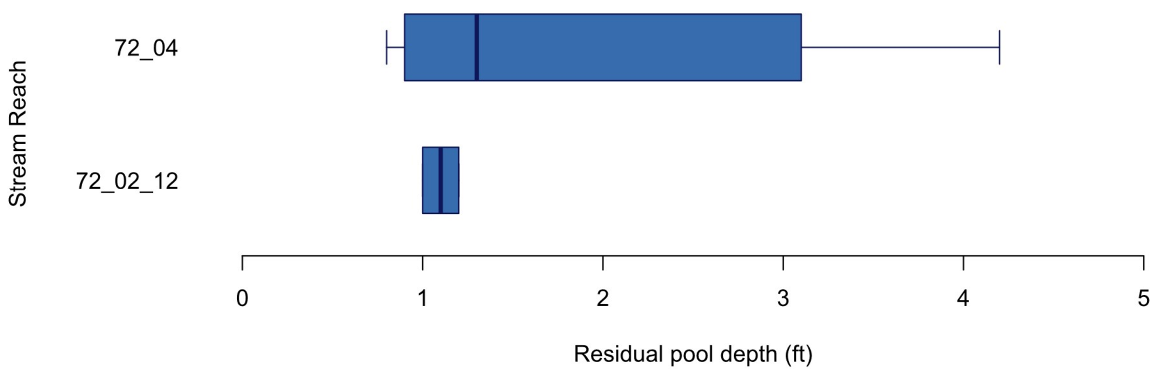


Figure B-15. Boxplot of residual pool depths in OSCA-surveyed stream reaches of the Meydenbauer Creek Subbasin. Mainstem Reach 1 is omitted as no pools were observed at the time of the survey.

B.3.2.3 Large Woody Material

Large woody material (LWM) is greatly lacking in the Meydenbauer Creek Subbasin. Across all surveyed reaches, only 19 pieces of wood were observed for a total of 44 pieces per mile (3 pieces per 100 m). This is the second lowest wood frequency observed in the City and far below LWM levels seen in similarly sized, unaltered streams (Fox and Bolton 2007; **Figure B-16**). All observed LWM is presumably of natural origin. The opportunities for natural recruitment of LWM are fair to poor given the generally sparce riparian canopy. When present, LWM appears to aid in the formation and maintenance of pools; 73% of all LWM in the subbasin is found in pool habitat.

Figure B-16. Large woody material frequency in surveyed reaches of the Meydenbauer Creek Subbasin compared to reference levels (Fox and Bolton 2007). No wood was present in Reach 1.

B.3.2.4 Streambed Substrate

Streambed substrate in the Meydenbauer Creek Subbasin is dominated by fines and gravels (**Figure B-17**). In riffle habitat of reaches surveyed under a Level 1 protocol, fines and gravels each comprise 41% of the substrate, followed by cobble (13%) and boulders (5%). There a several instances where the cobble and boulder substrate originated from streambank armoring that has failed and mobilized into the channel. The stream is scoured to hardpan glacial till in only one small portion of the mainstem, but in the South Fork Reach 2 there is a considerable portion of exposed hardpan which accounts for between 5% and 85% of the substrate throughout the reach.

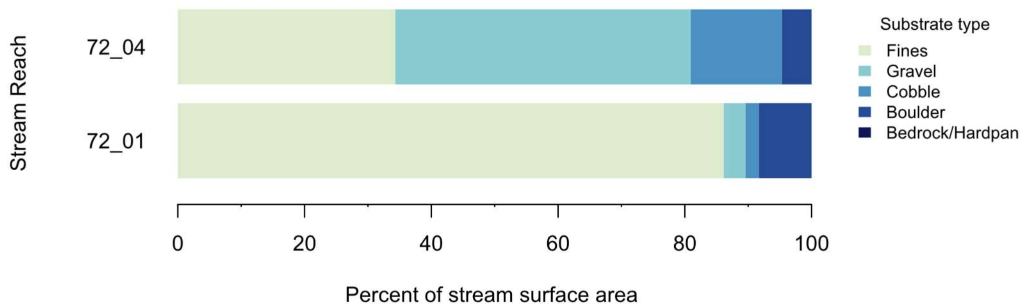


Figure B-17. Substrate composition of riffle habitat in the Meydenbauer Creek Subbasin surveyed under a Level 1 protocol, determined by visual estimation.

