SHORELINE ANALYSIS REPORT

TECHNICAL APPENDIX VOLUME II: SHORELINE INVENTORY REPORT – HABITAT

JANUARY 16, 2009

CITY OF BELLEVUE WASHINGTON

THE WATERSHED COMPANY

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SHORELINE INVENTORY REPORT – Technical Appendix Volume II - Habitat City of Bellevue's Shorelines: Lake Washington, Lake Sammamish, Phantom Lake, Kelsey Creek and Mercer Slough

Project: Shoreline Master Program Update

- **Task 1.3.4: Develop Specific Habitat Inventory**

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31 August 2008

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INTRODUCTION

A "Specific Habitat Inventory" is sub-task 1.3.4 of The Watershed Company's October 9, 2007 Scope of Work for the City of Bellevue's Shoreline Master Program Update. As outlined in the Scope of Work, this Specific Habitat Inventory will support the general shoreline inventory information (sub-task 1.3.2) by accomplishing the following:

- "Document the location of major wildlife habitat types and features in the shoreline area using multi-spectral images and/or air photos, including steep slope areas.
- Perform a reconnaissance level habitat evaluation of shorelines of Lake Washington and Lake Sammamish as well as Larsen and Phantom lakes. This task assumes up to three full days of fieldwork and is limited to public land, large private parcels, or open water areas accessed by watercraft. Incorporate in the inventory existing City documentation of the known locations of species of local importance that occur in the shoreline area as well as the location of suitable habitat for these species. Compile other relevant information on fish and wildlife provided by Washington Department of Fish and Wildlife (WDFW) local habitat biologists, and from federal agencies and tribes as appropriate.
- Incorporate City documentation of fish presence abutting Bellevue's shoreline jurisdiction by summarizing salmon spawner data collected by the City under a separate contract and WDFW mapping for beach spawners in Lake Washington. Contractor will provide a written summary and updated GIS maps of known and suspected spawning locations.
- Assess and document known primary salmonid and kokanee rearing and residence areas in City shoreline areas and provide text summary.
- Contact the US Geological Survey (USGS) or other appropriate agency to obtain accurate bathymetry maps, if possible.
- Identify information gaps and provide recommendations for future data collection.
- Provide text and tables for incorporation into the master inventory report."

These general objectives have been divided into upland and aquatic components. This report and map folio will support the general Shoreline Inventory and Analysis report, development of the Shoreline Master Program and Shoreline Restoration Plan, and City review of applicant proposals and its own activities and programs. A list of remaining data gaps has been developed to guide future upland and aquatic habitat evaluation efforts.

STUDY AREA

The study area for this report includes all land currently within the City of Bellevue's proposed shoreline jurisdiction. The City of Bellevue's regulatory shoreline includes the area within 200 feet of the ordinary high water mark (OHWM) of all Shorelines of the State, as defined by the Shoreline Management Act of 1971 and modified for the current Bellevue Shoreline Management Plan (SMP). This includes the shorelines of Lake Washington, Lake Sammamish, Phantom Lake, Lower Kelsey Creek, and Mercer Slough, along with their associated wetlands.

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UPLAND HABITAT

1.0 BACKGROUND

Overall, the City of Bellevue can be characterized as urban habitat (Ferguson *et al.* 2001). Urban habitat is highly variable in quality and the setting in which it exists is a continuum, ranging from highly developed inner city to low-density development with large, unfragmented tracts of land remaining. As land is urbanized, wildlife habitat can be maintained intact, altered, or lost entirely. In contrast to more natural environments, urban habitat changes are usually permanent, involving the addition of structures and impervious surface. Non-native plants are introduced to the landscape, and additional human pressures increase. Varying degrees of native habitat remain in even highly urbanized areas.

Forest habitat has been and continues to be greatly affected by urbanization in the Pacific Northwest. Impacts vary greatly and depend on the type and intensity of development. Forest complexity trends from less to more diverse with distance from inner-city areas, and wildlife communities can be expected to vary with some predictability, depending on their location on the urban spectrum. Greater bird abundance has been observed in suburban and urban reserves than in rural reserves. It has been hypothesized that individuals crowd into suburban and urban reserves when forest is rare in the landscape. Urban communities tend to vary in species composition, however, with species most commonly associated with humans occurring in high abundance in urban landscapes (Donnelly and Marzluff 2004). Perhaps of most significance is the relationship between bird abundance and non-native vegetative cover. Donnelly and Marzluff found a positive correlation between increasing exotic cover and decreasing forest bird abundance in urban Seattle. As well, species associated with human disturbance increased. The relationship between these wildlife community changes and cover is complicated by the fact that non-native vegetation increases with urbanization, particularly in the shrub layer.

Forest patch size also has an affect on wildlife communities. Although existing knowledge pertains primarily to larger tracts of land than the study area, evidence suggests that even small urban habitat patches are important for wildlife, with bird species being the most common indicators used in research. In fact, urban forest patches as small as one acre were shown to support substantial native bird communities (Marzluff 2001 and pers. comm., 15 April 2008). Bird species richness has been demonstrated to increase and abundance to decrease with increasing reserve size in urban areas. In general, larger forest patches may be able to support more individual birds from the greater regional species pool, and also contain a more diverse habitat, allowing for higher species richness in a greater variety of niches than smaller reserves. Of great importance is the degree of native vegetation and its structural diversity in the understory. Understory and vegetative diversity have been correlated with bird species richness and diversity in a number of studies (MacArthur and MacArthur 1961, Wilson 1974, Slater 1995, Patterson 2002). Donnelly and Marzluff (2004) observed a positive correlation between shrub diversity and bird species richness in urban Seattle. The smallest urban reserves may be unable to support breeding bird populations, and nests were entirely absent in small reserves in the City of Seattle (Donnelly and Marzluff 2004).

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Anecdotal evidence of the ability of urban habitat patches to support mammals is abundant in the cities of Western Washington. Coyote, deer, opossum, raccoon, and even black bear and cougar can occur in forested patches in Bellevue and surrounding jurisdictions, although patch size does appear to be important for at least the larger species. Many incidences of mammals in urban areas are reports of human-wildlife conflict. Attention to identification and management of urban reserves will promote a better understanding of such interactions.

The significance of forest patches to wildlife in urban areas is evident, and therefore this study identifies and locates two types of forest stands as areas of significance, called out as polygons on the shoreline maps in Appendix A. Additional habitat polygons are identified as significant for their unique habitat features and functions. Areas of dense or significant perch trees or snags enhance habitat by attracting wildlife with specific habitat needs. Bald eagles, osprey, and other raptors require tall, open perches, often near water bodies, for foraging. This particular habitat component exists in the City of Bellevue shoreline and it is called out as a distinct polygon where it exists because of the unique purpose it fulfills. Likewise, snags' importance as a habitat special feature is well known. While locating individual snags in the shoreline jurisdiction is beyond the scope of this study, snag-rich areas are especially important and are identified in habitat polygons. Overhanging aquatic vegetation in the Bellevue shoreline jurisdiction is of primary importance to fish and is discussed in the Aquatic Habitat section of this report.

Finally, dense infestations of reed canarygrass were located for this study. These areas are of significance because of their tendency to grow in monocultures, excluding native vegetation. Many such infestations exist in small patches in the study area; only large infestations are called out specifically in habitat polygons. Defining characteristics of all polygons are listed in Section 3.2, *Habitat Polygons*.

For the purpose of assessing conditions for wildlife, the City of Bellevue itself is urban habitat (Ferguson *et al*. 2001). The sub-climax species Douglas-fir dominates in the area, as a climax state has been prevented by a number of factors. A combination of logging and fire was the primary impact on forest stands in the as-yet unincorporated Bellevue area from the turn of the 20th century until roughly the time the City was incorporated in 1953. In Douglas-fir stands that remain undisturbed post-fire or -logging, the species tends to become closed-canopy and the understory sparse until age 60 to 100. Many of Bellevue's remaining forest patches can be described thusly. Deciduous areas often develop after logging, typically dominated by red alder and bigleaf maple (Chappell *et al.* 2001). In urban environs, forest succession is further altered by human impacts. Individual trees may be protected to maturity in human-populated areas, but genuine old-growth does not developed because of fragmentation, alteration of plant communities, understory removal, and introduction of exotic species. Older neighborhoods tend toward a later seral stage with higher species diversity, but structural diversity is still often reduced by preening and other maintenance (Ferguson *et al*. 2001).

The City of Bellevue comprises a combination of old and new development. In 1882, Isaac Bechtel Sr. settled in what is presently the downtown area and logged his land. By 1890, a sawmill had been constructed and mills and farms began to establish. The area was platted in 1904, and farming became the most common and productive industry in the community. Some forestland that had not already been logged was cleared for farming, and pressure on wetlands increased as farming grew.

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Prior to the opening of the Lake Washington (I-90) Floating Bridge in 1940, the area remained rural, with little development. After that point, it became a "bedroom community," attracting auto-commuters and the first shopping mall, opened by Kemper Freeman in 1946. The rate of development increased through incorporation in 1953 and again after the Evergreen Point Floating Bridge opened in 1963. The central downtown area grew dense, and farmland was converted to residential areas. Forested land by this time remained primarily in fragments, which faced increasing pressure that continues to the present.

The remaining habitat within Bellevue's regulatory shoreline is toward the highly developed end of the urban spectrum. For the purposes of this work, fine distinctions between what constitutes low- and high-level development are needed both because the study area is relatively small and the level of development more homogeneous than study areas of existing research. This study divides all land within the Bellevue shoreline into habitat units based primarily on development density. These are described in the Section 3.1, *Habitat Units*, below.

The importance of wetlands to wildlife, particularly reptiles, amphibians, water-associated birds, and fish, are well documented. Wetlands are identified as part of this study and are fully described in the Wetland Inventory. The wetland polygons are labeled "Reserve Habitat" in this Habitat Inventory because they are afforded a degree of protection under current regulation.

In the City of Bellevue shoreline jurisdiction, nearly all remaining native habitat is in what would be considered small patches. Most studies of forest fragmentation focus on fragments greater than one acre in size. However, local researchers have recently investigated the use of patches as small as two acres by wildlife. Donnelly and Marzluff (2004) qualified forest patches of approximately 4 to 6 acres as "small," 80 to 90 acres as "medium," and 2,500 to 4,500 acres as "large." By this standard, only the Mercer Slough and Phantom Lake complexes might be considered of medium size. Both these larger patches and the more common small patches are of great importance if wildlife species are to continue to inhabit the area. As well, proximity to other patches is of significance to wildlife using habitat patches. For some species, the lack of a travel corridor greater hinders their ability to travel between patches, but for others, a landscape comprising disconnected patches may be fulfill some or all lifecycle needs (McComb 2001).

As pressure increases on the remaining undeveloped space in the urban landscape, native habitat patches may be increasingly in danger of further fragmentation and decimation from encroaching disturbance. The identification of remaining refuges in the urban landscape is the first step in protecting the urban wildlife resource.

2.0 METHODS

2.1 Habitat Units

Parameters considered in identifying and characterizing habitat units were adapted from the literature for the narrow and relatively small City of Bellevue shoreline. Land in the entire shoreline area was assessed for two variables: native vegetation and impervious surface. While intact areas of native vegetation are limited and generally small in size, small patches of what might be characterized as Westside lowlands coniferous-hardwood forest and Westside riparian-

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wetlands (Chappell *et al*. 2001) exist within and among development in Bellevue. These patches comprise primarily native species and are for the most part not regularly maintained, although all have been subject to past disturbance. The presence of native forest patches was required for an area to be assigned a "moderate" or "high" unit designation (see below). Impervious surface was approximated using aerial photographs and areas classified into one of three rough categories, following Ferguson *et al*. (2001): >60% impervious surface, 30-59% impervious surface, and less than 30% impervious.

The shoreline was assessed using aerial and oblique photograph analysis followed by ground-truthing. All land within the regulatory shoreline was divided into habitat units based primarily on the relative level of habitat value they potentially provide using the forest patch and impervious surface indicators described above. These units are labeled "Low"- "Moderate"-, and "High Habitat" on the inventory maps (Appendix A-1, Figures 1-14). Known regulated wetlands are considered a separate habitat unit, as they are presently afforded a measure of protection and therefore make up the great majority of undeveloped land in the shoreline jurisdiction. They are labeled as "Reserve Habitat" on the inventory maps. Land presently in agricultural use is considered a distinct unit ("Agriculture"), although it often exists within a Reserve Habitat. Parameters used to determine which unit an area was assigned are presence and amount of native vegetation, amount of impervious surface, current land use, and proximity to other habitat patches in the surrounding landscape. Characteristics of each unit type are described below.

Low Habitat – This unit type is generally developed with large houses, apartment buildings or condominiums, or commercial properties. Developed recreational areas (excluding entirely passive recreation) may fall into this category. Vegetated areas are largely maintained recreation field, lawns, or ornamental trees and shrubs, and no intact canopy layer exists. On-site vegetation is not contiguous with significant off-site native stands or with the adjacent jurisdictional water body, and little valuable habitat is present in the surrounding landscape

Moderate Habitat – Properties within this unit type characterized by smaller structures and less impervious surface than low habitat units. Greater amounts of native vegetation exist. Vegetation does not form a closed canopy for more than 0.25 acre and may consist only of scattered large (i.e., perching or nesting) native trees. In most cases, continuity of vegetation from the jurisdictional water body to off-site native stands is not present.

High Habitat –These areas may be partially developed with residences, but structures are more widely spaced and lots contain more vegetation and less impervious surface than moderate habitat units. Vegetation in this unit type is forest with a shrub understory and canopies are closed in places. Vegetation extends to the shoreline in most cases, providing shade, foraging perches, and narrow travel corridors from inland to the lakeshores, and are usually contiguous with off-site forested areas or corridors.

Reserve Habitat – These units include significant wetlands identified in the Wetland Shoreline Inventory Report and are fully described therein.

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Agriculture – Land in agricultural use is called out because it generally provides habitat functions unique from naturally vegetated habitat types. The agriculture units on the study area all occur within Reserve Habitat.

2.2 Habitat Polygons

Areas of special interest were identified and are called out in polygons on the inventory maps. Each of these areas holds specific value as wildlife habitat, beyond the vegetative features represented in each habitat unit. There is no overlap between polygons like snags, perch trees, and forest patches. Habitat polygons are as follows:

Developed Forest Fragments – A number of areas within the regulatory shoreline have complete or near-complete tree canopies, despite the presence of structures or driveways within the stands. These are called out in Developed Forest Fragment polygons. These areas are made up of typical Westside coniferous forest species, and although understories are highly variable in structure and composition, they support at least some native shrubs. These fragments are a minimum of .5 acre in size, extending outside of the shoreline in most cases.

Forest Patch – These forested areas consist of mid-age or mature conifer-dominated forest stands and differ from developed forest fragments in that they are contain an undeveloped core. They exceed 1.0 acre in size and extend outside of the shoreline jurisdiction and are located on City-owned land. Understories are dominated by native species. Because the presence of discontinuous habitat patches in the surrounding landscape can add value to small habitat patches, such patches were considered in descriptions of patch value.

Snag-rich Areas – Several areas in which snag density exceeds 5 per acre are illustrated in polygons on the inventory maps. These are exhibited because of their unique value as wildlife habitat.

Significant Perch Trees – Although many potential perch trees exist within the shoreline area, some particularly valuable trees are shown in polygons. These specific trees are notable for their height and proximity to common foraging areas for bald eagles, osprey, and other species.

Invasive Species Infestations – Although non-native and invasive species are very common in urban and suburban areas, the inventory maps include a number of areas of dense infestations. They are singled out for their negative impacts on wildlife habitat, as they occur within areas of otherwise high quality habitat, particularly in wetlands.

For the most part, Reserve Habitat is not further sectioned into habitat polygons. This is because wetlands possess unique habitat values beyond those for forested areas, scrub-shrub, and other habitat areas. Further, cover types are described for each wetland in the Wetland Inventory. The exceptions to the exclusion of these features are snags, significant perch trees, and invasive species infestations. These features are included in habitat polygons where they occur in Reserve Habitat because they provide additional habitat value or restoration opportunities that may not be specifically addressed in the Wetland Inventory.

The amount of overhanging shoreline/riparian vegetation was assessed using a combination of aerial and oblique photos of the shoreline. There are many types of overhanging shoreline

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vegetation (mature trees, shrubs, and ground cover), but for the purposes of this study it is defined as a continuous block of vegetation extending at least 50 feet along the shoreline. As well, some portion of the vegetation's dripline must intersect or extend waterward of the OHWM. Streams and overhanging vegetation are depicted as line items on the Habitat Inventory maps.

3.0 FINDINGS

Bellevue's jurisdictional shoreline encompasses approximately 1,153 acres. For the purposes of this report, the shoreline is divided into four distinct locations: the Lake Washington shoreline, the Mercer Slough/Lower Kelsey Creek complex, the Phantom Lake complex, and the Lake Sammamish shoreline, each with their associated wetlands. Habitat unit areas for each of these locations are shown in Table 1. Habitat units and polygons are depicted in Appendix A-1, Figures 1-14 and discussed for each shoreline location below.

Table 1. Habitat Unit area in City of Bellevue shoreline jurisdiction.

Habitat Unit	Lake Washington (acres)	Mercer Slough/Lower Kelsey Creek (acres)	Phantom Lake (acres)	Lake Sammamish (acres)	Total Area (acres)
Low Habitat	80.5	5.6	N/A	55.4	**141.5**
Moderate Habitat	105.7	60.2	22.9	52.8	**241.6**
High Habitat	16.2	N/A	N/A	11.0	**27.2**
Reserve Habitat	1.4	367.0	192.0	N/A	**560.4**
Agriculture	N/A	28.3	27.5	N/A	**55.8**
Total Area (acres)	**203.8**	**461.1**	**242.4**	**119.2**	**1,026.6**

3.1 Lake Washington Shoreline

The majority of land in the Lake Washington regulatory shoreline is Moderate and Low Habitat (approximately 105.7 and 80.5 ac, respectively). Reserve Habitat makes up about 42.4 ac, and the remaining 13.7 ac is in High Habitat.

Low Habitat is centered in the Meydenbauer Bay and Newport Key areas of Bellevue, with a small additional area very close to the southern extent of the study area. Low Habitat in the Meydenbauer area is characterized by the presence of at least six commercial docks, large buildings with lawns extending to the lake, parking lots, and a number of large homes on comparatively small lots. Most vegetation is ornamental; a few native trees are confined by buildings and roads. Shoreline in the Newport Key area is densely developed with large single-family homes, lawns with little natural vegetation, docks, and bulkheads. The mouth of the stream just north of the area has a narrow riparian zone, with native species largely confined to a strip on the north bank. One particularly dense cluster of houses with private docks and very little space for shoreline vegetation constitutes the southern low habitat area.

Typical single-family homes with private docks and landscaping make up most of the Lake Washington shoreline in Bellevue. Although lots are landscaped with lawns and ornamental vegetation, large native trees have been retained throughout. Several of the Moderate Habitat areas are bordered by forest fragments, increasing the potential for the remaining trees to be used by wildlife. These forest fragments extend outside the shoreline area, and their value is enhanced somewhat by the presence of other fragments and patches in nearby areas outside of the jurisdictional shoreline. In particular, the south end of the Lake Washington shoreline is within approximately 0.2 mile of several forested tracts together exceeding 40 acres in size. These are a mix of private and public residentially zoned parcels, all presently undeveloped.

High Habitat along the City's Lake Washington shoreline is limited to Chism Beach and Newcastle Beach Parks and a private property housing the Sisters of St. Joseph retreat. Although the retreat lot is developed, it has a number of large Douglas-firs lining the lake and connected via a forested corridor to an approximately 3.5-ac conifer-dominated stand.

The Reserve Habitat in the Lake Washington area is associated with the Mercer Slough wetland and is addressed in the Mercer Slough/Kelsey Creek section of this report.

The on-site portion of the High Habitat associated with the Sisters of St. Joseph property contains two habitat polygons. One polygon is the significant perch tree stand along the lake, and the second is a fragmented forest stand polygon. Overhanging vegetation, which is generally sparse along the Lake Washington shoreline in Bellevue, is present along approximately half of the property.

Fragmented forest polygons also occur along a short reach of riparian corridor along the north edge of Meydenbauer Bay, in the SE Shoreline Drive area, in Chism Beach Park, and in BNSF right-of-way along 106th Avenue SE. Forested patches are located at the south end of Chism Beach Park, away from the area where park development is most intense, and in Newcastle Beach Park. Chism Beach Park vegetation also overhangs the lake for a portion of the shoreline, and larger trees may provide foraging perches for an eagle nest that is located less than 0.25 mile from the park. Together with adjacent forest stands, the areas depicted by the polygons in Chism Beach and Newcastle Beach Parks provide the largest patches of structurally diverse wildlife habitat in the Lake Washington shoreline. In particular, the shoreline of Newcastle Beach Park has a shoreline-associated wetland and stream that overlap a forest patch polygon, allowing for a diverse habitat stand potentially able to support small mammals, herptiles, and numerous bird species.

3.2 Mercer Slough/Lower Kelsey Creek

The Mercer Slough/Lower Kelsey Creek location accounts for 301.3 ac of reserve habitat. This high-functioning wetland and stream complex includes three areas planted with agricultural species (presently blueberry) totaling approximately 28.1 ac in size. The shoreline-associated wetland at the mouth of Mercer Slough represents the longest expanse of overhanging vegetation in the study area. Two notably large reed canarygrass infestations occur just north of I-90. A cluster of significant perch trees is depicted along the east side of the reserve unit and extends nearly to the OHWM of Mercer Slough. These trees not only provide the tallest perches in the area, but also add habitat value to the wetland.

The waters of Mercer Slough divide and flow around the privately held Bellefield Office Park. The slough and associated riverine wetland are in a reserve unit. However, the interior developed area is categorized as moderate habitat. Pervious surface in the area has hydric soils and supports wetland vegetation, including some forested patches, but the habitat is greatly fragmented by the large buildings, paved parking lots, and roads of the Office Park.

Paved roadways, including a section of I-405, separate the Mercer Slough reserve habitat from Lower Kelsey Creek, constituting approximately 5.6 ac of low habitat. Reserve habitat continues beyond the I-405 and includes Kelsey Creek and its associated wetland.

3.3 Phantom Lake/Larsen Lake

The Phantom Lake shoreline, including Larsen Lake and associated wetlands, is largely Reserve Habitat containing agriculture and forest patch components. While Phantom Lake itself is Reserve Habitat, it is surrounded by shoreline in a Moderate Habitat unit. The complex is nearly entirely undeveloped with structures, although the shoreline does extend into residential areas around Phantom Lake. Bordering the lake are four patches of perch trees, significant for their proximity to the lake, which is potential foraging habitat for bald eagles, osprey, and other wildlife. Two small snag-rich areas occur along the lake's southeast shore as well, providing foraging and nesting habitat for numerous species.

A wetland corridor extends between Phantom and Larsen Lakes, broken in three locations by paved roads but otherwise wide and free of structures. Three large Agriculture units, planted in herbaceous monocultures, are located in this corridor. A portion of the corridor boundary is designated as High Habitat because it is a line of trees functioning to shield the wetland from surrounding development. On the other side of the corridor and within the Reserve Habitat unit, a forest patch is called out to emphasize the high habitat value of forested wetland.

Kelsey Creek flows between Phantom and Larsen Lakes, traveling through a culvert beneath SE Lake Hills Boulevard. The wetland complex continues north of the road, encompassing Larsen Lake and a large wetland surrounding it. The reserve unit is broken by a near-total ring of agricultural land planted to fruiting shrubs surrounding the lake. A wetland forest patch is depicted along the south edge of the Larsen Lake wetland, where it provides potential roosting, nesting and foraging sites for birds using the wetland and lake. Along the edge of the lake itself is a snag-rich area that constitutes the highest quality lakefringe habitat in the complex. It provides overhanging vegetation on the lake; four additional areas of overhanging vegetation are also present.

The Larsen Lake wetland continues on the west side of 145th Place SE along a tributary to Kelsey Creek. The entirety of this portion falling within shoreline jurisdiction is Reserve Habitat and is described as Larsen Creek B in the Wetland Inventory report.

3.4 Lake Sammamish Shoreline

Nearly 90 percent of Bellevue's highly developed Lake Sammamish shoreline is in Low and Moderate Habitat units. Ornamental species are very common, and little vegetation exists along the lakefront. Although the landscape in general includes large, forested parks and private land,

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the Low Habitat areas do not gain value from the proximity of these more natural areas because the shoreline itself, with a few exceptions described in the following paragraphs, simply does not support vegetation or features of value to wildlife.

A few areas of High Habitat occur along parks and forested right-of-way. Although separated from large contiguous tracts by West Lake Sammamish Parkway NE, these are forested stands of primarily native species, and highly mobile species such as most songbirds can easily cross the barrier presented by the road.

Forest fragments along the Lake Sammamish shoreline are generally the edges of larger stands, including right-of-way, and are again for the most part separated from the larger stands by the Parkway. No significant perch tree stands or snag-rich areas were noted.

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AQUATIC HABITAT

1.0 BACKGROUND

To the extent possible, information for the aquatic habitat inventory was obtained from a combination of current watershed planning documents, ecological research publications, and interviews with natural resource managers (local, state, federal and tribe) that actively conduct work in these areas. The end product of this effort (i.e. mapping, literature review, and discussion) is intended to be used to develop an understanding of the location, condition and use of aquatic habitats.

Integration of the limnological and ecological elements will help define areas of current high function and areas with potential for restoration, and hopefully build a better understanding of aquatic habitat in the City's shorelines.

2.0 DISCUSSION

The Aquatic Habitat component of this report has been divided into discussions of *limnological* and *ecological* processes.

2.1 Limnological Processes

The limnological component addresses conditions that help develop an understanding of the limnological processes in Lakes Washington and Sammamish in general, and how these processes affect the water quality and physical characteristics of shoreline areas in the City of Bellevue. This includes discussions on *water quality*, *substrate and shoreline characteristics*, and *hydrologic inputs*.

2.1.1 Water Quality

The King County Major Lakes water quality program has monitored water temperature and other water quality parameters in Lakes Washington, Sammamish, and Union since the 1970s. These monitoring locations are dispersed throughout the lake (Figure 1), where temperature is recorded over a range of different water depths. King County's long-term data, in combination with the numerous Lake Washington investigations conducted by researchers at the University of Washington, provide a wealth of water quality information for these waters. In particular, Lake Washington is one of the more well-studied lakes in the world. The information below summarizes some of the data recorded at the Lake Washington and Sammamish monitoring stations nearest the Bellevue shoreline, and provides a general outline of how these water quality parameters can affect aquatic ecology in the nearshore waters of Bellevue.

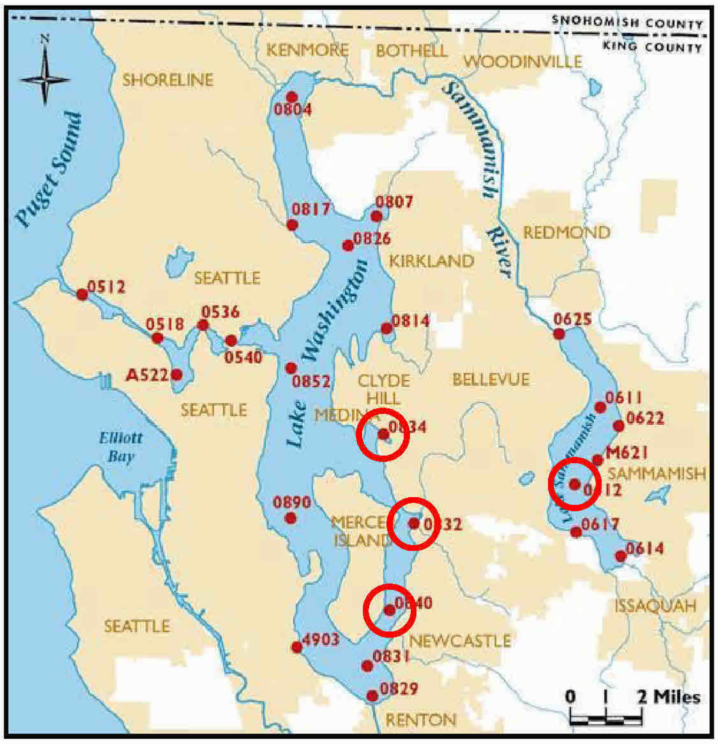

Figure 1. Major Lakes water quality monitoring stations (King County). Stations that best characterize water quality conditions in Bellevue shoreline areas are circled in red.

Water quality in Lakes Washington and Sammamish is largely determined by the availability of nutrients, water temperature dynamics, and light duration, all of which vary seasonally and are further affected by local weather patterns. Phosphorous is currently the limiting nutrient for Lakes Washington and Sammamish, and is made available in the water column through a combination of water column mixing, autotrophic uptake, and delivery by tributary streams (Arhonditsis et al. 2003). Prior to diversion of sewage effluents in Lake Washington (1941-1963), excessive amounts of phosphorous-rich nutrients were historically discharged to the lake (Edmondson 1994). By 1968 however, these effluents were diverted from both Lake Washington and Lake Sammamish and water quality in these lakes rapidly improved and has since stabilized (Edmondson 1994). Overall water quality in Lakes Washington and Sammamish is exceptionally high, especially for lakes located within a major urban area.

Water quality issues and limnological conditions have been well documented for Phantom and Larson Lakes (KCM 1993). Both of these lake systems have been the focus of lake restoration efforts in the past, including hypolimnetic oxygenation and aluminum sulfate treatment to control internal phosphorus loading. While immediate improvements in terms of clarity, reduced algal blooms, and internal phosphorus concentrations were made to both lake systems, long-term effectiveness of those treatments are unknown at this time.

As a limiting nutrient in Lake Washington, phosphorous is considered a pollutant of concern. Although phosphorus from sewage effluents has largely been controlled in these lakes, phosphorus from non-point sources associated with these urbanizing watersheds could still

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degrade water quality in Lakes Washington and Sammamish. Non-point source pollution can be generated by almost every land use activity in the watershed, including homes, gardens, stormwater runoff, construction sites, car washing, septic tanks, natural erosion processes, and more. A well-known negative effect of phosphorous enrichment is blooms of cyanobacteria, which cause surface scums and sometime produce toxic compounds (cyanotoxins) that are harmful to humans, livestock, pets, and wildlife (Bouchard et al. 2005). Current water quality management plans for Lakes Washington and Sammamish are composed of water quality indicators that track phosphorous concentrations as well as other parameters like water clarity, chlorophyll a concentrations, etc.

The Cedar River flows into the south end of Lake Washington and contributes approximately 25% of the annual phosphorous load and 57% of the annual hydraulic load, while the Sammamish River enters the north end of Lake Washington carrying approximately 41% of the annual phosphorous load and 27% of the annual hydraulic load (Arhonditsis et al. 2003). Smaller tributaries in the immediate watershed (including Kelsey Creek and Coal Creek) deliver approximately 14% of the annual phosphorous load and 4% of the water to Lake Washington (Brett et al. 2005). The largest Lake Sammamish tributary stream is Issaquah Creek, which contributes approximately 70% of the hydraulic load and carries a phosphorus concentration of about 30 μg/L (Brett el al. 2005). No published data was found to estimate the percent phosphorous loading from Issaquah Creek.

Each spring (late February-early March) a large algal bloom, consisting of high chlorophyll concentrations, occurs in Lake Washington in response to warming water temperatures and increases in daylight (Edmondson 1994). This annual phytoplankton bloom persists through May and results in a dramatic reduction in nutrient concentrations in the lake (Arhonditsis et al. 2003). After May, the lake begins to stratify, preventing vertical mixing and nutrient enrichment, and subsequently limiting phytoplankton abundances to relatively low levels for the duration of the summer stratification period (Arhonditsis et al. 2003). The spatial distribution of the spring algal bloom is relatively homogenous (Arhonditsis et al. 2003), affecting most sections of the lake relatively equally. Patchiness of the bloom may occur in response to local wind or weather patterns, but location of these patches are not typically predictable. The bloom and summer stratification may occur more quickly adjacent to the City of Bellevue's shoreline, as this portion of the Lake Washington basin is shallow in relation to the deep western central area of the lake.

The King County Department of Natural Resources and Parks (Water and Land Resources Division) administers several programs that monitor water quality in many of the local lakes and streams. Some of the King County programs monitoring water quality in Bellevue's shoreline waters include the Stream and River Monitoring Program, the Major Lakes Monitoring Program, and the Swim Beach Monitoring Program. Routine sampling collects a number of water quality parameters like temperature, dissolved oxygen, nutrient content, turbidity, etc throughout the year. Figure 1 shows the location of monitoring stations in the King County Major Lakes Monitoring Program, Figure 2 shows the monitoring stations that make up the King County Streams and Rivers Monitoring Program, and Figure 3 shows the King County Swim Beach Monitoring Program monitoring stations.

In addition to phosphorous concentrations, another water quality indicator currently tracked in many areas of Lakes Washington and Sammamish is fecal coliforms, an intestinal bacteria commonly associated with sewage pollution in the water. Fecal coliforms pose a human health threat and can lead to closures of numerous swimming (and non-swimming) beaches around Lakes Washington and Sammamish. Specific areas are monitored weekly from May through September to detect high counts of these bacteria. The King County Department of Natural Resources and Parks administers this program, called the King County Swimming Beach Monitoring Program (http://dnr.metrokc.gov/wlr/waterres/swimbeach/default.aspx). Lake Washington swimming beaches that are part of the Swimming Beach Monitoring Program and also located in or near Bellevue include Newcastle Beach, Meydenbauer Bay Beach, and Luther Burbank Park (Mercer Island) (Figure 3). Lake Sammamish beaches in the monitoring program and also located near Bellevue shorelines include Lake Sammamish State Park and Idylwood Park.

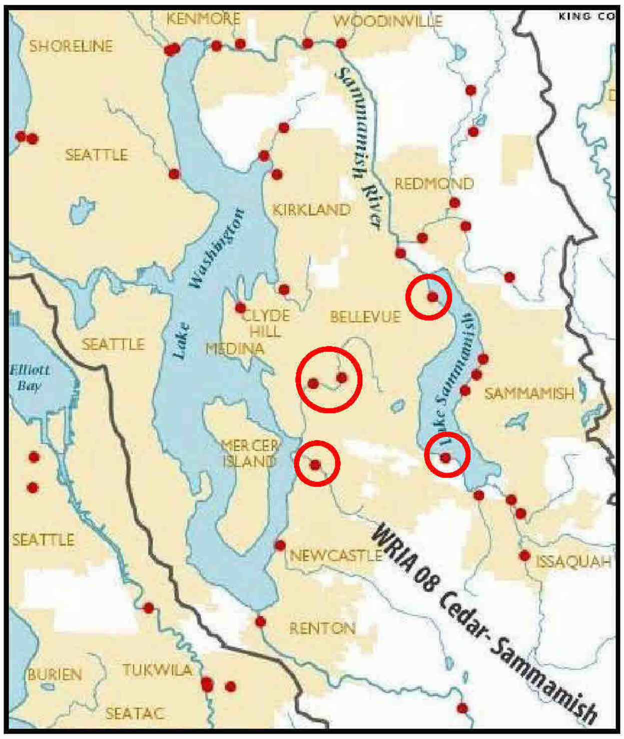

Figure 2. Streams and Rivers water quality monitoring stations (King County). Stream sampling locations with the potential to affect water quality in Bellevue's shoreline areas are circled in red.

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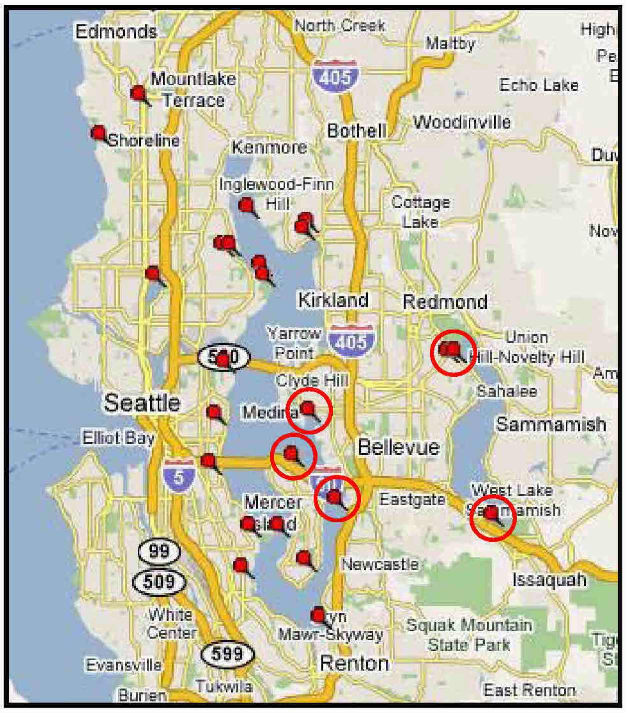

Figure 3. Swim beaches monitored by King County. Sites nearest the City of Bellevue shoreline are circled in red.

Fecal coliforms are measured in Colony Forming Units (CFUs), and always occur at low levels (less than 50 CFUs) in the water, even in lakes and rivers with high water quality. The sources of fecal coliforms vary, but CFU counts are always very high (more than 1,000 CFU) when sewage is present in the water, such as when a sewer line breaks. Other sources include fecal contamination from waterfowl, dogs, cats, surface run-off from grassy areas adjacent to the beach, and tributary streams (King County Swim Beach Monitoring Program). Beaches located in enclosed bays with limited water exchange or beaches with a nearby tributary draining an urbanized area experience relatively high fecal coliform counts, while CFUs at beaches on open shorelines with greater water circulation are generally lower. Juanita Bay Beach (Kirkland) is an example of a beach in an enclosed area with an urban tributary nearby. Fecal coliform counts have been relatively high at Juanita Beach (Figure 4), and water pumps have been installed in an effort to increase water circulation and periodically lower CFU counts.

Fecal coliform counts from the 2007-monitoring season at beaches in or near the Bellevue shoreline are included in Figures 5 through 9 for comparison purposes. This information was taken from the King County Swim Beach Monitoring Program, and has been recorded since 1997. Last year's data indicate that relatively high fecal coliform counts are periodically recorded at Meydenbauer and Newcastle Beaches, while CFUs are typically lower at Luther Burbank. Lower CFUs are typically observed at Luther Burbank because this park has greater wind/wave exposure and higher rates of water exchange. Meydenbauer and Newcastle Beaches, however, are more protected with lower rates of water exchange, and typically experience higher CFUs. High fecal coliform counts were relatively rare in the Lake Sammamish beaches (Idylwood and Lake Sammamish State Park) located nearest the Bellevue shoreline, indicating that the rates of water exchange may be higher along this part of Lake Sammamish.

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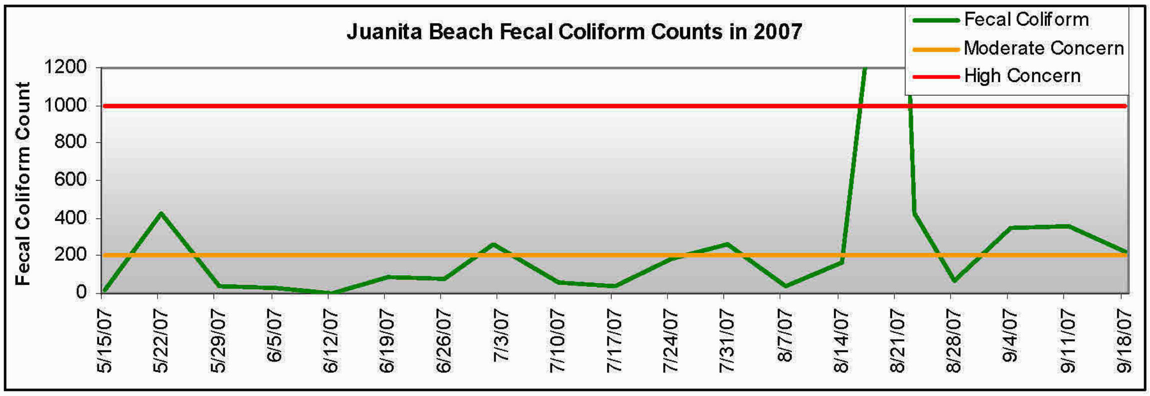

Figure 4. Juanita Beach fecal coliform count in 2007.

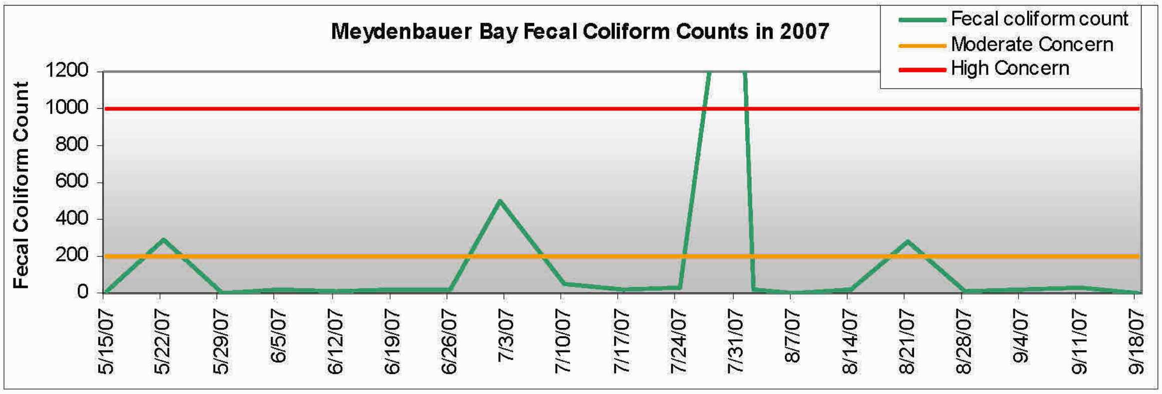

Figure 5. Meydenbauer Bay fecal coliform count in 2007.

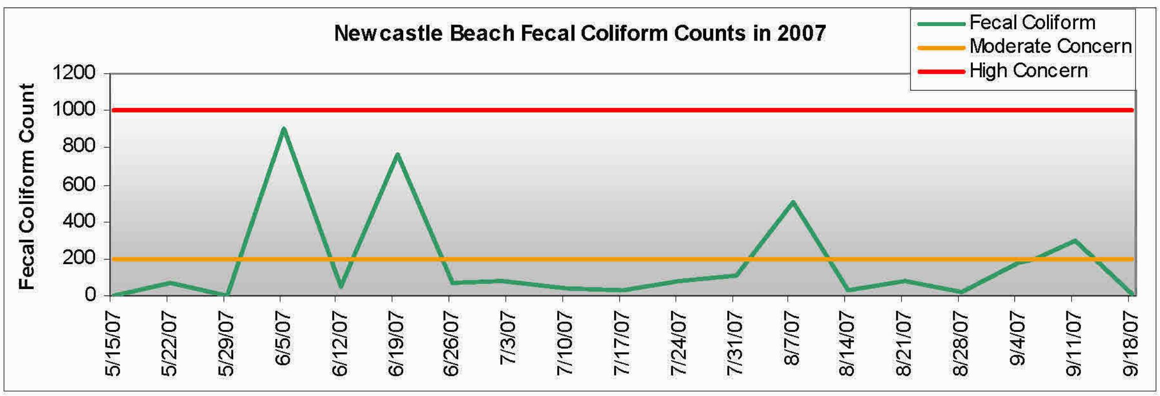

Figure 6. Newcastle Beach fecal coliform count in 2007.

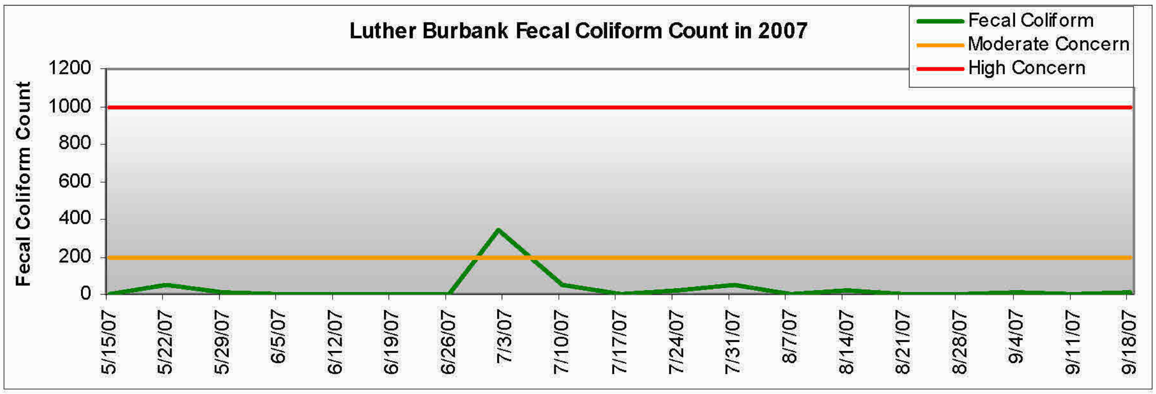

Figure 7. Luther Burbank fecal coliform count in 2007.

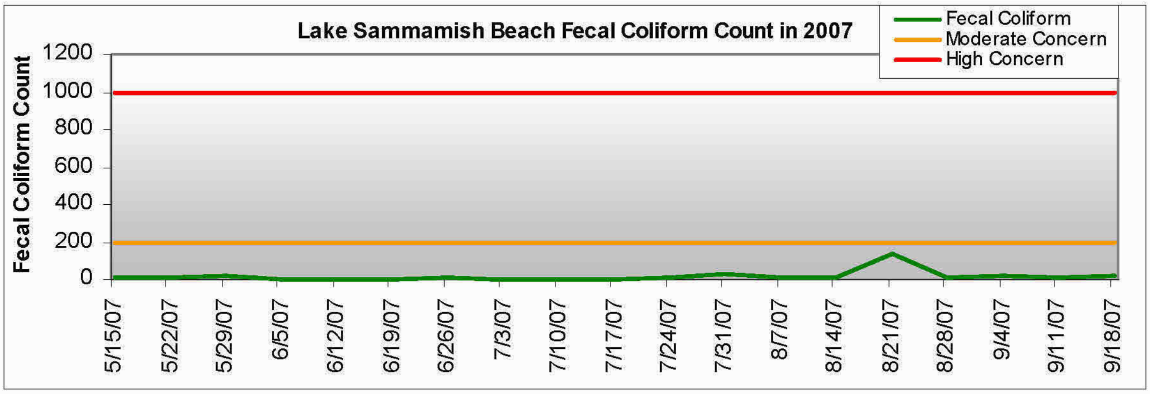

Figure 8. Lake Sammamish Beach fecal coliform count in 2007.

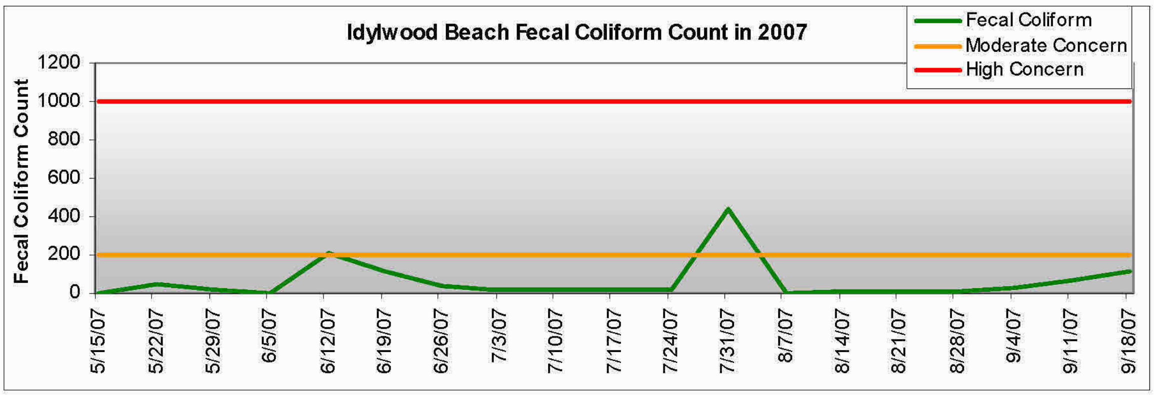

Figure 9. Idylwood Beach fecal coliform count in 2007.