B.3.2.5 Streambank Conditions

Streambank armoring is prevalent in the Meydenbauer Creek Subbasin. Across all surveyed reaches, 19% of the streambanks are armored which is more than average for subbasins in the City. This armoring is generally less than 5 ft in height (**Figure B-18**) and is usually rather short in length, usually extending for only about 20 ft at a time although some instances of armoring stretch for over 100 ft. All armoring in the subbasin is traditional "hard" armoring and mostly consists of large angular rock. More than a fifth of all streambank armoring in the subbasin is at least partially failing and around 5% of the armoring is associated with streambank erosion.

The Meydenbauer Creek Subbasin has the highest frequency of streambank erosion of all subbasins in the City which appears to be the result of flashy, high velocity streamflow. Across all surveyed reaches, 31% of the streambank shows evidence of erosion and 16% of the streambanks are undercut (**Figure B-19** and **Figure B-20**). Most of the streambank erosion is less than 5 ft in height, although about 16% of all erosion is between 5 and 10 ft in height. Similarly, most of the erosion extends for about 30 ft (which is higher than average for the City), although some instances of erosion extend up to 200 ft.

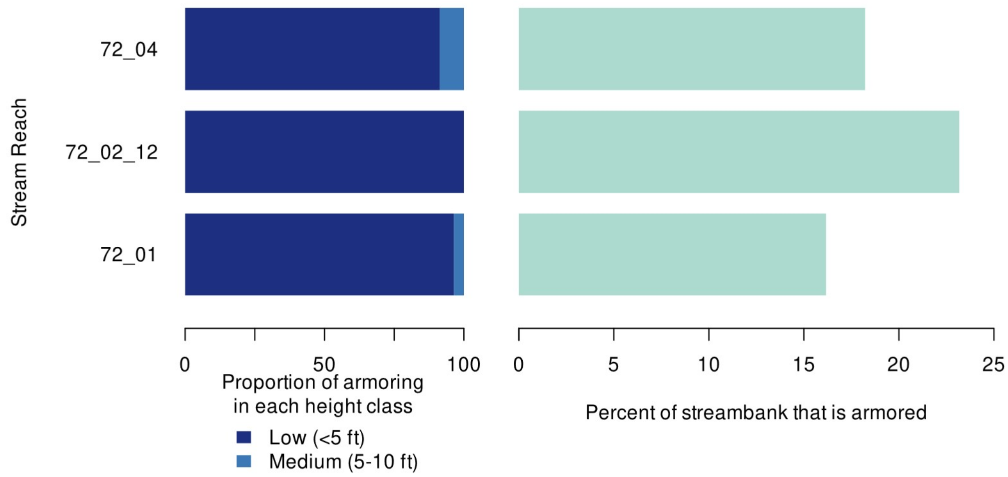


Figure B-18. Multi-panel bar graph showing the percent of each OSCA-surveyed stream reach in the Meydenbauer Creek Subbasin that is armored as well as the proportion of armoring in each armoring height class.

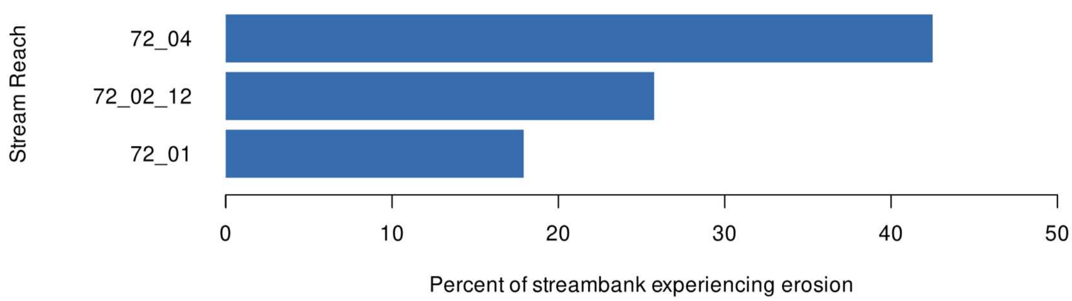


Figure B-19. Percent of each surveyed stream reach in the Meydenbauer Creek Subbasin that is experiencing erosion.