Areas of Low Mixing and Flushing Potential

Portions of bays, such as Meydenbauer Bay and areas within manmade channels, such as in Newport Shores, are protected from wind and waves, but also experience lower rates of water exchange. Tributary streams that enter these areas, such as Meydenbauer Creek, may provide some flushing action, but streams draining urban areas can also carry high phosphorous loads or bacteria. Phosphorous or fecal bacteria loading from tributary streams can exacerbate water quality problems along the shoreline, especially in protected bays with lower rates of water exchange. As described above, several monitoring programs track water pollutants (like phosphorous and fecal coliforms) in Lakes Washington and Sammamish and also address areas with low mixing or flushing potential. Areas with low mixing or flushing potential are typically included in the water quality monitoring programs because the highest concentrations of pollutants are generally found in these portions of the shoreline. As shown in Figure 1, King County water quality monitoring stations are located within and adjacent to Meydenbauer Bay and the mouth of Coal Creek (near Newport Shores). Fecal coliform counts are taken near Meydenbauer Beach Park and Newcastle Beach Park (located just south of Newport Shores) (Figure 3). As indicated by the monitoring program results, both Meydenbauer Bay and Newcastle Beach Park (and presumably the channels within Newport Shores), are at a higher risk of poor water quality due to low mixing and flushing rates.

Known and potential contaminated substrate areas

In 1999 and 2000, sediment samples were collected from sixty-one stations in different areas of Lake Washington, Lake Sammamish, and Lake Union (King County 2004b). This study was part of an effort to characterize benthic community structure, toxicity, and chemistry (sediment quality triad analysis) throughout these three water bodies. Seventeen stations were located in Lake Sammamish, twenty-nine stations were in Lake Washington, and 15 stations in Lake Union were assessed (Figure 10). Many of the near-shore stations were located in shallow areas where sediment quality was most likely influenced by creeks, storm drains, or emergency bypass outfalls. Three of the Lake Washington stations were in or near Bellevue's shoreline area, located at: 1) Meydenbauer Bay, 2) Near the mouth of Coal Creek, and 3) Near Mercer Island, across the lake from the May Creek confluence. Four of the Lake Sammamish stations were evenly dispersed along the shoreline throughout the Bellevue City limits (Figure 1).

The sediment quality triad study analyzed three components of the aquatic substrate: 1) diversity of the benthic invertebrate community, 2) bioassays that evaluated the sediment's toxicity to aquatic organisms, and 3) sediment chemistry to gauge contaminant concentration. Figure 11 shows the results of the sediment triad analysis at all sampling stations in Lake Washington and Sammamish. The results indicated that, relative to Lake Union or some contaminated areas of Lake Washington, sediment quality in selected shoreline areas of Bellevue is generally good (King County 2004b). The only relative exception to this result was one station along Lake Sammamish near the City's northern boundary. This site was found to have relatively high benthic invertebrate diversity. Given the location of sampling near a storm water outfall to Lake Sammamish, the high benthic diversity is believed to be a result of high nutrient concentrations in stormwater runoff from upland urban areas. A similar result was found along the City of Sammamish's shoreline near a storm water outfall location. In all locations, PCBs were the chemical group that most frequently exceeded the study's sediment quality guidelines, followed by metals, polycyclic aromatic hydrocarbons (PAHs), and phthalates.

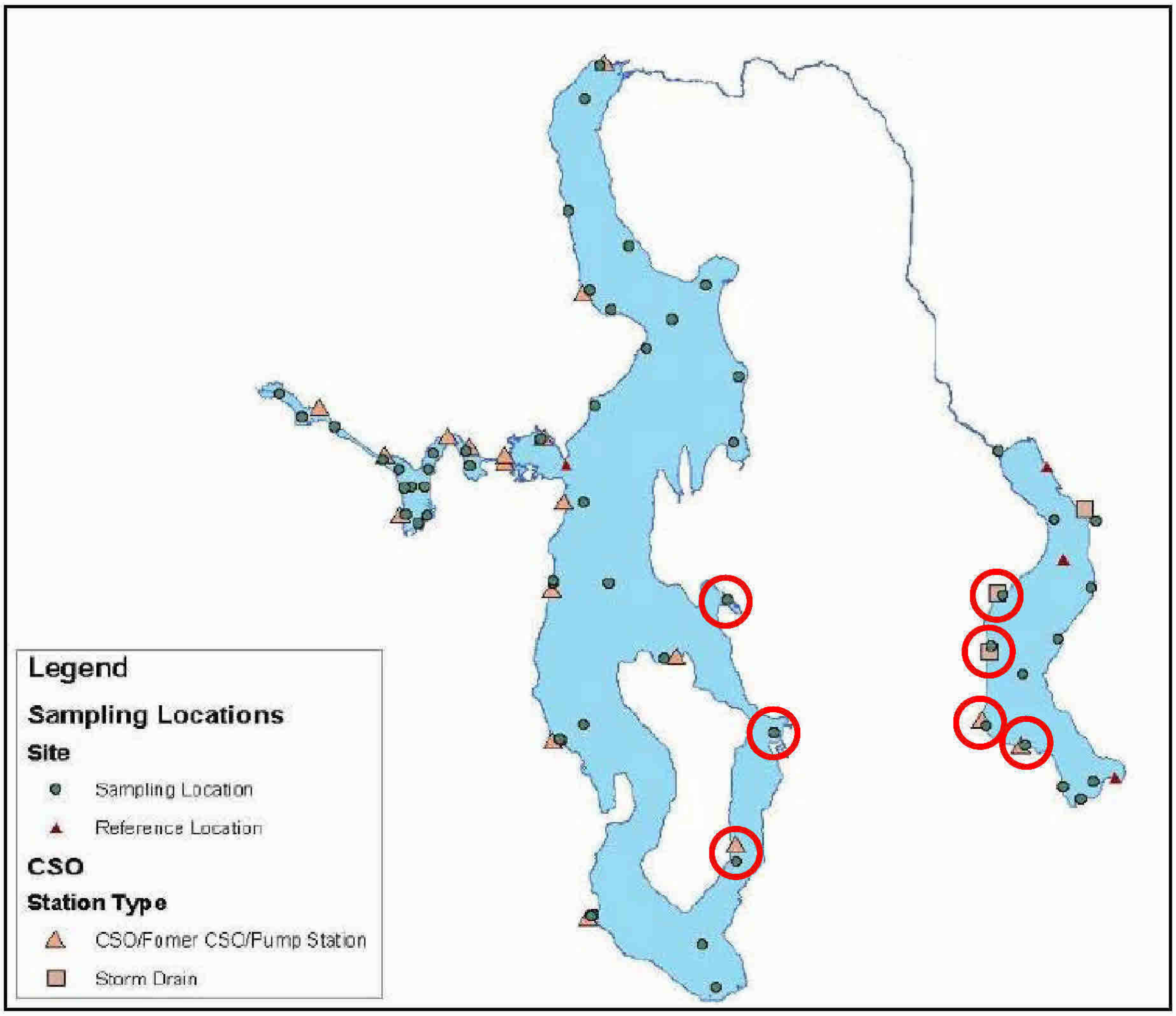

Figure 10. Sediment sampling stations in Lake Washington, Lake Sammamish and Lake Union (King County 2004b). Stations nearest the Bellevue shoreline are circled in red.

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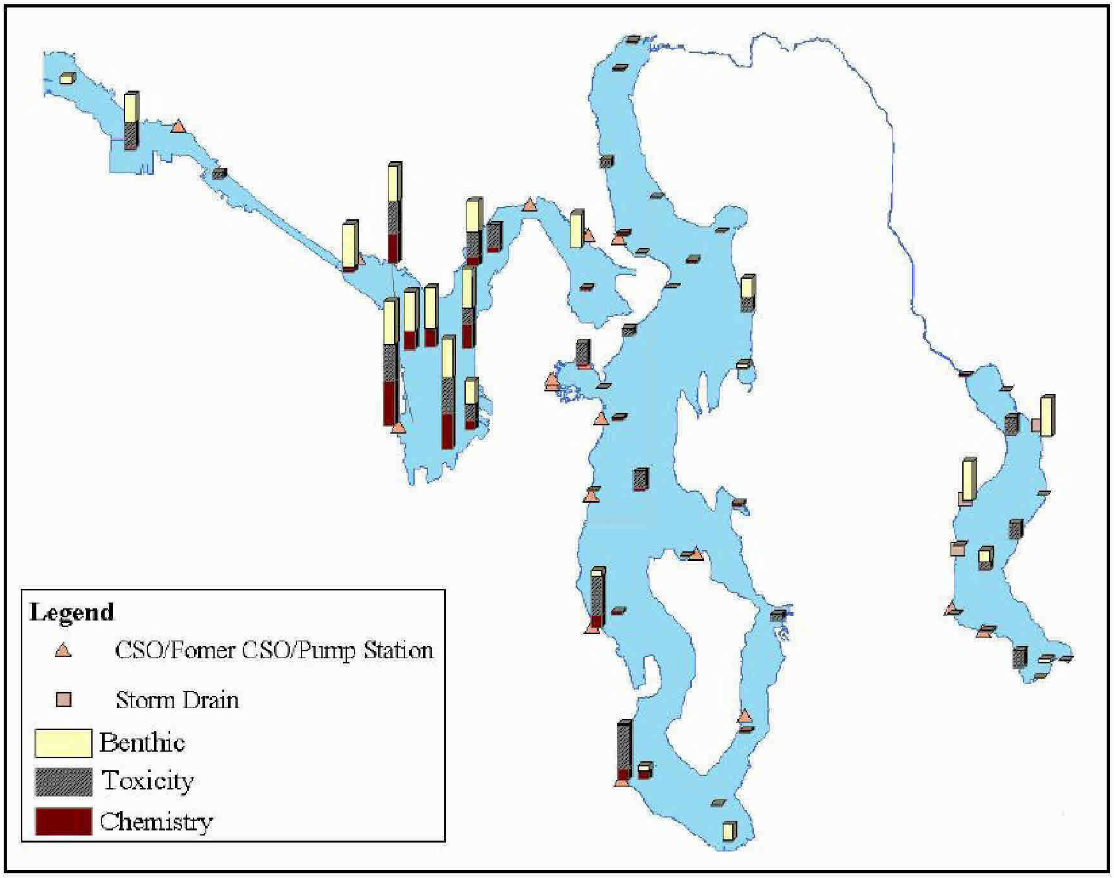


Figure 11. Relative contamination at sediment sampling stations in Lake Washington, Lake Sammamish and Lake Union (King County 2004b).

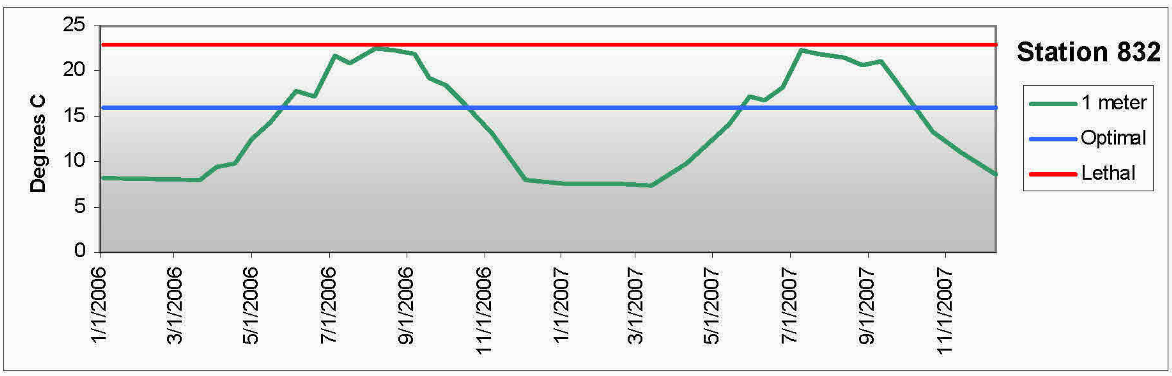
Water Temperature

Water temperature and the timing of seasonal water temperature fluctuations has a powerful effect on the aquatic ecology in Lake Washington, especially in the shallow margins and shoreline areas. One of the local effects of global climate change has been a documented warming trend in water temperatures in Lake Washington (Winder and Schindler 2004, Hampton et al. 2006, Arhonditsis et al. 2004). Lake Washington is generally stratifying earlier in the year, and remaining stable for a longer duration before destratification (King County 2007). The ecological response to this warming trend is the focus of a number of ongoing investigations. One concern is that changes in seasonal thermal dynamics of the lakes will affect the timing and abundance of zooplankton populations that juvenile salmonids rely on for food. Fundamental changes in these food webs may result in a less productive rearing environment for juvenile salmonids using Lake Washington and Sammamish (Arhonditsis 2004, Hampton et al. 2006, Beauchamp et al. 2004)

Lakes Washington and Sammamish are both monomictic (having one mixing and one stratification event per year) lakes. Lake Washington predictably stratifies in late spring (April-May), remains stable throughout the summer, destratifies in the fall (October), and undergoes complete mixing during the winter (December –March, King County 2003). Thermal stratification in Lake Sammamish, usually beginning in late May and extending until mid November, results in mean epilimnetic (upper layer) temperatures of 16 degrees C, coinciding with decreasing dissolved oxygen levels throughout the hypolimnetic (lower layer) zone (Kerwin 2001). For both lakes, but especially for Lake Sammamish, the lack of sufficient oxygen in the hypolimnion combined with relatively warm temperatures in the epilimnion serves to constrict the suitable habitat area available to salmonids during the summer. Thus, neither juveniles nor adults are expected in nearshore waters from June through September.

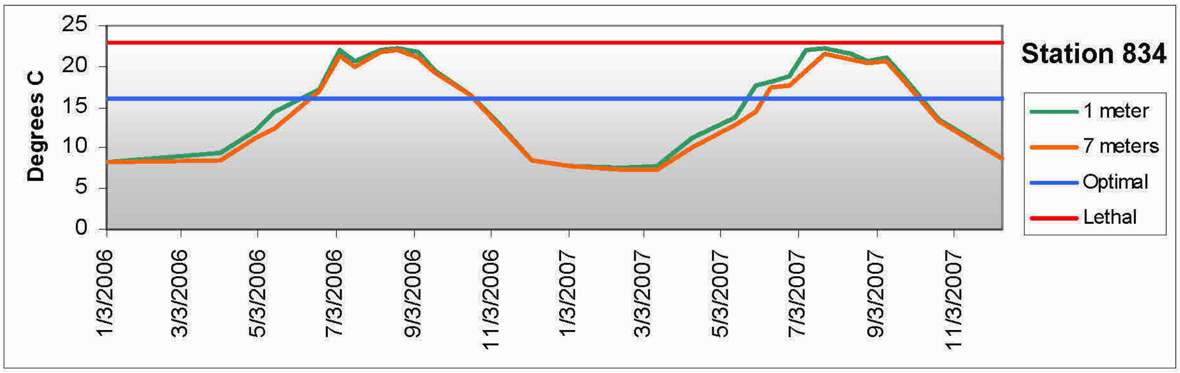
Figures 12-15 depict a two-year cycle characterizing annual temperature dynamics at the three Lake Washington monitoring stations (832, 834, and 840) and one Lake Sammamish monitoring station (612) located nearest the Bellevue shoreline. Optimal and lethal temperature thresholds for salmonids are also provided in these figures. These optimal and lethal thermal levels are for a 24 hr period. Cutthroat trout have often been observed in water temps in excess of 27 degrees C for short periods of time. Similarly, the optimal temperature for fish is highly dependent on body and ration size. Based on this information, both Lake Washington and Lake Sammamish reach near lethal temperature limits within their surface waters during summer months.

One of the most significant factors controlling surface water temperature dynamics during the summer stratification period in Lake Washington is a wind-forced deflection of the thermocline, which causes cold-water upwelling in the south end of the lake and warm water downwelling in the north end of the lake. These extended periods of upwelling/downwelling are thought to be a more important determinant of water temperature differences in the lake than the thermal influence of either the Cedar of the Sammamish Rivers (King County 2007). Wind and associated upwelling/downwelling has a lesser effect on water temperatures in the middle section of Lake Washington than it does on the north and south ends. Water temperatures and the position of the thermocline are relatively stable in the middle portion of the lake. The Bellevue shoreline is situated near the middle of the lake, and summertime water temperatures are probably relatively stable, and less likely to be affected by fluctuations caused by the upwelling/downwelling phenomenon. Similar to Lake Washington, Lake Sammamish has a north-south orientation and the predominant southerly winds result in a similar pattern of upwelling and downwelling in this lake (King County 2007).



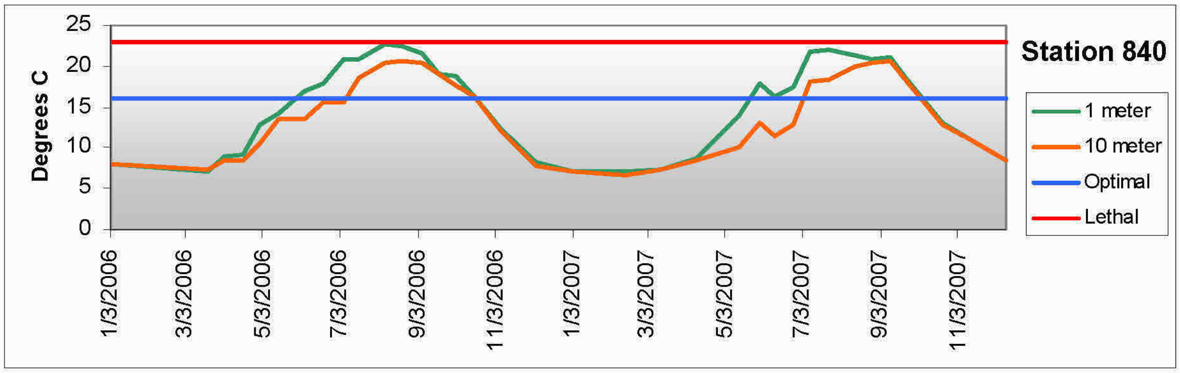
Blue and red lines denote Optimal and Lethal water temperatures for salmonids.

Figure 12. Lake Washington water temperature fluctuations (one-meter depth) over the past two years at Station 832, near the mouth of Coal Creek.



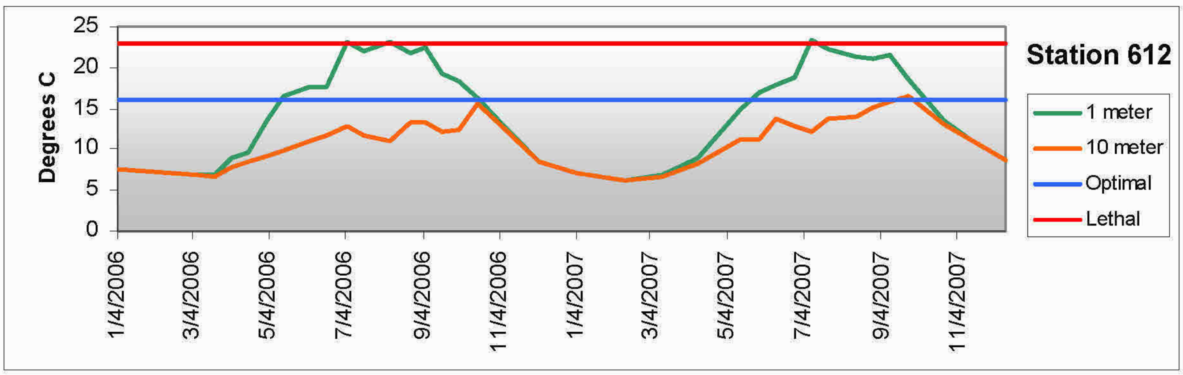
Blue and red lines denote Optimal and Lethal water temperatures for salmonids.

Figure 13. Lake Washington water temperature fluctuations (one-meter and seven-meter depths) over the past two years at Station 834, in Meydenbauer Bay.



Blue and red lines denote Optimal and Lethal water temperatures for salmonids.

Figure 14. Lake Washington water temperature fluctuations (one-meter and ten-meter depths) over the past two years at Station 840, just south of Bellevue.



Blue and red lines denote Optimal and Lethal water temperatures for salmonids.

Figure 15. Water temperature fluctuations (one-meter and ten-meter depths) over the past two years at Station 612, in Lake Sammamish near the Bellevue shoreline.

2.1.2 Substrate Characteristics

The King County Major Lakes Monitoring Program does not track the movement of sediment around shoreline areas in Lake Washington or Lake Sammamish (Frodge, pers. comm. 2008). Sediment quality has been tested at several locations within these lakes via the sediment triad analysis (King County 2004b), but sources, rates of delivery, and transport patterns of substrate material along the lakeshore has not been documented.

Shoreline distribution of various substrate types was not described or mapped in this report. Sediment composition in shoreline areas is in a constant state of flux, and substrate types are often patchy, frequently varying between sandy-mud to gravel-cobble in relatively small areas. Although areas within protected coves, such as Meydenbauer Bay, have not been mapped for sediment composition, fine sediments (sand, silt, and mud) likely dominate most of this area. These areas of fine sediments are likely interspersed with small isolated patches of gravel and cobble. Areas with high exposure to wind and boat derived waves and with no obstructions, (e.g. rock groins or pier skirting) to littoral drift are likely to have less fine sediment accumulation and predominantly more cobble and large gravel substrates. However, with littoral drift and changes in wave dynamics over the course of a year, substrate composition in high energy environments can still be highly variable. Other factors contributing to substrate movement and characteristics include wave fetch, bathymetry, and shoreline armoring. The City of Bellevue study of the ordinary high water mark of Lake Sammamish (The Watershed Company 2004) noted the high degree of variability in substrate accumulation along the Lake Sammamish shoreline.

Wave fetch is commonly known as the uninterrupted distance that prevailing winds, and thereby surface waves, travel over water. Typically, shorelines with long wave fetch distances are more susceptible to wind-driven waves and thereby experience higher than normal erosion forces. In Lake Washington, the prevailing annual wind direction is from south to north (as reported by meteorological data from Boeing Field in Seattle). This prevailing wind direction typically exists from October through May. Conversely, between June and September, the prevailing wind is from the northwest.

The overall result is extremely high wave fetches for areas such as Holmes Point, near Kirkland (approximate 9 mile fetch) and Lake Forest Park (approximate 7 mile fetch). For the City of Bellevue's Lake Washington shoreline, the areas just west of Mercer Slough and just south of Meydenbauer Bay are subject to rather high wave fetches (5 miles and 4 miles, respectively), although these two shoreline areas are subjected to varying degrees of fetch during different times of the year. Mercer slough being impacted heavily during winter storms having a southerly wind and the shoreline south of Meydenbauer Bay impacted during summer months when the winds tend to come from the northwest. Due to the reverse hydrograph of Lake Washington, where the US Army Corps of Engineer raises the level of the lake by 2 feet during the late spring and summer, wave impacts can be severe. During this high water period, significant wave impacts can also come from boat traffic through the east channel along the east side of Mercer Island. Unfortunately, impacts from boat driven wakes are difficult to quantify since their magnitude is directly related to the speed, size, and location of the vessel on the water.

On Lake Sammamish, the annual prevailing wind is from the southeast, coming down from Cougar Mountain through the Issaquah valley, although, similar to Lake Washington, a northerly

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prevailing wind is also experienced during summer months. The annual prevailing wind results in a large fetch (approximately 3 to 4 miles) along most of the City's shoreline north of Vasa Park. Conversely, the shoreline to the southeast of Vasa Park is subject to a nearly 5 mile wave fetch from a northerly wind.

Wave fetch has not been mapped on either Lake Washington or Lake Sammamish. While assumptions of potential wave fetch, as discussed above, are possible, development of a wave fetch model would be the most effective and accurate method to assess potential impacts to shoreline areas. Modeling of wave fetch has been conducted for areas of Puget Sound, but would require extensive historical inputs for wind speed, direction, and duration for Lakes Washington and Sammamish and may not be cost effective. Use of existing fetch models from USGS would result in a grid size of 50 meters, which would be too coarse for proper evaluation for the City's shoreline area.

The bathymetry of these lakes also interacts with wind and wave forces to affect lake mixing and substrate movement. Lake Washington is a glacial trough that was formed by the Vashon ice sheet, and is generally a deep, narrow basin with steeply sloping sides (Edmondson 1991). The City of Bellevue shoreline is largely fronted by a relatively shallow and narrow channel separating it from Mercer Island. This East Channel, at the point closest to Bellevue, is approximately 30 feet deep at its shallowest point. Water depth near the southern city boundary reaches nearly 75 feet while water depths just southwest of Meydenbauer Bay can reach over 150 feet. The central portion of Lake Washington is comparatively deeper, reaching over 200 feet deep. Lake Sammamish is about half as deep as Lake Washington, a bit over 100 feet at its deepest point. Bathymetry information for both lakes (5-foot contours) has been obtained from King County and is depicted in Appendix A-2, Figures 1-2. Areas of relatively deep shoreline areas and high wave fetch are typically more highly susceptible to wave impacts and erosion forces. Areas with gentle sloping shorelines (mouth of Coal Creek for example), are better able to attenuate wave energy and tend to have relatively stable shorelines. Areas where combined high wave fetch, deep water, and high levels of shoreline armoring (see discussion below) are considered high impact areas. While these areas are not specifically identified in the accompanying maps, the areas of armoring and deep water are shown to give relevance to this discussion.

Shoreline armoring typically consists of rock, concrete, or wood bulkheads positioned at or near the OHWM of a waterbody. The extent of shoreline armoring along the City's shoreline has been mapped by the City based on a combination of aerial photo interpretation and ground-truthing (see Appendix A-2, Figures 1-2).

Residential shoreline properties along Lake Washington and Sammamish are highly valuable, and these areas are typically armored with bulkheads to reduce erosion caused by waves. Shoreline armoring is also used to protect structures near the water's edge or to maximize shoreline lot size. Bulkheads or other types of shoreline armoring affect juvenile salmonids by eliminating shallow-water refuge habitat, or indirectly, by the elimination of shoreline vegetation and in-water woody debris that generally accompanies bulkhead construction. Shoreline armoring also disrupts the natural process of beach erosion, which reduces the rate of sediment delivery, affects patterns of sediment transport, and ultimately changes the size and shape of nearshore habitats.

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Placing bulkheads waterward of OHWM creates an abrupt, deep-water drop-off at the shoreline while eliminating shallow water habitat in the nearshore. Lange (1999) found that bank stabilization (i.e., various forms of erosion control structures that we refer to as "bulkheads") was negatively correlated to fish abundance and species richness at all spatial scales investigated. Juvenile chinook salmon and other small fishes rely on shallow-water habitats in the littoral zone for foraging, refuge, and migration (Collins et al. 1995; Tabor and Piaskowski 2002). Shoreline armoring and bulkheads can also reduce species diversity and abundance in macroinvertebrate populations inhabiting the littoral zone (Northcote and Northcote 1996; Schmude et al. 1998; Lange 1999; Jennings et al. 1999). Armored waterfront properties in residential areas may also reduce production of terrestrial invertebrates in shoreline areas, limiting access to a potentially valuable food source for juvenile salmonids and other fishes rearing in nearshore habitats (Koehler et al. 2006).

The City's shoreline is approximately 79 percent armored along Lake Washington and approximately 73 percent armored along Lake Sammamish. A high percentage of the Lake Washington armoring can be contributed to residential development (88 percent armored). Conversely, nearly all of Lake Sammamish is residential, yet is 15 percent less armored. The extent and area of shoreline armoring, as well as bathymetry and relative wave fetch, are all aspects which should lend input to analysis of shoreline ecological functions and may provide guidance during later evaluation of the City's Shoreline Master Program update.

2.1.3 Hydrologic Inputs

Surface water inputs to the City's shoreline waterbodies consist of streams, ditches, and stormwater discharges. These may consist of open water or piped channels and are mapped in Appendix A-3, Figures 1-14.

Overall, the two major tributaries to Lake Washington are the Cedar River and the Sammamish River, which contribute approximately 57% and 27% of the annual hydraulic load, respectively. The retention time for Lake Washington averages about 2.4 years (Edmondson 1991), and water drains through the Lake Washington Ship Canal to Puget Sound.

Issaquah Creek, the major tributary to Lake Sammamish, delivers about 70% of the annual hydraulic load for Lake Sammamish. Water in Lake Sammamish exits the lake via the Sammamish River and discharges to the north end of Lake Washington.

Generally, streams within the City of Bellevue which discharge to Lake Washington (e.g. Yarrow Creek, Meydenbauer Creek, Kelsey Creek, Coal Creek) and Lake Sammamish (e.g. Vasa Creek and Lewis Creek) do not significantly impact the limnology of those lake systems, as their respective hydrologic inputs are only a fraction of the overall inflow. Instead, their respective impacts are more related to sediment delivery, nutrient content, and other water quality issues. The functions and values of these stream systems and their respective basins are well documented (Herrera Environmental Consultants 2005). This includes detailed inventory of fish use conducted by the City during efforts to classify their stream systems (The Watershed Company 2001).

The City of Bellevue Utilities Department currently monitors water quality in many of the stormwater outfalls discharging to Lake Washington and Sammamish (Graves, pers. comm.

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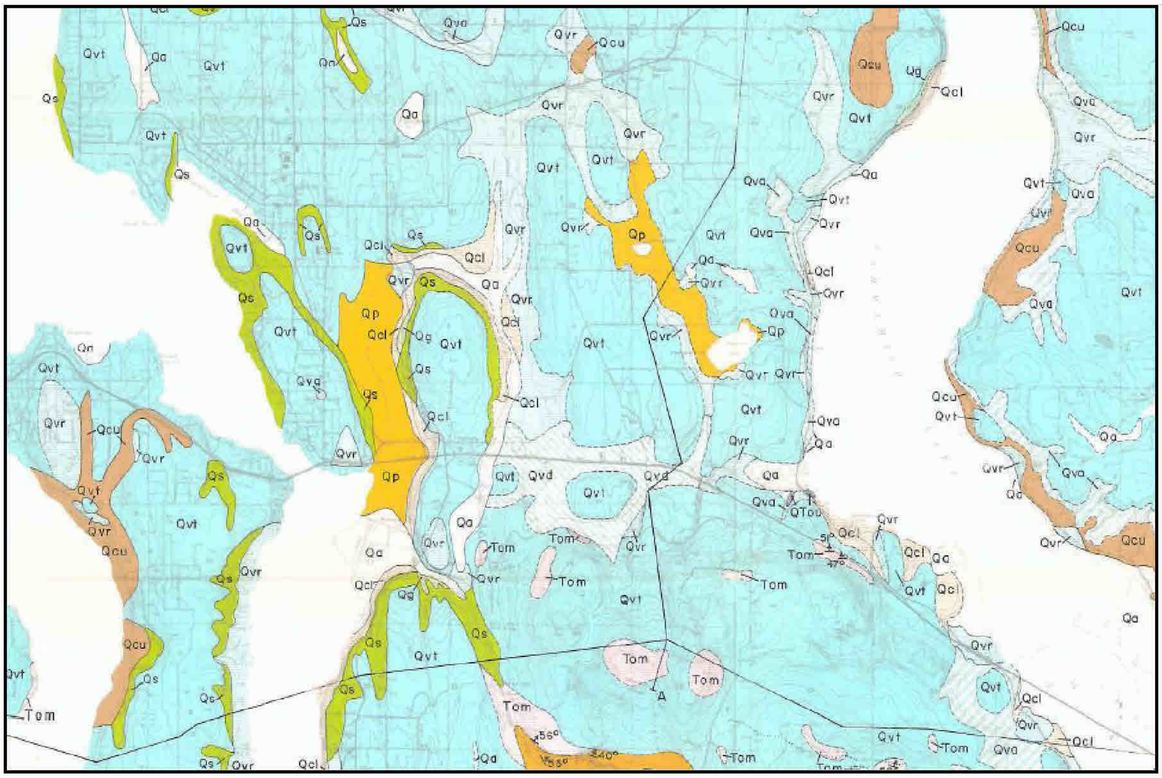
2008). Both private and public facilities contribute to stormwater outfall into shoreline waterbodies. A majority of water discharge is from single-family residential development, of which many of the older developments empty directly into the lakes and streams. There is very limited water quality treatment for outfalls. If so, these are limited to newer large-scale developments, particularly in the downtown area. Meydenbauer Bay developments have limited, if any, water treatment facilities. The City conducts occasional sediment removal in the bay, most recently at the Meydenbauer Bay Yacht Club outfall in August 2008 (Varner, pers. comm., 2008).

In addition to surface water inputs, groundwater is delivered to the lakes through local aquifers that are located at varying depths. Soil surveys show that the overlying surface is relatively impermeable and rainfall on those areas runs off on the surface or as shallow ground water. Unfortunately, comprehensive hydrogeologic maps describing how groundwater moves through the landscape have not been developed for the Bellevue area (Stockton, pers. comm. 2008), although they have been constructed for the Sammamish River corridor and the City of Seattle. A geologic map (Figure 16) can be used to make general inferences about groundwater movement within the City of Bellevue, but hydrogeologic information in this area is currently an information gap. Similar mapping efforts can be found in the City's mapping of critical areas (Adolfson Associates 2005).



Qa: Sedimentary deposits, undifferentiated. Interfingered beds of clay, silt, muck, peat, sand, and gravel, as much as 340 feet thick. Where peat is exposed at the surface, it is shown separately as Qp. Coarse-grained material is moderately permeable. Water commonly contains objectionable quantities of iron.
Qp: Peat. Organic material deposited chiefly in closed depressions. Where mapped, generally ranges in thickness from about 3 feet to 50 feet. Water contains objectionable quantities of organic matter.
Qvr: Recessional stratified drift, undifferentiated. Predominantly light-gray sand and gravel. The stratified drift is 100 feet or more thick. The upper surface is commonly a terrace. Permeability is medium to high.

<u>Qvd:</u> Delta gravel of the recessional stratified drift. Light-gray gravel and sand deposied at the mouths of streams tributary to ice-dammed glacial lakes. The thickness of the delta gravel is 100 feet or more. The upper surface is generally a terrace. Permeability is high.
<u>Qvt:</u> Till. Predominantly light-gray till but includes small amounts of stratified sand and gravel both within and overlying the till. The till is a hard, unsorted mixture of clay, silt, sand, and gravel, 150 feet or more thick. Although the till is relatively impermeable, thin beds of sand and gravel mapped with the till commonly yield small quantities of perched or semiperched water.
<u>Qva:</u> Advance stratified drift. Predominantly gray sand and gravel but some clay and silt. The thickness is 100 feet or more. Permeability is medium to high.
<u>Qs:</u> Unnamed sand. Predominantly brown stratified sand and small discontinuous lenses of silt, gravel, and clay. The thickness is 200 feet or more. Exposed only in the west half of the area. Permeability is moderate.
<u>Qcu:</u> Upper clay unit. Predominantly laminated to massive gray, blue-gray, or brown clay and silt. Locally includes sand, gravel, and peat. The thickness is 200 feet or more. In outcrops the sand and gravel are nearly impermeable as a result of oxidation; where unweathered, the permeability generally is moderate.
<u>Qg:</u> Unnamed gravel. Gravel and sand. Maximum thickness is more than 200 feet. In outcrops the gravel and sand are nearly impermeable as a result of oxidation; in the subsurface the permeability is generally moderate.
<u>Qcl:</u> Lower clay unit. Principally massive to laminated gray, blue, and brown clay and silt; locally includes varved clay, stony clay, till, peat, and pumiceous sand. The thickness is 50 feet or more. It is relatively impermeable.
<u>Tom:</u> Marine sedimentary rocks. Marine sandstone, shale, conglomerate, and volcanic ash. Maximum inferred thickness is more than 8,000 feet. Permeability of coarse materials is low to moderate. Dotted line represents surface trace of top of impermeable shale bed, which is inferred to be 1,000 to 2,000 feet thick.

Figure 16. Geologic map of the Bellevue area (from Liesch et al. 1963).

2.2 Ecological Processes

The ecological component addresses conditions that help develop an understanding of the relationships between biological factors, rather than chemical or physical. This includes discussions on *aquatic food web dynamics*, *fisheries*, and *aquatic vegetation management*.

2.2.1 Aquatic Food Web Dynamics

The aquatic food web, in general, has many factors affecting the overall dynamics of the food chain. The discussion below is related primarily to distribution and abundance of important food sources at the base of the food chain, and how their habitat requirements are affected by activities along the shoreline. As with the other components, this description of aquatic ecology relies heavily on existing publications and practical knowledge of local scientists actively conducting research in or near shoreline areas of Bellevue. Most of this information, both published and anecdotal, has not been depicted in map form and thus is not provided in a spatial context for the City's shoreline areas. Areas which are mapped as part of this inventory include areas of overhanging vegetation (Appendix A-4, Figures 1-14) and surface water outfalls (Appendix A-3, Figures 1-14).

Zooplankton are an important food resource for juvenile salmonids (and other juvenile fishes) rearing in Lakes Washington and Sammamish. The primary zooplanktons utilized by juvenile fishes in these lakes include *Daphnia, Bosmina, Cyclops*, Calanoids, and Chironomid pupae (Beauchamp et al. 2004, Koehler et al 2006, Hampton et al 2006, McIntyre et al. 2006). Lake-wide populations of zooplankton fluctuate seasonally, and they are generally well distributed between both littoral and limnetic habitats (Shepherd et al. 2000). Zooplankton population abundances are affected by water temperature and clarity, and can be dramatically affected by water quality changes (eutrophication). Growth rates for juvenile sockeye and chinook salmon rearing in the Lake Washington/Sammamish system are relatively high, and the availability of

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food is not currently thought to be a limiting factor in these lakes (Beauchamp et al. 2004, Koehler et al. 2006).

Timing and seasonal abundance of zooplankton populations largely dictates growth rates and survival of juvenile salmonids (and other fish) in Lakes Washington and Sammamish (Beauchamp et al. 2004, Koehler et al 2006, Hampton et al 2006, McIntyre et al. 2006). Chironomid pupae are benthic invertebrates inhabiting nearshore littoral habitats with soft sediments. Chironomid pupae are an important food source for juvenile sockeye and chinook salmon rearing in littoral habitats in February-May (Beauchamp et al. 2004, Koehler et al. 2006). Juvenile sockeye salmon rely heavily on the copepod *Cyclops* for food between February and May, prior to when the seasonal *Daphnia* bloom occurs (Beauchamp et al 2004, Hampton et al. 2006). When the abundance of *Daphnia* increases in the spring (generally in May), most planktivorous fishes, including juvenile sockeye and chinook, begin eating *Daphnia* almost exclusively (Scheuerell et al 2005). Invertebrates from terrestrial sources (allochthonous inputs from riparian vegetation) are rare in the diets of juvenile chinook salmon in Lake Washington (Koehler et al. 2006), and this food source may be limited due to a lack of shoreline vegetation in Bellevue.

Shoreline armoring can alter substrate delivery and distribution in nearshore habitats, and may impact littoral populations of invertebrate food sources like chironomid pupae. Other zooplankton generally occupy limnetic habitats of Lake Washington and Sammamish, and activities along the shoreline are less likely to negatively effect abundance levels. Organic pollution or inputs of limiting nutrients like phosphorous, commonly delivered to the lake via tributary streams or stormwater conveyance systems, have the greatest potential to influence zooplankton populations in Lake Washington and Sammamish. Climatic variability and its affect on the seasonal water temperature fluctuations in Lake Washington and Lake Sammamish (Arhonditsis and Brett 2004) is another environmental variable with the potential to influence local zooplankton populations.

Overhanging terrestrial vegetation is known to supply food sources to the aquatic environment. However, the percentage of terrestrial organisms in the diet of juvenile salmonids in Lake Washington and Lake Sammamish is small, indicating that inputs from shoreline areas may be limited (Koehler et al. 2006) or of limited value as a food resource to littoral fishes. The relatively robust growth rates for juvenile chinook rearing in littoral habitats of Lake Washington suggest that the lake provides ample food resources for chinook during this critical life stage. Chironomids and *Daphnia* currently constitute a reliable food source for rearing chinook in Lake Washington. Shoreline armoring and the elimination of riparian vegetation may reduce production and delivery of terrestrial organisms to Lake Washington and Sammamish, subsequently detracting from the dietary diversity of juvenile chinook salmon inhabiting the littoral zone.

The amount of overhanging vegetation was assessed using a combination of aerial and oblique photos of the shoreline. For the purpose of this study, overhanging vegetation was re-defined as "shoreline vegetation". There are many types of shoreline vegetation (mature trees, shrubs, and ground cover), and some rules were applied to determine what qualified as "shoreline vegetation". To qualify, a contiguous block of vegetation had to extend at least 50 feet along the shoreline, thus eliminating most single shrubs or trees that typically occur along the shoreline on

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many residential properties. There was no height requirement for shoreline vegetation (ie. tall trees and small shrubs can all count), but some portion of the vegetation's drip-line must intersect or extend waterward of the delineated OHWM. This eliminates many of the shrubs and trees that are separated from the lake by wide bulkheads that are common in residential areas. The distance between the water's surface and the overhanging vegetation did not matter, as long as some portion of the canopy crown or drip-line of the vegetation intersected or extended beyond the OHWM. The overhanging vegetation rules are summarized as follows:

1. Drip-line of vegetation must intersect or extend beyond the OHWM to count as shoreline vegetation, and

2. Shoreline vegetation must extend a minimum of 50 linear feet along the OHWM.

Based on an analysis of aerial and oblique photography, very little of the Bellevue shoreline along Lake Washington or Lake Sammamish had vegetation that met the "shoreline vegetation" rule. The OHWM in City of Bellevue's Lake Washington shoreline measured approximately 9.25 miles (48,819 linear feet). Approximately 2,367 feet (about 5% of the available shoreline) of vegetation met the "shoreline vegetation" rule in Lake Washington. However, the Lake Washington shoreline vegetation analysis did not include Mercer Slough, where almost all (~100%) of the shoreline has overhanging vegetation that qualifies. If Mercer Slough is included in the Lake Washington estimate, the percentage of shoreline vegetation will increase significantly. The OHWM in City of Bellevue's Lake Sammamish shoreline was measured at approximately 4.96 miles (26,197 linear feet). Approximately 378 feet (just over 1% of the available shoreline) of vegetation met the "shoreline vegetation" rule in Lake Sammamish.

2.2.2 Fisheries

Including Pacific salmonids, the City of Bellevue shorelines are inhabited by at least 29 resident or migratory fish species. The following discussion will describe fish use and habitat within the City's shorelines, focusing on rearing, spawning, and migratory conditions for salmonids, but also addressing other fish inhabiting the lakes and streams. New map elements and discussion are provided for areas of historical sockeye spawning (Appendix A-2, Figures 1-2) and fish use distribution throughout the Lake Washington and Lake Sammamish system (Appendix A-5, Figures 1-2). Additional relevant map materials include overhanging vegetation (Appendix A-4, Figures 1-14), shoreline armoring and bathymetry (Appendix A-2, Figures 1-2), and surface water inputs (Appendix A-3, Figures 1-14).

The primary native piscivores that live in Lake Washington and Lake Sammamish are cutthroat trout, northern pikeminnow, and prickly sculpin, while non-native piscivores include rainbow trout, adult yellow perch, smallmouth bass, and largemouth bass. Smaller fish that inhabit these lakes and prey on zooplankton are juvenile salmonids (Sockeye, chinook, and coho salmon, cutthroat and rainbow trout, and kokanee salmon), longfin smelt, threespine stickleback, yellow perch, and the freshwater shrimp *Neomysis*. These fish are supported by an invertebrate community composed primarily of *Daphnia, Bosmina, Cyclops*, Calanoids, and Chironomid pupae.

Fish Use: Salmonids

Adult chinook salmon migrate from Puget Sound through the Chittenden Locks and into Lake Washington between July and September, continuing on to various tributary streams where they spawn in October and November. Although the majority of Chinook salmon production in the Lake Washington watershed occurs in the Cedar River, the North Lake Washington tributary streams (feeding into the Sammamish River), or at the Issaquah Fish Hatchery, Chinook salmon also use many other smaller Lake Washington tributary streams. The primary tributary streams in or near the Bellevue area that are used by chinook salmon or other anadromous salmonids include Kelsey Creek, Coal Creek, and May Creek. Other tributary streams within the City, which include Vasa Creek, Yarrow Creek, and Sturtevant Creek, are known to support spawning activity for various salmonids including chinook, coho, sockeye, and kokanee salmon. Chinook fry emerge from their redds between January and March, and either rear in their natal stream or emigrate to Lake Washington for a rearing period extending from three to five months (Seiler et al. 2005). The juveniles emigrate through the Chittenden Locks and into Puget Sound between May and August, but most emigrate in June and July (DeVries et al. 2004). Most all juvenile chinook salmon leave the Lake Washington system during their first year (Kerwin 2001; Tabor and Piaskowski 2002). Other anadromous salmonids spawning and/or rearing in the Lake Washington watershed not mentioned above include steelhead trout and bull trout. Shoreline and stream use by these species is documented as part of the Washington Department of Fish and Wildlife's Priority Habitats and Species database (Appendix A-5, Figures 1-2).

For juvenile chinook, once they enter Lake Washington, they often congregate near the mouths of tributary streams, and prefer low gradient, shallow-water habitats with small substrates (Tabor and Piaskowski 2002; Tabor et al. 2004b; Tabor et al. 2006). Chinook fry entering Lake Washington early in the emigration period (February and March) are still relatively small, typically do not disperse far from the mouth of their natal stream, and are largely dependant upon shallow-water habitats in the littoral zone with overhanging vegetation and complex cover (Tabor and Piaskowski 2002; Tabor et al 2004b). The mouths of creeks entering Lake Washington (whether they support salmon spawning or not), as well as undeveloped lakeshore riparian habitats associated with these confluence areas, attract juvenile chinook salmon and provide important rearing habitat during this critical life stage (Tabor et al. 2004b; Tabor et al. 2006). Appendix A-3, Figures 1-14 provides the location of surface water inputs and potential important rearing areas for juvenile salmonids.

Later in the emigration period (May and June), most chinook juveniles have grown to fingerling size and begin utilizing limnetic areas of the Lake more heavily (Kohler et al. 2006). As the juvenile chinook salmon mature to fingerlings and move offshore, their distribution extends throughout Lake Washington. Although early emigrating chinook fry from the Cedar River and North Lake Washington tributaries (primary production areas) initially do not disperse to shoreline areas in Bellevue, any salmon fry from smaller tributaries such as Kelsey Creek, May Creek, or Coal Creek would depend on nearshore habitats of the Bellevue waterfront. Later in the spring (May and June), however, juvenile chinook are known to be well distributed throughout both limnetic and littoral areas of Lake Washington, and certainly utilize shoreline habitats in Bellevue.

Existing sockeye spawning area maps for Bellevue shoreline areas in Lake Washington and Sammamish have not been updated by the WDFW for over 20 years (Foley, pers. comm. 2008). Beach spawning by sockeye salmon in Lakes Washington and Sammamish was historically

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much more common than it is today. Most sockeye spawning and production in the Lake Washington watershed occurs in the Cedar River. Few sockeye currently spawn in beach areas relative to stream spawning fish, and boat surveys are only conducted one or two times annually at four different index areas in Lake Washington. No surveys for sockeye beach spawning are conducted in Lake Sammamish. The four index areas in Lake Washington where annual boat surveys are conducted are 1) just north of Pleasure Point near southern City limits, 2) the north end of Mercer Island, 3) just west of the mouth of Mercer Slough, and 4) Coleman Point in Renton. Few sockeye are observed during these index surveys, and few lake residents report seeing sockeye salmon spawning in nearshore areas (Foley, pers. comm. 2008).

When sockeye salmon are observed spawning in beaches, they typically utilize nearshore areas with gently sloping shorelines with small gravel substrates. Bulkheads at the shoreline can discourage beach spawning because the bulkhead typically eliminates the gradually sloping shoreline gradient and shallow water habitat that sockeye favor for spawning. Dense mats of milfoil can also occlude sockeye spawning areas along the shoreline, as they tend to trap fine sediment, decrease wave action and oxygenation, and result in reduced levels of dissolved oxygen (Foley, pers. comm. 2008). There is little documentation of the habitat conditions that beach-spawning sockeye select, except that they seem to favor shallow areas of low gradient beaches. Anecdotal evidence also indicates that adult sockeye select beach areas with groundwater upwelling or beaches that are aerated by frequent wind/wave action. Areas of historical sockeye spawning, based on existing WDFW information, is depicted in Appendix A-2, Figures 1-2.

Sockeye salmon production (natural and hatchery) primarily occurs in the Cedar River, but some sockeye are also produced in the Sammamish River tributaries or smaller tributaries like Kelsey Creek. Sockeye fry typically migrate to Lake Washington between January and May where most reside for about one year before emigrating to Puget Sound the following May (Kiyohara and Volkhardt 2008). Sockeye salmon fry are another important planktivore in Lake Washington's aquatic community where they feed heavily on *Daphnia* when this zooplankton is available (Beauchamp et al. 2004). Sockeye fry disperse quickly throughout Lake Washington following migration from their natal streams (Beauchamp et al. 2004). Initially, the small bodied migrant sockeye fry are primarily found in the surface waters and nearshore areas in close proximity to their natal streams. However, the newly arriving fry grow quickly and move offshore to open-water areas and are rarely found in water depths less than 15 meters once they reach fork lengths of around 25 mm. (Beauchamp et al. 2004).