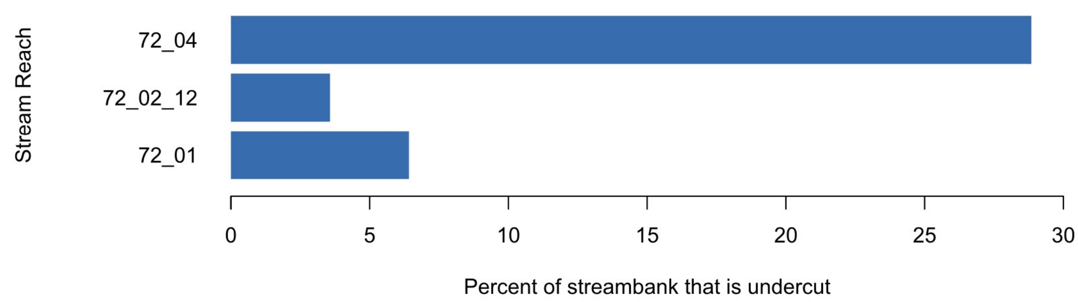


Figure B-20. Percent of each surveyed stream reach in the Meydenbauer Creek Subbasin that has undercut streambanks.

B.3.2.6 Fish Habitat and Passage Barriers

Historically, Meydenbauer Creek supported salmon and trout (Kerwin 2001), but unfortunately, this stream no longer provides quality fish habitat. Although the South Fork is listed as a potentially fish-bearing stream, the fact that it was dry at the time of the survey indicates that it provides seasonal habitat at best. During the OSCA surveys, fish were only observed in the downstream-most portion of Reach 1 below 101st Avenue SE. The high proportion of fines in the substrate is generally unsuitable for spawning salmonids. There are only localized patches of gravel with a proportion of fines low enough for successful spawning. Additionally, pool habitat is lacking in both frequency and quality and is primarily restricted to Reach 4. The scarcity of fish in this system is likely due to the lack of habitat complexity, flashy stream flows, and potential water quality impacts from urbanization.

Additionally, there are multiple barriers that may impede fish movement and migration. WDFW has formally documented one partial fish passage barrier and two barriers whose passability has not been determined (WDFW 2021). All three of these barriers are owned by the City. Additionally, beavers are active in Reach 1 and may create dams that form temporary barriers at periods of low streamflow.