Food resources for juvenile salmonids are thought to be more abundant in Lake Washington than in its associated tributary streams, and young fish that enter the lake early generally display greater growth rates than fish that rear for longer periods in the tributaries (Koehler et al. 2006). Juvenile chinook in Lake Washington primarily eat chironomids early in the spring (February to May), and, similar to juvenile sockeye (Scheuerell et al 2005), switch to *Daphnia* later in the spring (May and June) as chinook increasingly utilize limnetic habitats and *Daphnia* populations become more abundant (Koehler et al. 2006). The relatively robust growth rates for juvenile chinook rearing in littoral habitats of Lake Washington suggest that the lake provides ample food resources for chinook during this critical life stage. Although chironomids and *Daphnia* currently constitute a reliable food source for rearing chinook in Lake Washington, the percentage of terrestrial organisms in their diet is small, indicating that inputs from shoreline areas may be limited (Koehler et al. 2006). Shoreline armoring and the elimination of riparian vegetation may reduce production and delivery of terrestrial organisms to Lake Washington and Sammamish, subsequently detracting from the dietary diversity of juvenile chinook salmon inhabiting the littoral zone.

Fish Use: Others

Although most populations of longfin smelt are anadromous (living in marine waters and migrating to rivers to spawn in fresh water), a landlocked population inhabits Lake Washington. These fish are relatively short-lived and most mature, spawn, and die after two years (Chigbu and Sibley 1994). Most longfin smelt in Lake Washington migrate to the lower Cedar River to spawn, but some spawning is known to occur in Coal Creek, May Creek, and other small tributaries to Lake Washington (Moulton 1974). The population of longfin smelt is abundant in Lake Washington, and these fish are an important planktivore in the aquatic community. The smelt generally inhabit pelagic areas of the lake, occupying deepwater areas (60-120 feet) in the day and making diel vertical migrations to shallower portions of the water column during the night (Chigbu and Sibley 1998, Eggers et al. 1978, Wydoski and Whitney 2003).

Warm water fish species, especially largemouth bass and yellow perch, are known to be the predominant fish in Phantom and Larson Lakes (KCM 1993). However, chinook salmon have been historically documented in Kelsey Creek within and above Larson Lake (Appendix A-5, Figure 2).

Habitat

Large wood is rare in shoreline habitats associated with Lake Washington and Lake Sammamish. Most of the shoreline areas in these lakes have been developed (Toft 2001), and the potential for large woody debris (LWD) recruitment is very limited. Contrary to other shoreline areas in the City, Mercer Slough and lower Kelsey Creek both have well-vegetated riparian corridors flanked by associated wetlands, resulting in recruitment of some large wood to the adjoining waterbody. Areas of LWD recruitment can be assessed based on the maps and discussion provided in the Upland Habitat section of this inventory report (Appendix A-1, Figures 1-14). Areas shown as forested or forest fragments would presumably allow for LWD recruitment, especially if these areas are immediately adjacent to the shoreline.

Other habitat features more associated with streams include substrate size and distribution, stream gradients, pool/riffle sequences, and overhanging vegetation. Both Mercer Slough and lower Kelsey Creek can be considered low gradient depositional areas with little diversity in terms of substrate composition. Mercer Slough primarily consists of a single homogenous glide-type habitat. Lower Kelsey Creek, upstream of I-405, contains some pool riffle habitat but is not considered significant habitat for salmonids. Some salmon spawning has been documented by City staff and volunteers between I-405 and Lake Hill Connector. As indicated above, nearly the entire lower Kelsey Creek/Mercer Slough corridor contains overhanging vegetation.

There are no known fish passage blockages in the Bellevue shoreline area. Seasonal fish passage barriers can occur at the entrance to some tributary streams, such as Coal Creek and Kelsey Creek. However, these seasonal barriers primarily affect migratory fish, and are generally caused by seasonal low flows or high water temperatures.

2.2.3 Aquatic vegetation management

Noxious weeds of Washington State are non-native, invasive plants defined by law as a plant that when established is highly destructive, competitive, or difficult to control by cultural or chemical practices (RCW 17.10). These plants have been introduced intentionally and unintentionally by human actions. Most of these species were brought in without any natural enemies, such as insects or diseases, to help keep their populations in check. As a result, these plants can often multiply rapidly (Ecology and Washington State Department of Agriculture 2004). Eurasian Watermilfoil (*Myriophyllum spicatum*) and water lily (*Nymphaea odorata*) are a public and, in some areas, an ecological nuisance along the majority of Bellevue's shorelines, particularly in some of the marinas and other shallow-water nearshore areas. Where milfoil is dense and close to the surface, it can entangle swimmer's legs and clog boat props. Propeller action can also chop the milfoil into small bits, which disperse in the lake and start new infestations. Species of aquatic noxious weeds found throughout Bellevue's shorelines are listed in Table 2.

Table 2. Aquatic noxious weeds found throughout City of Bellevue shorelines - modified from *Aquatic Plants and Fish* (WDFW 1997).

Common Name	Scientific Name	Growth Habitat
Eurasian watermilfoil	*Myriophyllum spicatum*	Submergent
Brazilian elodea	*Egeria densa*	Submergent
Parrot-feather	*Myriophyllum aquaticum*	Submergent
Hydrilla	*Hydrilla verticillata*	Submergent
Fanwort	*Cabomba caroliniana*	Submergent
Fragrant (or white) water lily	*Nymphaea odorata*	Floating mats

WDFW and the Washington Department of Ecology (DOE) are the two primary state agencies that regulate aquatic vegetation management. Manual removal of aquatic nuisance species by residential homeowners living along the shoreline is permitted through a "pamphlet Hydraulic Project Approval (HPA)" that is issued by the WDFW. These methods include installation of bottom barriers, hand removal, raking, and cutting. Individuals interested in removing aquatic nuisance species (milfoil) from their shoreline can legally do so when they follow the provisions in Aquatic Plants and Fish, the WDFW pamphlet HPA (available online at http://wdfw.wa.gov/hab/aquaplnt/aquaplnt.htm). Aquatic vegetation management is conducted by residential landowners and private contractors specializing in removal of aquatic nuisance species. They are not required to report to the WDFW if they follow all the provisions in the pamphlet HPA. The WDFW has not issued any specific aquatic weed control permits to anyone on either Lake Sammamish or Lake Washington, and the WDFW does not track the removal of aquatic nuisance species by residential homeowners acting under the pamphlet HPA (Bieber, pers. comm. 2008).

The DOE regulates the use of aquatic herbicides to control nuisance species. In 2007, there were five permits issued within the city limits of Bellevue for in-water aquatic plant control in Lake Washington. No permits were issued in Bellevue on Lake Sammamish in 2007 (McLain, pers.

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comm. 2008). The City of Bellevue has a permit for treatment at high use public access areas, including Bellevue Marina at Meydenbauer Bay, Newcastle Beach Park, Meydenbauer Beach Park, and the SE 40th Boat Launch. Newport Shores has a permit to treat a relatively large area in the canals and boat marina areas. The remaining three permits are held by the Meydenbauer Bay Yacht Club, the Meydenbauer Condominiums, and the Bayshore East Condominiums. Figures 17 and 18, and Table 3 show the locations of treatment areas and the different types of herbicides used. Not all areas within each permit are treated in all years. If weed growth is minimal, herbicides may not be applied.

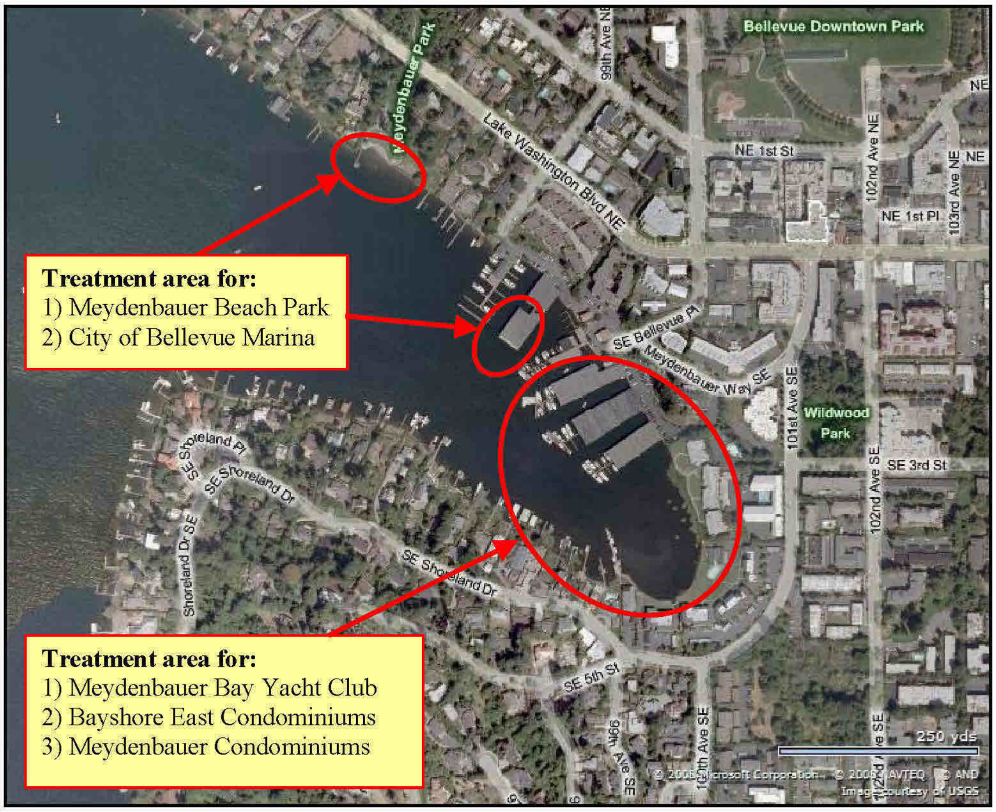

Figure 17. Aquatic herbicide treatment areas within Meydenbauer Bay permitted by DOE in 2007.

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Figure 18. Aquatic herbicide treatment areas in and around the Coal Creek delta permitted by DOE in 2007.

Table 3. A summary of the existing permits to apply aquatic herbicides along City of Bellevue shorelines.

Permittee	Treatment Area	Size (Acres)	Contractor	Chemical	Targeted Plant
City of Bellevue Department of Parks and Community Services	City of Bellevue Marina	2	Northwest Aquatic Eco-Systems	1) Diquat Dibromide 2) Triclopyr TEA	Milfoil, Egeria densa
	Newcastle Beach Park	2	Northwest Aquatic Eco-Systems	1) Diquat Dibromide 2) Triclopyr TEA	Milfoil, Egeria densa
	Meydenbauer Beach Park	2	Northwest Aquatic Eco-Systems	1) Diquat Dibromide 2) Triclopyr TEA	Milfoil, Egeria densa
	SE 40th Boat Launch	2	Northwest Aquatic Eco-Systems	1) Diquat Dibromide 2) Triclopyr TEA	Milfoil, Egeria densa
Meydenbauer Condominiums	Whalers Cove, Meydenbauer Bay	3	Northwest Aquatic Eco-Systems	1) Diquat dibromide 2) Fluidone 3) Glyphosate	Elodea, Potamogetons, Myriophyllum, Ceratophyllum, Nymphaea
Meydenbauer Bay Yacht Club	Whalers Cove, Meydenbauer Bay	10	Northwest Aquatic Eco-Systems	1) Diquat dibromide 2) Fluidone	Elodea, Potamogetons, Myriophyllum, Ceratophyllum,
Bayshore East Condominiums (EMB Mgnt.)	Whalers Cove, Meydenbauer Bay	3	Northwest Aquatic Eco-Systems	1) Diquat dibromide 2) 2, 4-D Amine	Elodea, Potamogetons, Myriophyllum, Ceratophyllum,
Aquatechnex,	Newport Shores	<69	Aquatechnex, LLC	1) Diquat dibromide	Potamogetons,

Permittee	Treatment Area	Size (Acres)	Contractor	Chemical	Targeted Plant
LLC	Canals and Yacht Basin			2) 2, 4-D Amine 3) Endothall 4) Fluridone 5) Glyphosate 6) Triclopyr TEA 7) Adjuvant(s)	Lemnas, Egeria densa, Myriophyllum,

Depending on the herbicide used, it may take several days to weeks or several treatments during a growing season before the herbicide controls or kills treated plants. Rapid-acting herbicides like endothall and diquat may cause low oxygen conditions to develop as plants decompose. Low oxygen can cause fish kills. Additional information about invasive aquatic plants and methods of control can be found in the Water Quality section of Ecology's website.

There is often a fine line between whether or not control is biologically necessary or justifiable. Depending on the method of control chosen, there could be disturbance of the substrate, reduction in benthic invertebrates (which are an important food source), and increased risk of spread of the invasive species to other areas. Depending on the condition of the sediments, substrate disturbance can result in acute, although temporary, increases in turbidity and may re-introduce pollutants bound to the sediments back into the water column. In addition, reductions in aquatic vegetation, whether native or non-native, reduce primary productivity, which is the foundation of the lake food chain. This could result in reduced fish production at the top of the food chain (Kahler et al. 2000). However, control of invasive aquatic vegetation may be biologically justifiable where the plants are so dense that dissolved oxygen (DO) levels fall to suboptimal or even lethal levels (2-4 mg/L). DO levels drop below dense surface mats because light is blocked to the submerged aquatic vegetation which produces the majority of the oxygen to the water column. Much of the oxygen produced by the surface mats of vegetation is lost to the atmosphere. Decomposition of submerged dead material also depletes the water column of oxygen. In addition, dense vegetation can reduce wave action at the surface, which would otherwise help oxygenate the water. Reduced wave action can also contribute to increased water temperature, as the cooler water from deep areas does not flush the warmer, vegetated shallow areas. Warmer water holds less oxygen than cold water, resulting in lower rates of dissolved oxygen.

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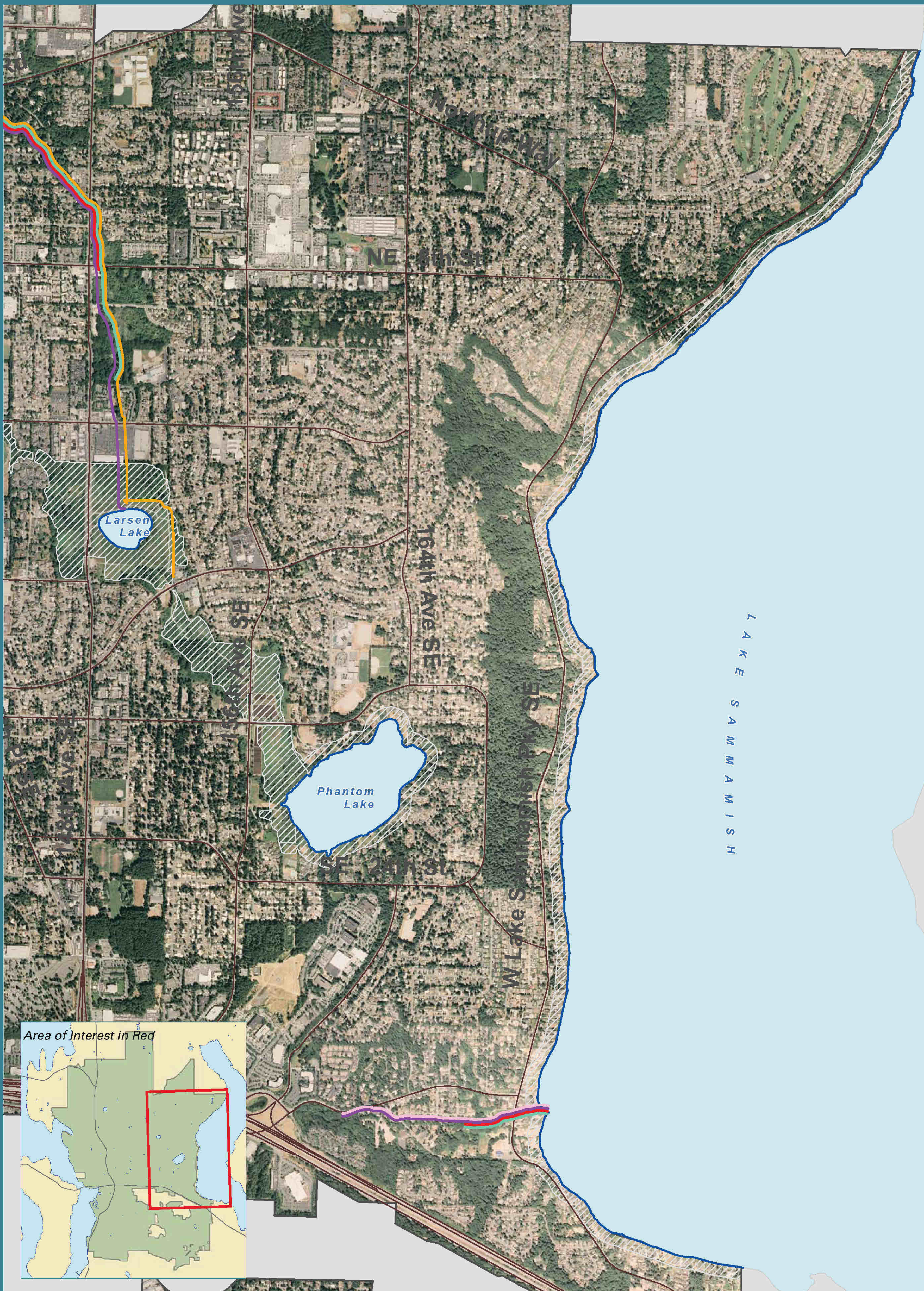
APPENDIX A

HABITAT INVENTORY MAPS



Fish Distribution from Priority Habitats and Species

Lake Washington, Mercer Slough, and Kelsey Creek

City of Bellevue Shoreline Master Program

CITY OF BELLEVUE WASHINGTON

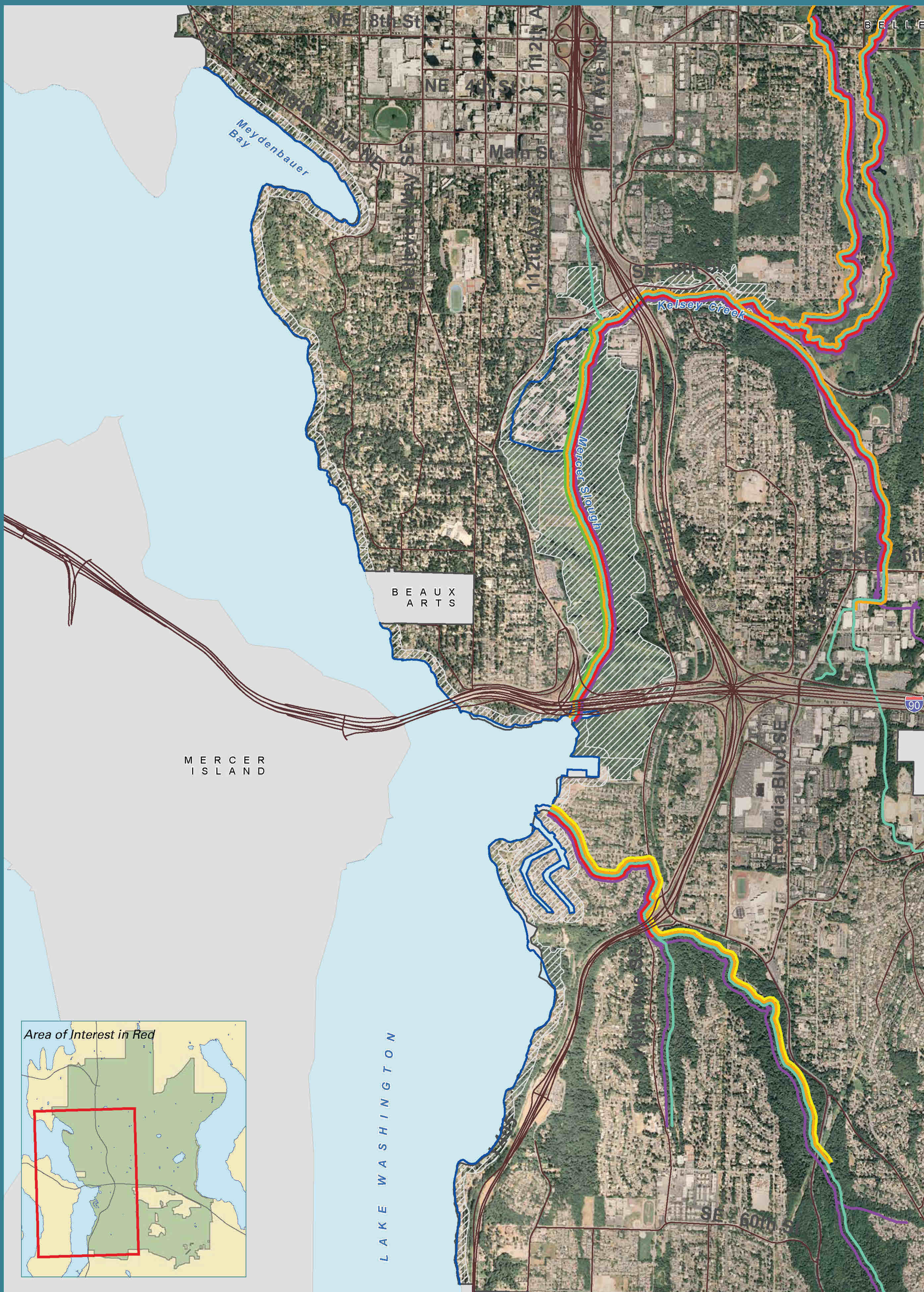
THE WATERSHED COMPANY

0 0.25
Miles

August 2008
Data: The Watershed Company, City of Bellevue, WDFW
Finalized 10/09/2015

- Rainbow Trout
- Kokanee Salmon
- Coast Resident Cutthroat
- Sockeye
- Steelhead Trout
- Chinook Salmon
- Coho Salmon
- Ordinary High Water Mark
- Shoreline Juris.
- Lakes
- City Boundary
- Major Streets

Shoreline jurisdiction boundaries depicted on this map are approximate. They have not been formally delineated or surveyed and are intended for planning purposes only. Additional site-specific evaluation may be needed to confirm/verify information shown on this map.



Fish Distribution from Priority Habitats and Species

Lake Washington, Mercer Slough, and Kelsey Creek

City of Bellevue Shoreline Master Program

0 0.25
Miles

August 2008
Data: The Watershed Company, City of Bellevue, WDFW
Finalized 10/09/2015

- Rainbow Trout
- Coast Resident Cutthroat
- Sockeye
- Steelhead Trout
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- Lakes
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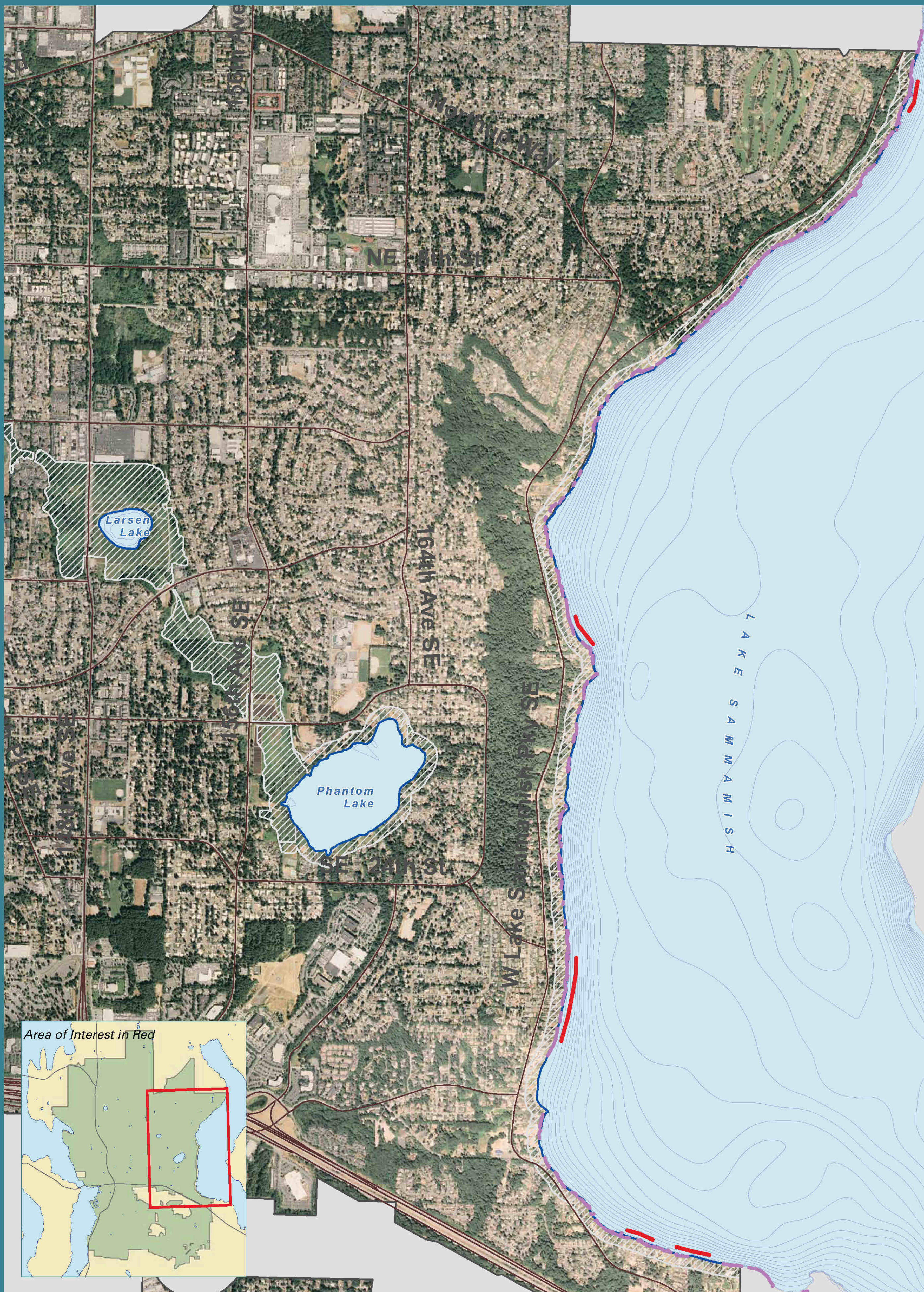


Historical Sockeye Spawning Areas

Lake Sammamish/Phantom Lake

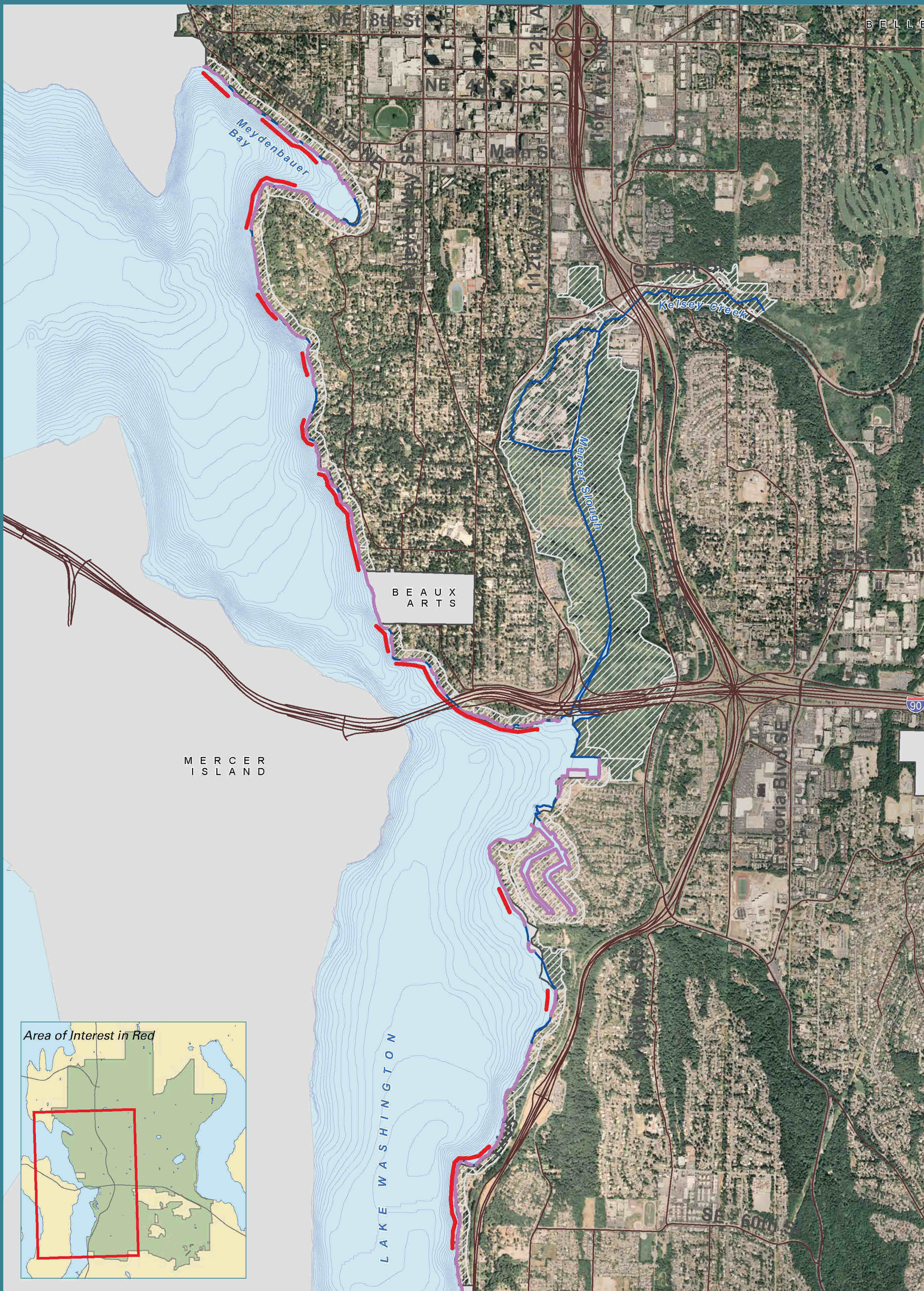
City of Bellevue Shoreline Master Program

0 0.25
Miles

August 2008
Data: The Watershed Company, City of Bellevue
Finalized 10/09/2015

- Historical Sockeye Spawning Areas
- Shoreline Hardening
- Bathymetry (5' Interval)
- Ordinary High Water Mark
- Shoreline Juris.
- Lakes
- City Boundary
- Major Streets

Shoreline jurisdiction boundaries depicted on this map are approximate. They have not been formally delineated or surveyed and are intended for planning purposes only. Additional site-specific evaluation may be needed to confirm/verify information shown on this map.



Historical Sockeye Spawning Areas

Lake Washington, Mercer Slough, and Kelsey Creek

City of Bellevue Shoreline Master Program

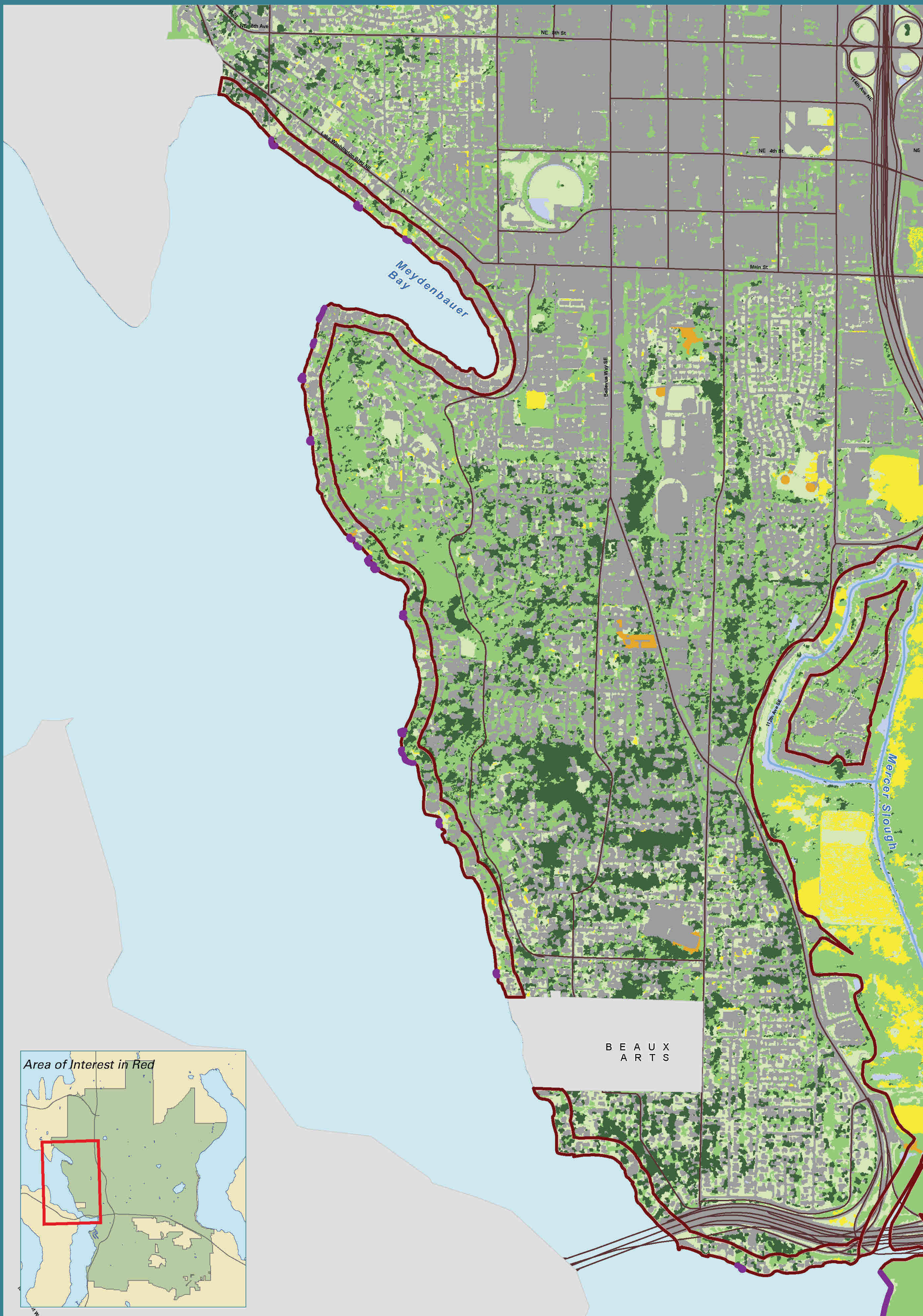
0 0.25
Miles

August 2008
Data: The Watershed Company, City of Bellevue
Finalized 10/09/2015

THE WATERSHED COMPANY

- Historical Sockeye Spawning Areas
- Shoreline Hardening
- Bathymetry (5' Interval)
- Ordinary High Water Mark
- Shoreline Juris.
- Lakes
- City Boundary
- Major Streets

Shoreline jurisdiction boundaries depicted on this map are approximate. They have not been formally delineated or surveyed and are intended for planning purposes only. Additional site-specific evaluation may be needed to confirm/verify information shown on this map.



Shoreline Vegetation

City of Bellevue Shoreline Master Program

Tile 1

0 250 500 750
Feet

August 2008
Data: The Watershed Company,
City of Bellevue
Finalized 10/09/2015

THE WATERSHED COMPANY

Vegetation

- Unclassified
- Non-Woody
- Shrub
- Deciduous
- Coniferous
- Unknown
- Impervious
- Water
- Bare
- Overhanging Vegetation
- Shoreline Jurisdiction
- Ordinary High Water Mark
- Lakes
- Major Streets

Shoreline jurisdiction boundaries depicted on this map are approximate. They have not been formally delineated or surveyed and are intended for planning purposes only. Additional site-specific evaluation may be needed to confirm/verify information shown on this map.

COB_SMP000927

Shoreline Vegetation

City of Bellevue Shoreline Master Program

Tile 2

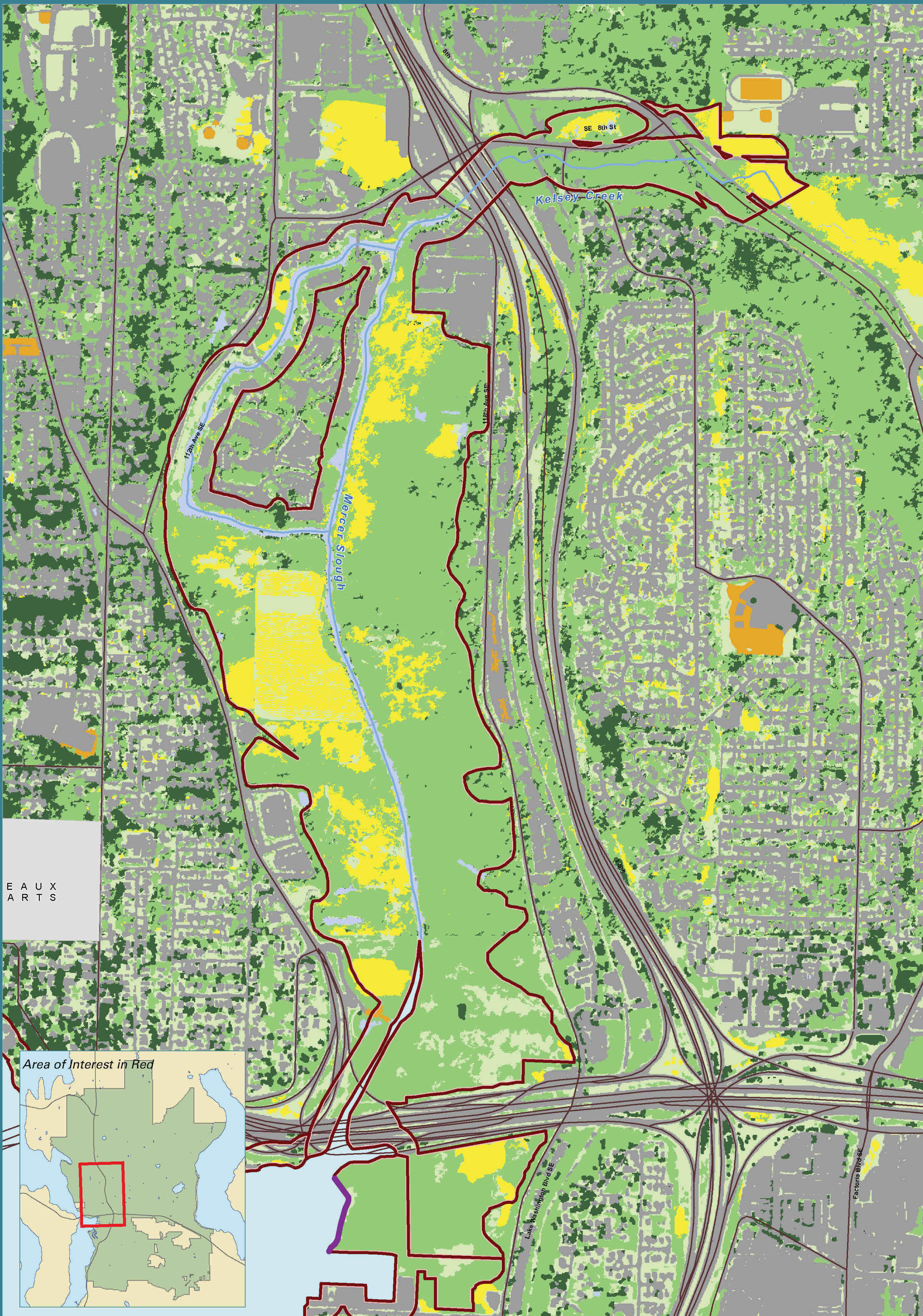
0 250 500
Feet

August 2008
Data: The Watershed Company, City of Bellevue
Finalized 10/09/2015

Vegetation

- Unclassified
- Non-Woody
- Shrub
- Deciduous
- Coniferous
- Unknown
- Impervious
- Water
- Bare
- Overhanging Vegetation
- Shoreline Jurisdiction
- Ordinary High Water Mark
- Lakes
- Major Streets

Shoreline jurisdiction boundaries depicted on this map are approximate. They have not been formally delineated or surveyed and are intended for planning purposes only. Additional site-specific evaluation may be needed to confirm/verify information shown on this map.



Shoreline Vegetation

City of Bellevue Shoreline Master Program

Tile 3

City of Bellevue Washington

The Watershed Company

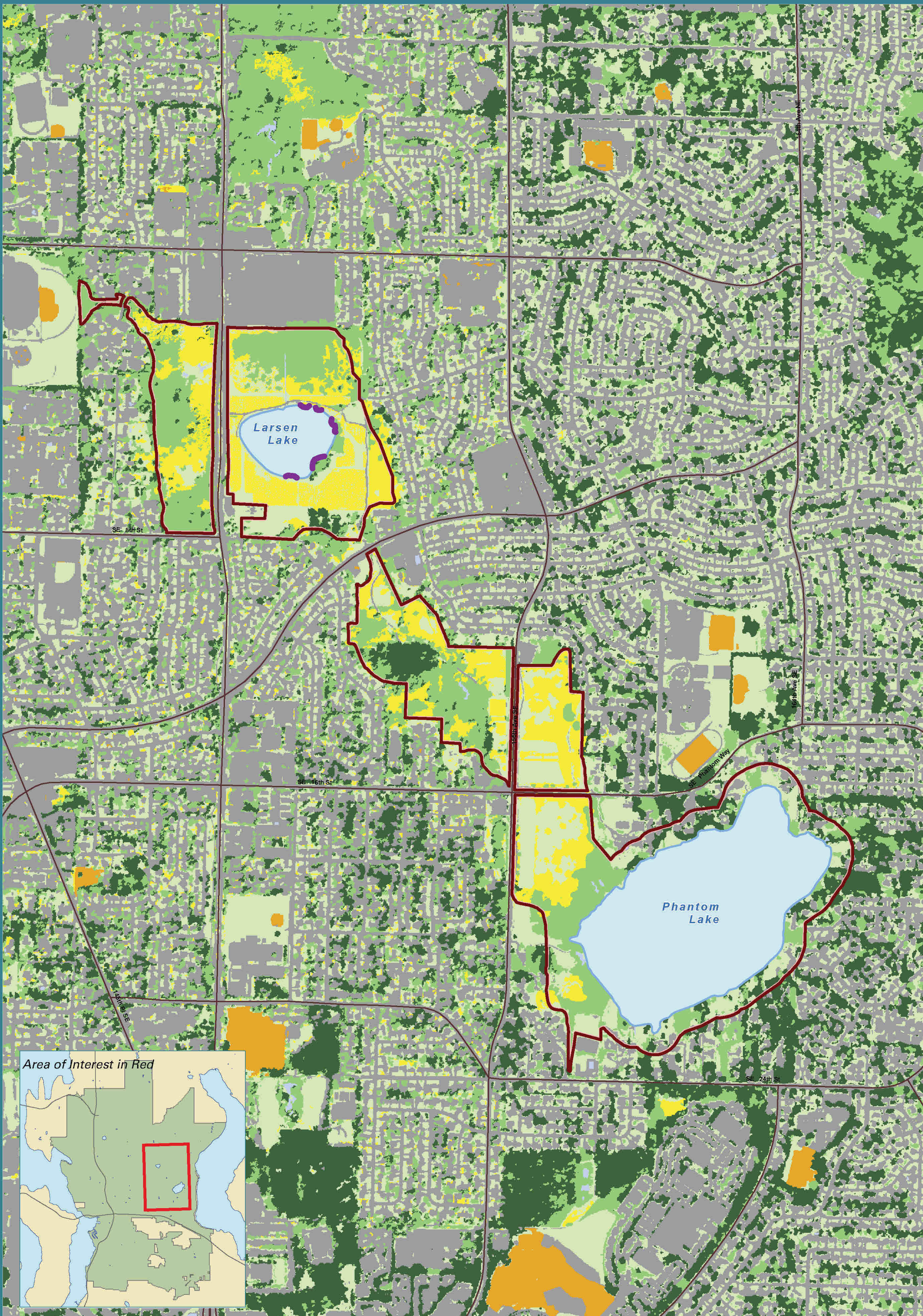
0 250 500
Feet

August 2008
Data: The Watershed Company, City of Bellevue
Finalized 10/09/2015

Vegetation

- Unclassified
- Non-Woody
- Shrub
- Deciduous
- Coniferous
- Unknown
- Impervious
- Water
- Bare
- Overhanging Vegetation
- Shoreline Jurisdiction
- Ordinary High Water Mark
- Lakes
- Major Streets

Shoreline jurisdiction boundaries depicted on this map are approximate. They have not been formally delineated or surveyed and are intended for planning purposes only. Additional site-specific evaluation may be needed to confirm/verify information shown on this map.



Shoreline Vegetation

City of Bellevue Shoreline Master Program

Tile 4

CITY OF BELLEVUE WASHINGTON

THE WATERSHED COMPANY

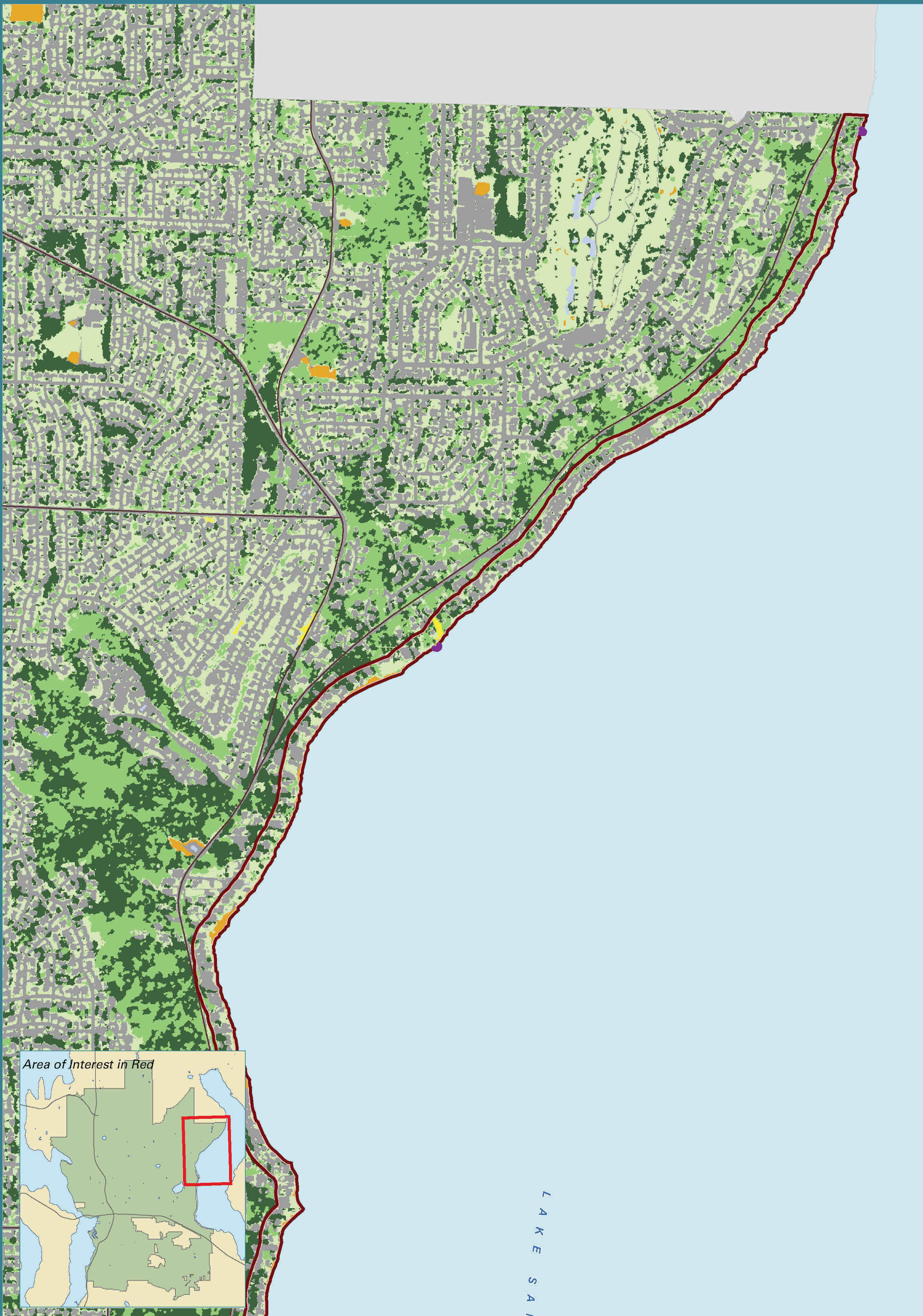
0 250 500
Feet

August 2008
Data: The Watershed Company,
City of Bellevue
Finalized 10/09/2015

Vegetation

- Unclassified
- Non-Woody
- Shrub
- Deciduous
- Coniferous
- Unknown
- Impervious
- Water
- Bare
- Overhanging Vegetation
- Shoreline Jurisdiction
- Ordinary High Water Mark
- Lakes
- Major Streets

Shoreline jurisdiction boundaries depicted on this map are approximate. They have not been formally delineated or surveyed and are intended for planning purposes only. Additional site-specific evaluation may be needed to confirm/verify information shown on this map.