B.3.2.7 Opportunities

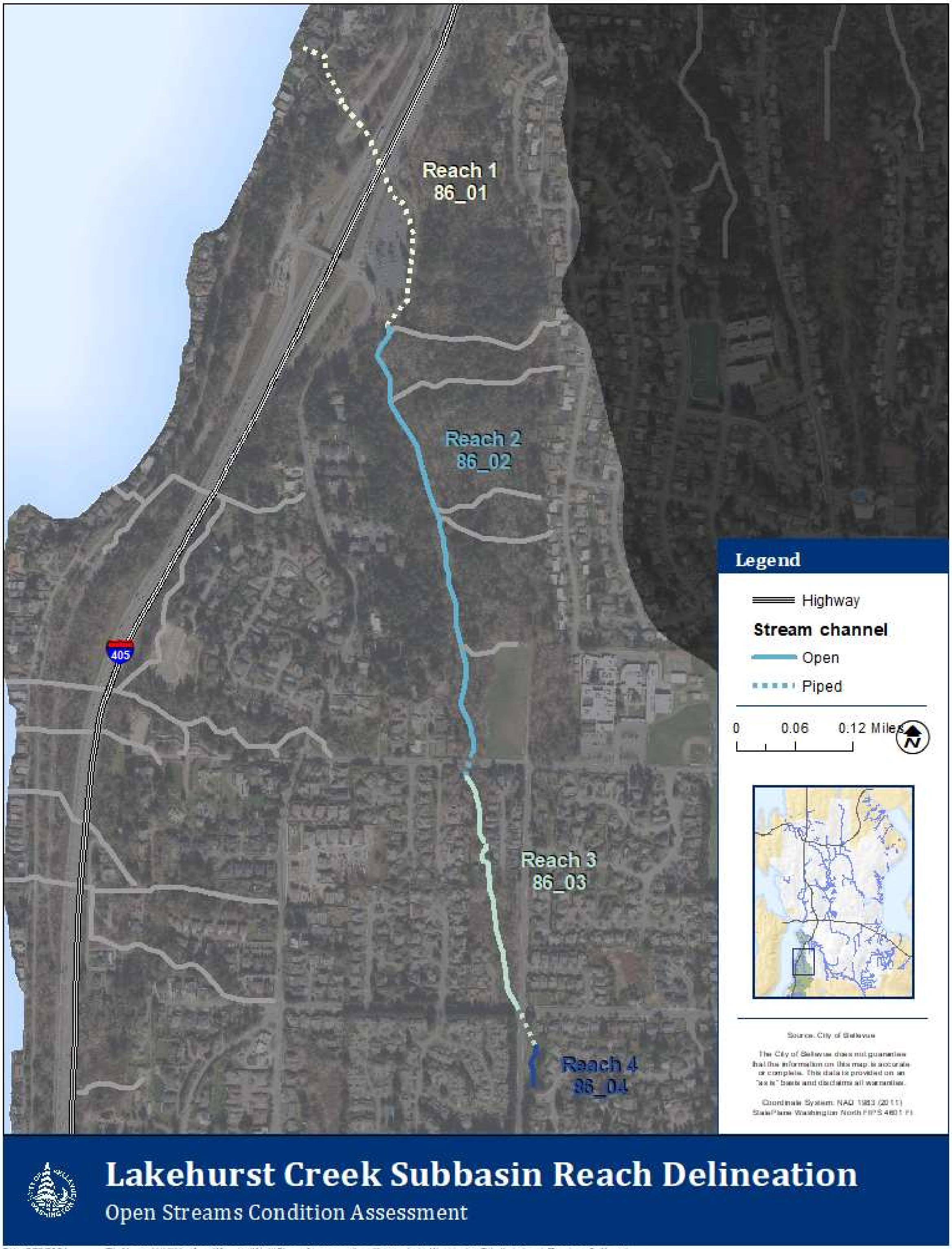
The most notable challenges in the Meydenbauer Creek Subbasin are flashy stream flows and associated water quality concerns, channel incision, streambank instability, and encroaching invasive riparian vegetation. Projects targeting these issues should be prioritized before stream habitat enhancement. Projects focusing on upland detention and treatment of stormwater runoff would greatly benefit this system by reducing erosion, pollutant input, and flooding risk. Streambed and streambank stability projects should include placing large woody material to help retain and sort sediment, attenuate flow velocities, and increase channel complexity and habitat. Riparian enhancements are also recommended, particularly the control of invasive plants and the maintenance and planting of native vegetation. Land acquisition of Reach 2 may provide opportunities for the creation of off-channel habitat and the use of process-based restoration to combat flooding and sedimentation issues.

B.3.3 LAKEHURST AREA

Located in the Newport neighborhood of southwest Bellevue, the Lakehurst Area comprises 1,284 acres, about half of which is within the City of Bellevue while the remainder is within Newcastle, Renton, and King County. More than 60% of the subbasin area within Bellevue city limits is public right of way (most notably related to I-405), while single family residential land use accounts for much of the remaining area. Elevation ranges from 17 ft to 569 ft. Overall, the subbasin has 6.8 miles of open channel, much of which is minor seasonal drainages, and 11.3 miles of storm drainage pipes within Bellevue city limits (Bellevue 2017). The largest drainage in the Lakehurst Area is Lakehurst Creek which was the primary focus of the OSCA surveys. One more notable drainage in this area is the fish-bearing stream that flows through Newcastle Beach Park which headwaters in the vicinity west of I-405. This stream has two distinct reaches, an extensive wetland complex that gathers drainages from south bound I-405 and a lacustrine plane-bed channel with intact alluvial fan at the Lake Washington shoreline. This small stream was surveyed under a Level 3 protocol and will therefore not be discussed in this report.

Lakehurst Creek consists of one channel; although several short tributaries have been mapped, none were observed during the OSCA surveys (**Map B-5**). The present-day headwaters to Lakehurst Creek are mostly contained within the storm drainage network that outfalls near SE 46th Street and 116th Avenue SE where there is a large open swale and then a small forested riparian area where altered hydrology from an undersized private driveway culvert has created a small wetland area. The stream then passes into a residential area and on into a ravine north of SE 60th Street. Here, the channel flows through the Newport Hills Park and borders residential properties. The final stream reach is piped from an instream detention pond at the Newport Hills Park and Ride to Lake Washington. During the late summer on low water years, Lakehurst Creek has been known to run dry.

Property access could not be obtained for much of the residential Reach 3. Therefore, only Reach 2 was surveyed under a Level 2 protocol.



Map B-5. Stream reaches of Lakehurst Creek.

B.3.3.1 Channel Morphology and Riparian Corridor

Lakehurst Creek has three distinct morphologies: a piped portion, a well-vegetated ravine, and a lower gradient residential area (**Map B-5** and **Table B-7**). Besides the small wetland area at the upstream end of Reach 3, the channel generally takes on a plane-bed morphology due to numerous weirs that control the grade in the ravine. Overall, the average stream gradient for the surveyed reach (Reach 2) is 4.6% which is greater than that seen in the other tributaries in the Small Lake Washington Watershed and slightly above average for streams across the City. Approximately 24% of the stream is piped.

Lakehurst Creek has excellent riparian vegetation in the ravine but less so in the residential areas. Overall, within the 100 ft riparian buffer, the stream has 66% tree canopy cover, which is slightly better than average for the City, and 19% impervious surfaces, which is worse than average for the City. The canopy is primarily composed of cedar and big leaf maple with an understory of ferns and vine maple. Himalayan blackberry and English ivy are also prevalent and occasionally form dense thickets.

Lakehurst Creek is smaller than most of the other surveyed streams in the City. In Reach 2, the wetted width is approximately 4 ft and the bankfull width is around 7.5 ft. It is also quite shallow. Wetted depths were not taken as part of the Level 2 survey, but the maximum bankfull depth measured 1.0 ft.

Table B-7. Reach attributes for Lakehurst Creek.

	Reach 1	**Reach 2**	**Reach 3**	**Reach 4**
Reach Segment ID	86_01	86_02	86_03	86_04
River Mile Boundaries	0.00 – 0.21	0.21 – 0.66	0.66 – 0.93	0.93 – 1.02
Sediment Dynamics	Forced transport	Response	Unknown	NA†
Channel Type	Piped conveyance	Forced plane-bed*	Unknown	NA†
Stream Gradient (%)	5.9	4.6	2.3	0.4
Riparian Canopy Cover (%)	-	91.6	55.0	57.8
Riparian Impervious Surface Cover (%)	47.9	2.7	23.5	26.8
Reach Length (ft)	1,100	2,400	1,425	475

* Frequent weirs control the grade and cause the channel to take on a stepped plane-bed morphology.

† The channel is a maintained swale that was dry at the time of the surveys.

B.3.3.2 Habitat Unit Composition and Off-Channel Habitat

Lakehurst Creek is dominated by riffle habitat. The only pools present are small plunge pools associated with weirs or small debris jams. Overall, the pool frequency averages 9 pools per mile, which is below average for streams in the City. In keeping with the small size of the stream, the pools tend to be shallow with a median residual pool depth of 1.1 ft.

There is no off-channel habitat in Lakehurst Creek. The confined nature of the ravine and residential reaches provide no opportunity for off-channel habitat formation. The upper portion of Reach 3 has formed a small wetland due to an undersized culvert and likely provides some sediment and stormwater storage capacity, yet fish habitat is minimal, and their presence is highly unlikely.

B.3.3.3 Large Woody Material

The healthy riparian canopy found in Reach 2 of Lakehurst Creek contributes to fair levels of large woody material (LWM) in the stream. The reach averages 251 pieces per mile (16 pieces per 100 m) which is higher than average for subbasins across the City. However, this level of LWM falls below the 25th percentile for LWM frequency observed in similarly sized reference streams (Fox and Bolton 2007). All observed LWM was presumed to be of natural origin and the intact riparian corridor provides opportunities for future natural recruitment.