Shoreline Vegetation

City of Bellevue Shoreline Master Program

Tile 5

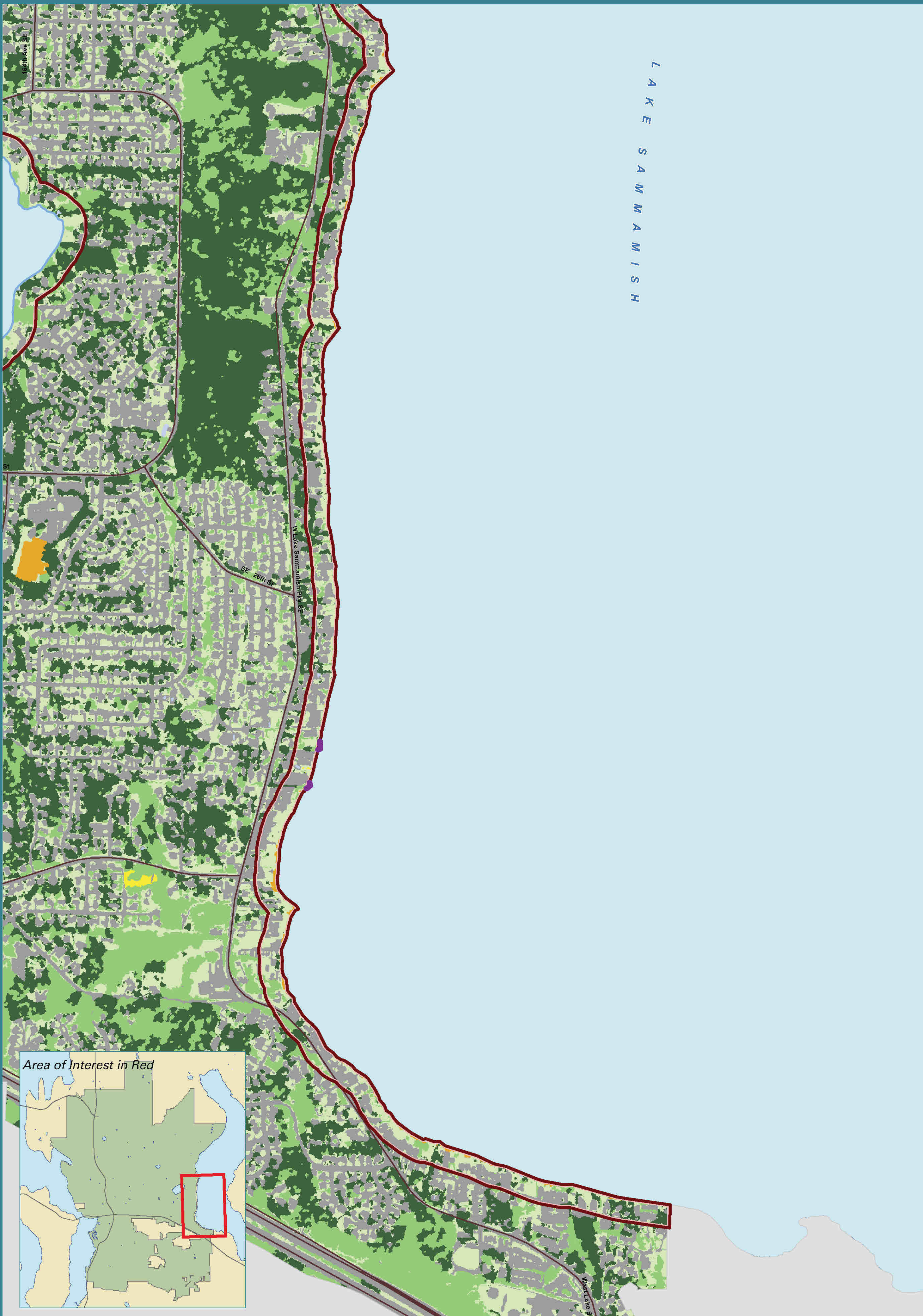
0 250 500
Feet

August 2008
Data: The Watershed Company,
City of Bellevue
Finalized 10/09/2015

Vegetation

- Unclassified
- Non-Woody
- Shrub
- Deciduous
- Coniferous
- Unknown
- Impervious
- Water
- Bare
- Overhanging Vegetation
- Shoreline Jurisdiction
- Ordinary High Water Mark
- Lakes
- Major Streets

Shoreline jurisdiction boundaries depicted on this map are approximate. They have not been formally delineated or surveyed and are intended for planning purposes only. Additional site-specific evaluation may be needed to confirm/verify information shown on this map.



Shoreline Vegetation

City of Bellevue Shoreline Master Program

Tile 6

0 250 500
Feet

August 2008
Data: The Watershed Company,
City of Bellevue
Finalized 10/09/2015

THE WATERSHED COMPANY

Vegetation

- Unclassified
- Non-Woody
- Shrub
- Deciduous
- Coniferous
- Unknown
- Impervious
- Water
- Bare

- Overhanging Vegetation
- Shoreline Jurisdiction
- Ordinary High Water Mark
- Lakes
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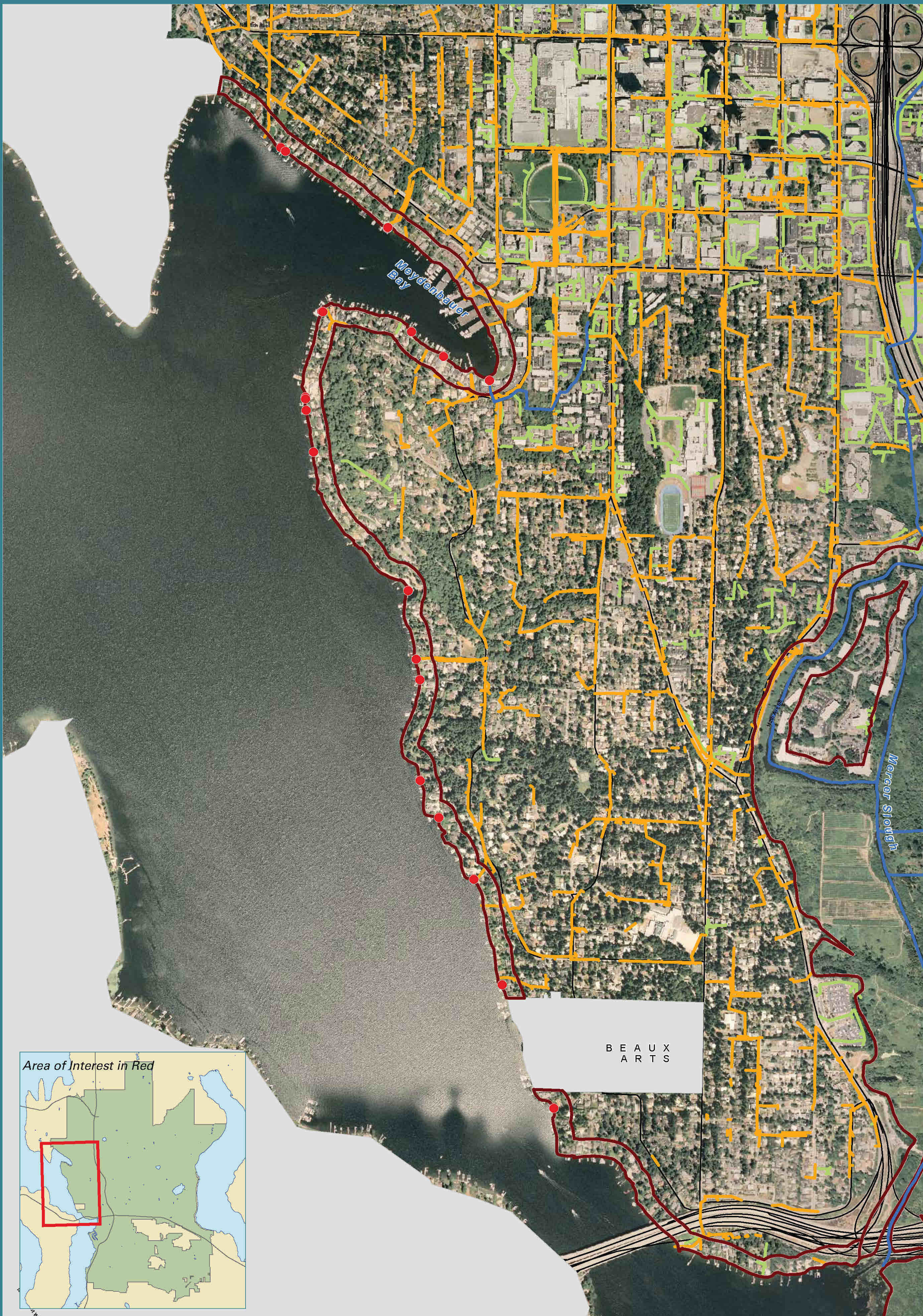

Streams and Stormwater Outfalls

City of Bellevue Shoreline Master Program

Tile 1

CITY OF BELLEVUE WASHINGTON

THE WATERSHED COMPANY

0 250 500 750
Feet

August 2008
Data: The Watershed Company, City of Bellevue
Finalized 10/09/2015

- Storm Drainage Pipes
- Storm Drainage Private Pipes
- Outfalls
- Shoreline Jurisdiction
- Streams
- Ordinary High Water Mark
- Major Streets

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Streams and Stormwater Outfalls

City of Bellevue Shoreline Master Program

Tile 2

CITY OF BELLEVUE WASHINGTON

THE WATERSHED COMPANY

0 250 500
Feet

August 2008
Data: The Watershed Company,
City of Bellevue
Finalized 10/09/2015

- Storm Drainage Pipes
- Storm Drainage Private Pipes
- Outfalls
- Shoreline Jurisdiction
- Streams
- Ordinary High Water Mark
- Major Streets

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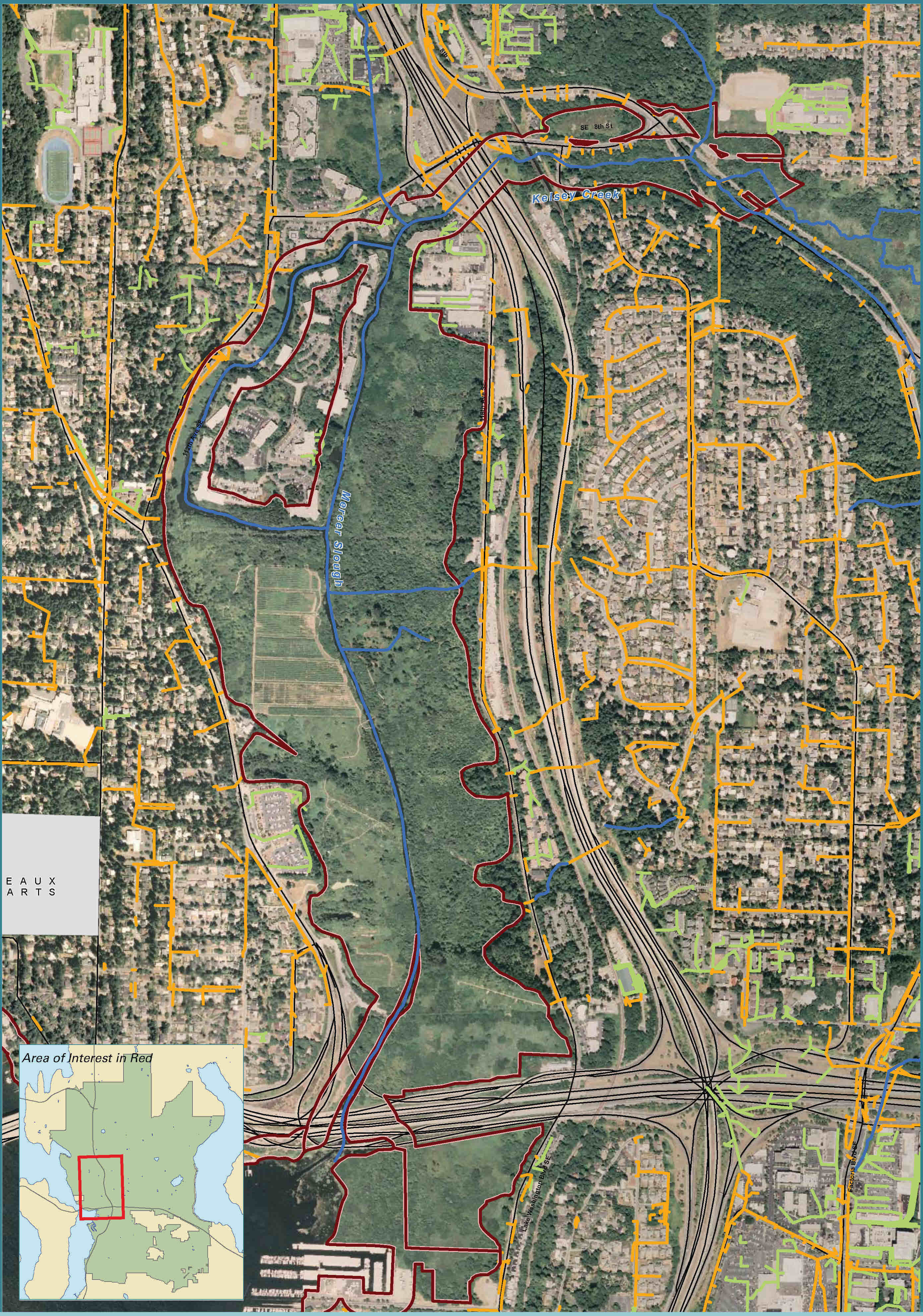

Streams and Stormwater Outfalls

City of Bellevue Shoreline Master Program

Tile 3

City of Bellevue Washington

The Watershed Company

0 250 500
Feet

August 2008
Data: The Watershed Company, City of Bellevue
Finalized 10/09/2015

- Storm Drainage Pipes
- Storm Drainage Private Pipes
- Outfalls
- Shoreline Jurisdiction
- Streams
- Ordinary High Water Mark
- Major Streets

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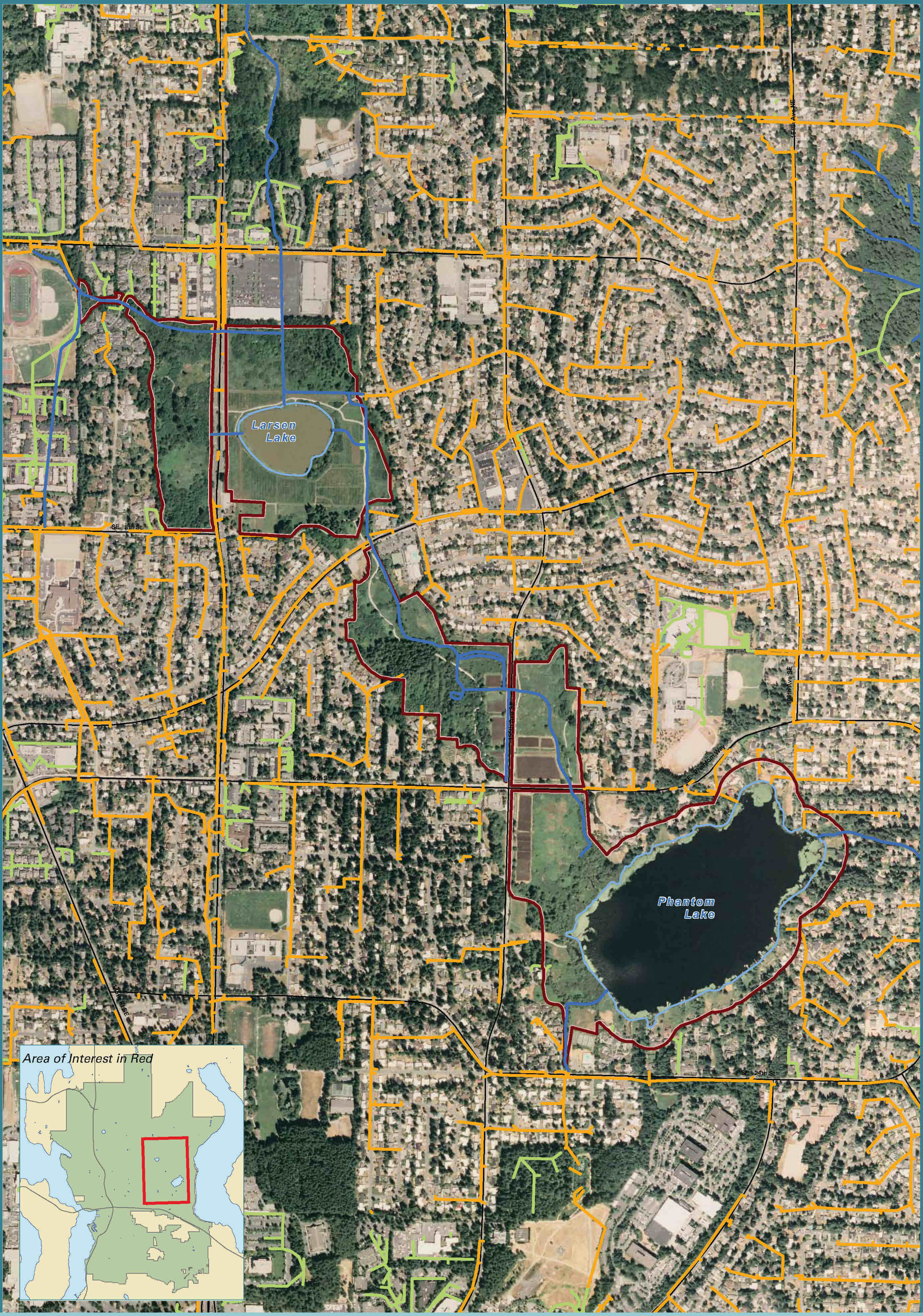

Streams and Stormwater Outfalls

City of Bellevue Shoreline Master Program

Tile 4

0 250 500
Feet

August 2008
Data: The Watershed Company, City of Bellevue
Finalized 10/09/2015

THE WATERSHED COMPANY

- Storm Drainage Pipes
- Storm Drainage Private Pipes
- Outfalls
- Shoreline Jurisdiction
- Streams
- Ordinary High Water Mark
- Major Streets

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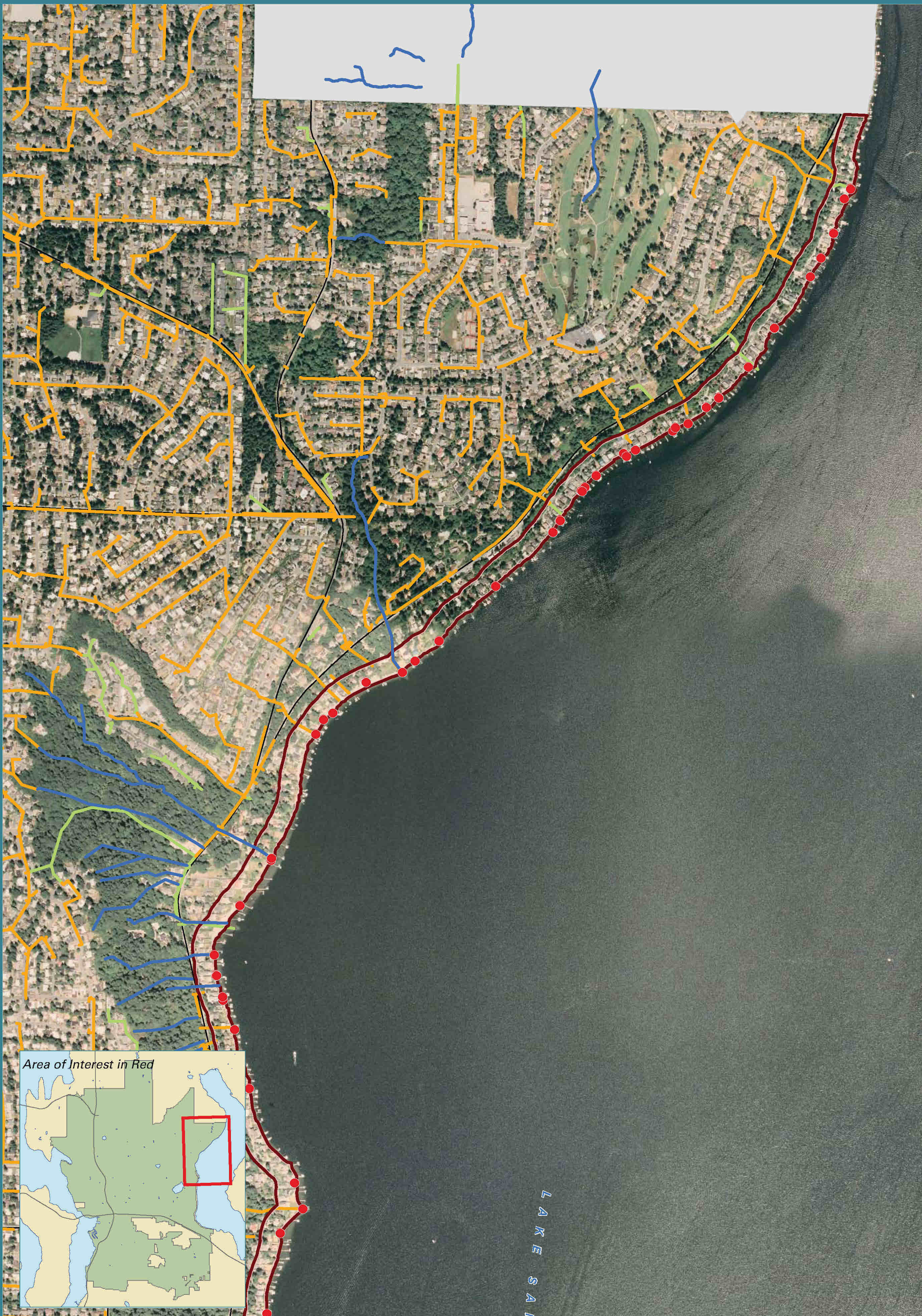

Streams and Stormwater Outfalls

City of Bellevue Shoreline Master Program

Tile 5

CITY OF BELLEVUE WASHINGTON

THE WATERSHED COMPANY

0 250 500
Feet

August 2008
Data: The Watershed Company, City of Bellevue
Finalized 10/09/2015

- Storm Drainage Pipes
- Storm Drainage Private Pipes
- Outfalls
- Shoreline Jurisdiction
- Streams
- Ordinary High Water Mark
- Major Streets