B.3.3.4 Streambed Substrate

Streambed substrate in the surveyed reach of Lakehurst Creek is primarily a mixture of fines and gravels. At the representative cross-sectional profile, the substrate consisted of 75% fines and 25% gravels. However, cobble and some boulders are occasionally present in low proportions and become more frequent as you progress upstream. Exposed glacial till is also intermittently prevalent throughout the reach.

B.3.3.5 Streambank Conditions

The surveyed reach of Lakehurst Creek has a moderate to low amount of streambank armoring. Overall, 8% of the reach is armored which is slightly lower than average for subbasins in the City. Most of this streambank armoring consists of large angular rock or concrete. However, 14% of all streambank armoring is bioengineering (generally logs and small angular rock) which is usually placed around each of the weirs.

Like the other subbasins in the Small Lake Washington Watershed, erosion is prevalent in Lakehurst Creek. Overall, 23% of the surveyed reach shows evidence of streambank erosion which is the 4th highest proportion of erosion for subbasins in the City. Likewise, 12% of the streambanks are undercut which is greater than average for subbasins in the City. Although the majority of erosion in Lakehurst Creek Reach 2 is less than 5 ft in height, more than 40% of all erosion is between 5 and 10 ft. The streambanks show evidence of flashy streamflow which is a key driver of channel incision and streambank instability in this subbasin. There is also a fairly substantial amount of erosion in conjunction with a failing culvert in the middle of the ravine.

B.3.3.6 Fish Habitat and Passage Barriers

Lakehurst Creek is listed as a fish-bearing stream (Bellevue 2010) although its historic use by salmon is unknown (Kerwin 2001). However, no fish were observed during the OSCA survey. Because the streamflow becomes very low during the dry summer months and there is little pool habitat to serve as refugia, it seems unlikely that Lakehurst Creek could currently support fish populations.

If fish were able to utilize this habitat, there are multiple barriers that could impede fish movement and migration. WDFW (2021) has documented six complete and two partial fish passage barriers. The City is listed as owning two of the complete barriers. The most notable fish passage barrier is the catch basin and piped portion of stream in Reach 1 which is owned by the City and cuts off the entire stream to access from fishes in Lake Washington.

B.3.3.7 Opportunities

Projects in Lakehurst Creek should focus on upland stormwater detention and streambed and streambank stability. Removal is recommended for the failing culvert in the middle of Reach 2 followed by stream channel stabilization and restoration. The addition of LWM would aid in reducing flow velocity, while increasing sediment retention with the secondary benefit of increasing pool habitat that is valuable to fish as well as other wildlife. Riparian vegetation enhancement, community awareness, and incentive programs would be highly beneficial for the residential areas in Reach 3.

Small creek mouths offer a unique opportunity to enhance fish habitat for salmonids in Lake Washington and their restoration is encouraged in the WRIA 8 Chinook Salmon Recovery. Because Lakehurst Creek is piped at its downstream-most reach into Lake Washington, removing the pipe and restoring the channel would allow for natural alluvial processes and would create habitat for juvenile Chinook Salmon while improving conditions for shoreline spawning Sockeye Salmon and kokanee. Additionally, the stream and lakeshore at Newcastle Beach Park offer the opportunity to engage the community through stewardship activities and outreach (i.e., volunteer planting events, signage directed to behavior change, etc.) and promote general awareness of stream health and aquatic resources.

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Appendix C
Small Lake Washington Tributaries Watershed Benthic Index of Biotic Integrity Scores

Table C-1. Small Lake Washington Tributaries Benthic Index of Biotic Integrity Scores

Stream	Agency	Site Code	Latitude	Longitude	8/27/2010	8/5/2013	8/25/2016	8/17/2021	8/18/2021
Lakehurst Creek	City of Bellevue	Lkhrst405RM0.3	47.55537	-122.188856	9.4				1.2
Yarrow Creek East Tributary	City of Bellevue	YarrowEastTribBelRM0.3	47.6371	-122.1968			1.2		
Yarrow Creek Subbasin	City of Bellevue	YarrowMain_21	47.63967	-122.18577					37.4
Yarrow Creek Subbasin	City of Bellevue	YarrowWestTribBelRM0.2	47.64225	-122.20417		35.6			19.2