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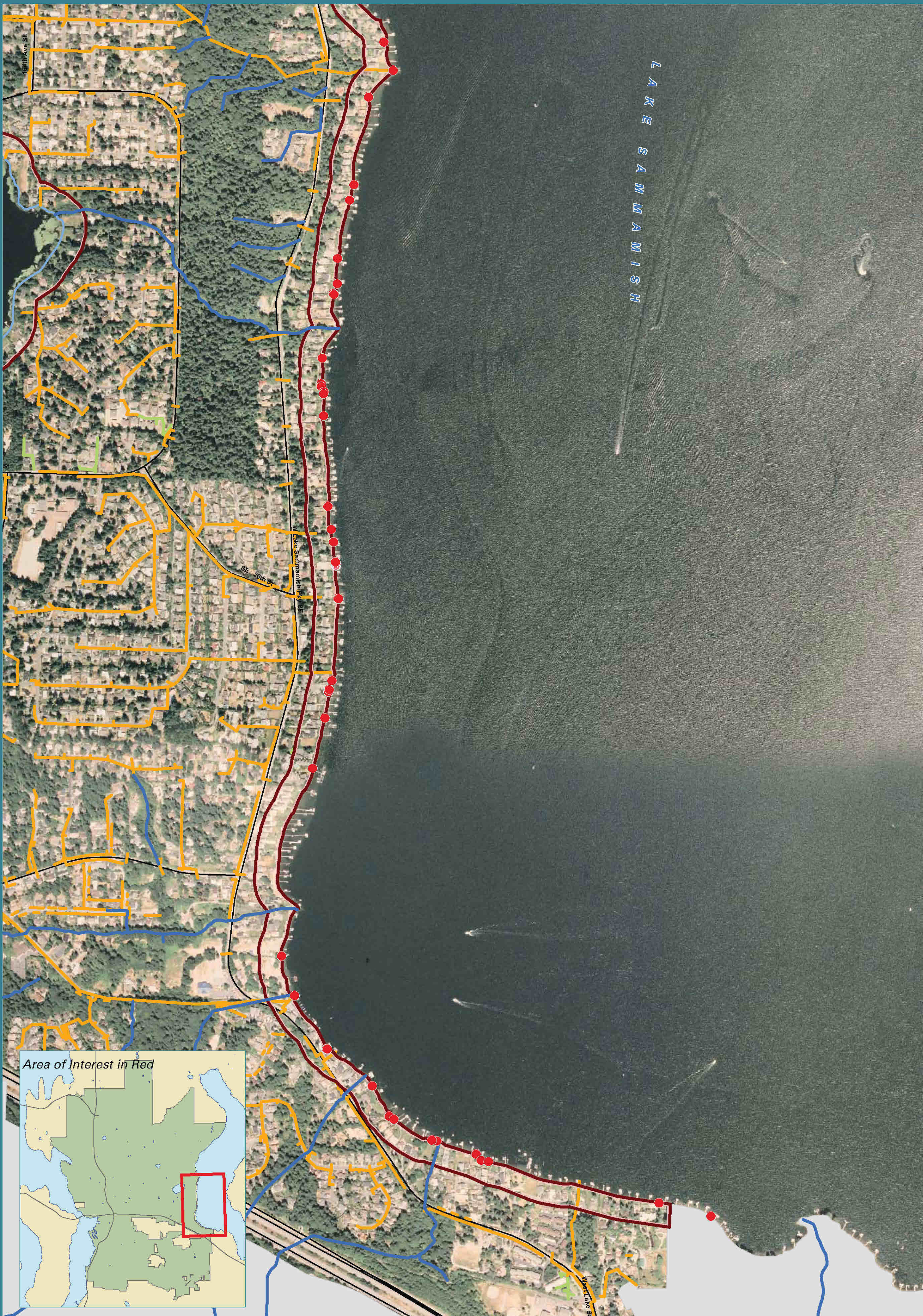

Streams and Stormwater Outfalls

City of Bellevue Shoreline Master Program

Tile 6

CITY OF BELLEVUE WASHINGTON

THE WATERSHED COMPANY

0 250 500
Feet

August 2008
Data: The Watershed Company, City of Bellevue
Finalized 10/09/2015

- Storm Drainage Pipes
- Storm Drainage Private Pipes
- Outfalls
- Shoreline Jurisdiction
- Streams
- Ordinary High Water Mark
- Major Streets

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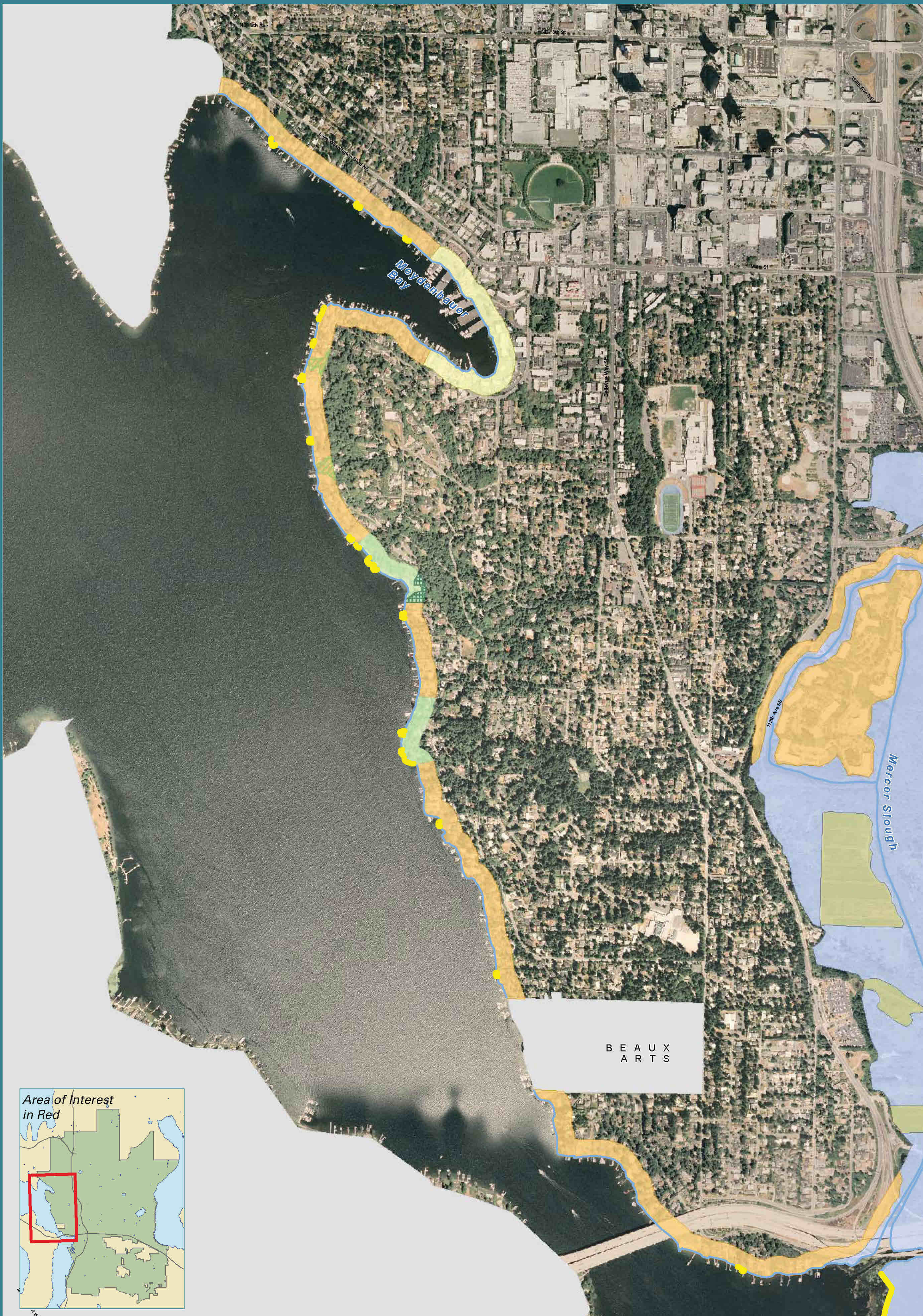

Upland Habitat Within Shoreline Areas

City of Bellevue Shoreline Master Program

Tile 1

0 250 500 750
Feet

August, 2008
Data: The Watershed Company, City of Bellevue
Finalized 10/09/2015

Habitat Units
- High habitat
- Moderate habitat
- Low habitat
- Reserve habitat
- Agriculture

Habitat Polygons
- Forest Patch
- Fragmented
- Invasives
- Perch Nest Trees
- Snag Rich Area

- Overhanging Vegetation
- Ordinary High Water Mark

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Upland Habitat Within Shoreline Areas

City of Bellevue Shoreline Master Program

Tile 2

CITY OF BELLEVUE WASHINGTON

THE WATERSHED COMPANY

0 250 500
Feet

August, 2008
Data: The Watershed Company,
City of Bellevue
Finalized 10/09/2015

Habitat Units
- High habitat
- Moderate habitat
- Low habitat
- Reserve habitat
- Agriculture

Habitat Polygons
- Forest Patch
- Fragmented
- Invasives
- Perch Nest Trees
- Snag Rich Area

- Overhanging Vegetation
- Ordinary High Water Mark

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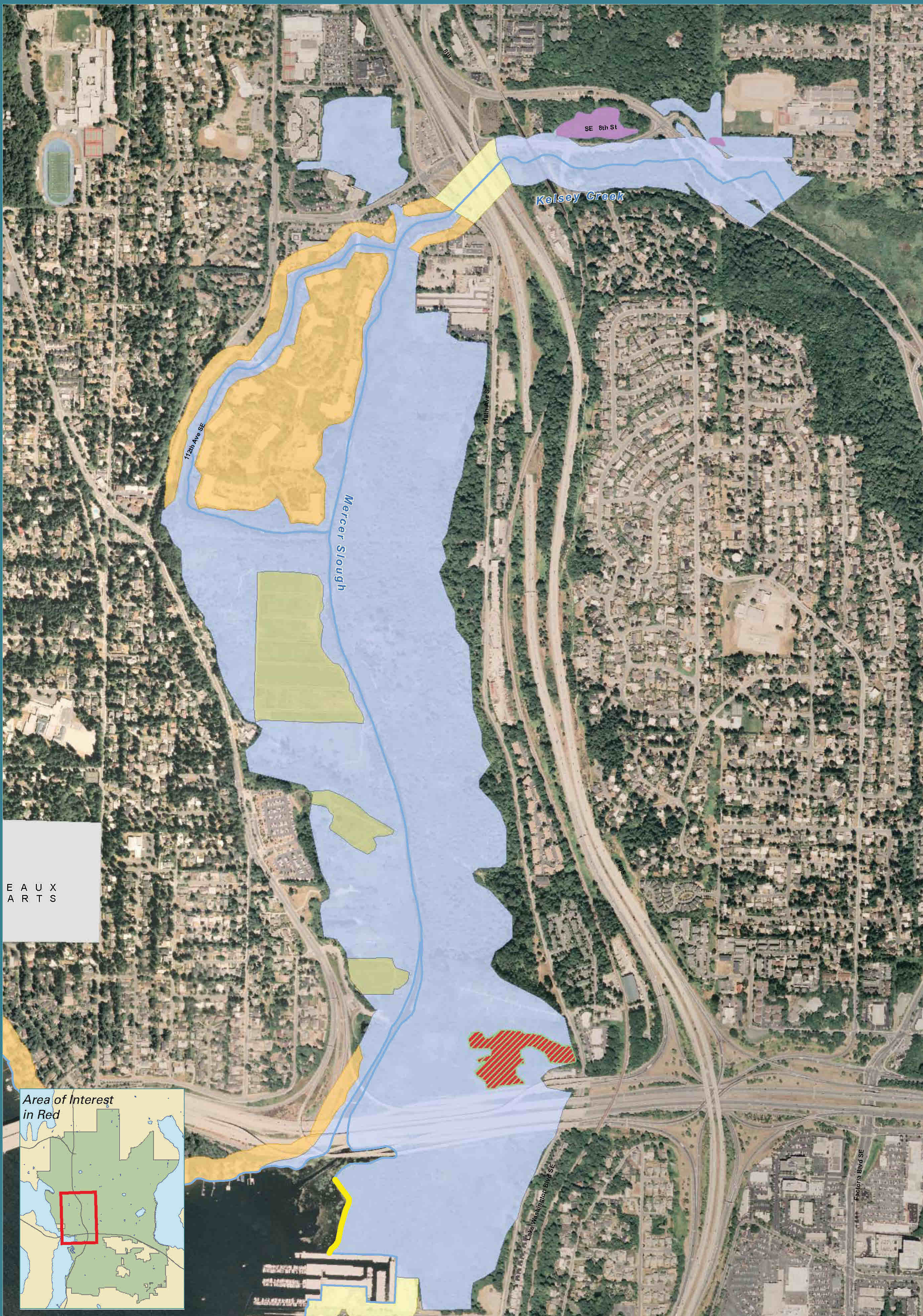

Upland Habitat Within Shoreline Areas

City of Bellevue Shoreline Master Program

Tile 3

0 250 500
Feet

August, 2008
Data: The Watershed Company,
City of Bellevue
Finalized 10/09/2015

Habitat Units

- High habitat
- Moderate habitat
- Low habitat
- Reserve habitat
- Agriculture

Habitat Polygons

- Forest Patch
- Fragmented
- Invasives
- Perch Nest Trees
- Snag Rich Area

- Overhanging Vegetation
- Ordinary High Water Mark

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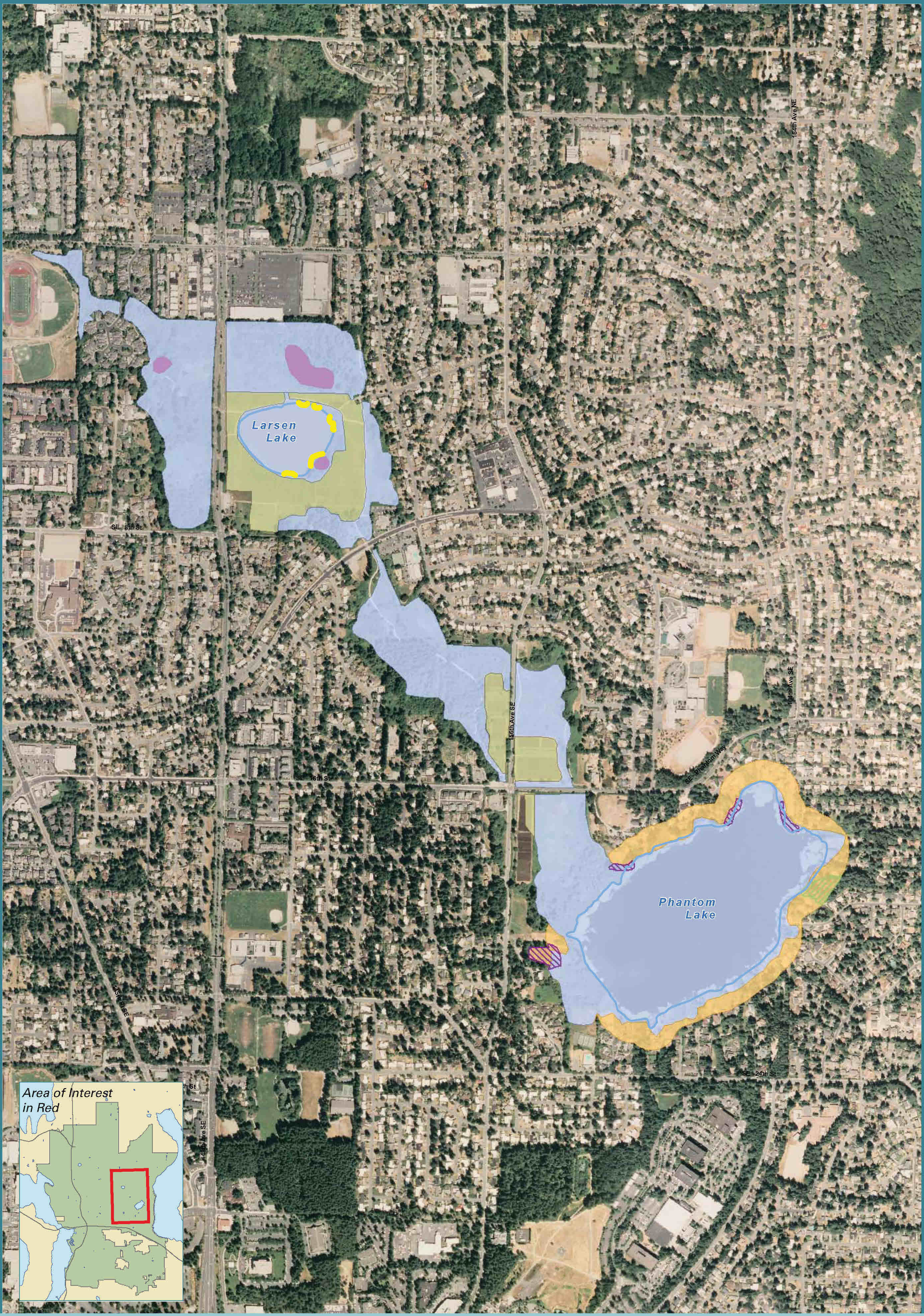

Upland Habitat Within Shoreline Areas

City of Bellevue Shoreline Master Program

Tile 4

CITY OF BELLEVUE WASHINGTON

THE WATERSHED COMPANY

0 250 500
Feet

August, 2008
Data: The Watershed Company, City of Bellevue
Finalized 10/09/2015

Habitat Units
- High habitat
- Moderate habitat
- Low habitat
- Reserve habitat
- Agriculture

Habitat Polygons
- Forest Patch
- Fragmented
- Invasives
- Perch Nest Trees
- Snag Rich Area

- Overhanging Vegetation
- Ordinary High Water Mark

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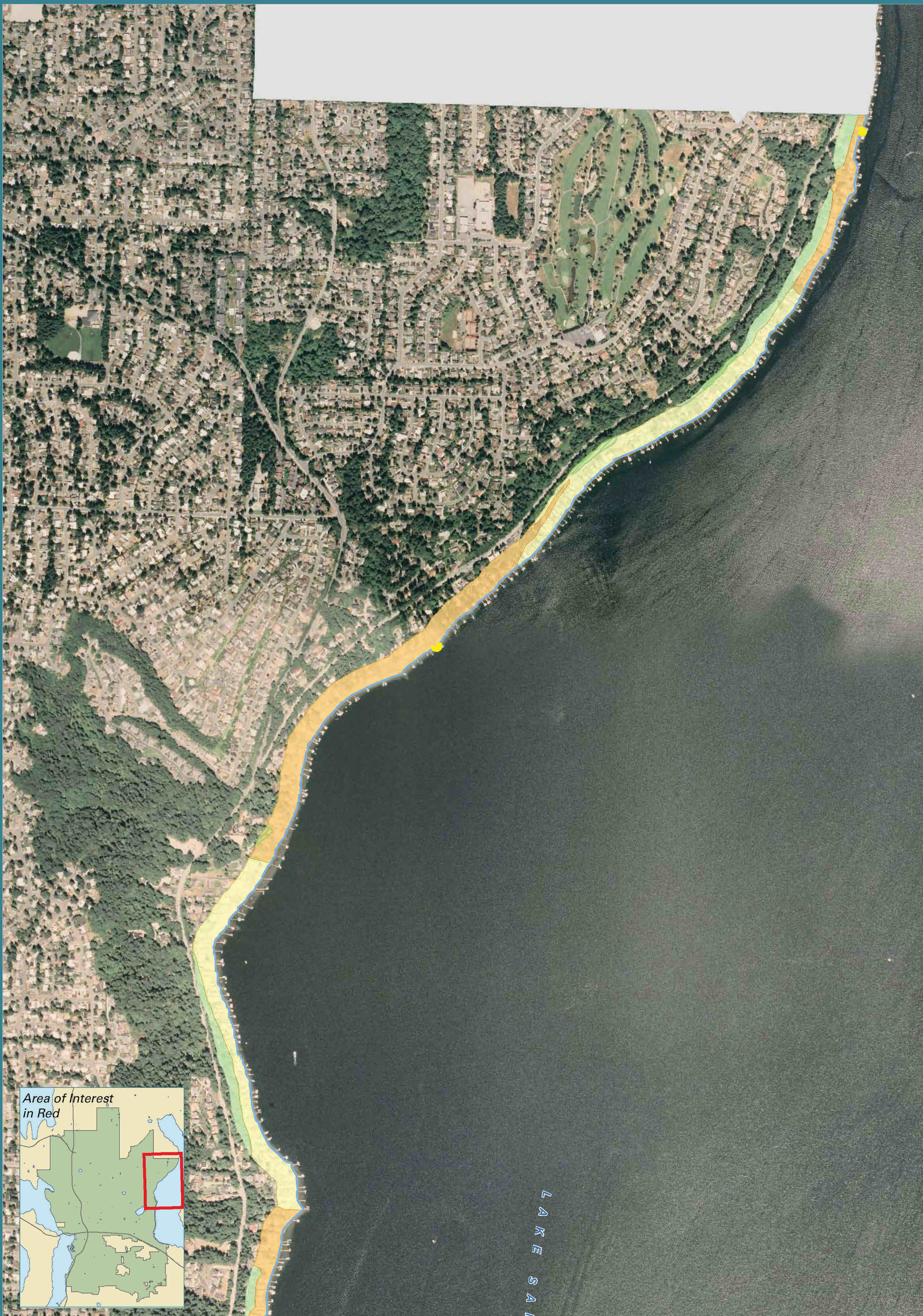

Upland Habitat Within Shoreline Areas

City of Bellevue Shoreline Master Program

Tile 5

0 250 500
Feet

August, 2008
Data: The Watershed Company,
City of Bellevue
Finalized 10/09/2015

THE WATERSHED COMPANY

Habitat Units
- High habitat
- Moderate habitat
- Low habitat
- Reserve habitat
- Agriculture

Habitat Polygons
- Forest Patch
- Fragmented
- Invasives
- Perch Nest Trees
- Snag Rich Area

- Overhanging Vegetation
- Ordinary High Water Mark

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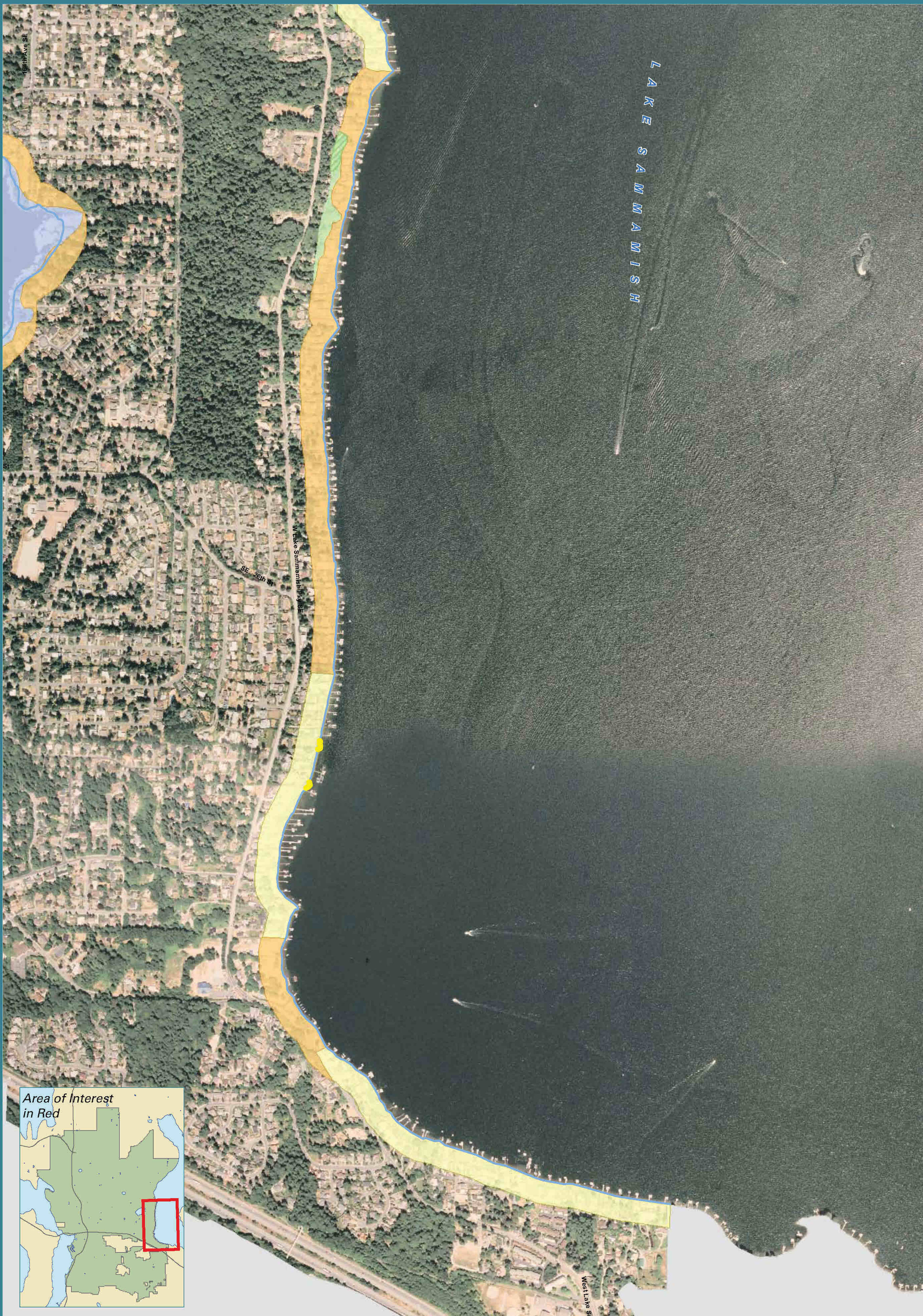

Upland Habitat Within Shoreline Areas

City of Bellevue Shoreline Master Program

Tile 6

CITY OF BELLEVUE WASHINGTON

THE WATERSHED COMPANY

0 250 500
Feet

August, 2008
Data: The Watershed Company, City of Bellevue
Finalized 10/09/2015

Habitat Units
- High habitat
- Moderate habitat
- Low habitat
- Reserve habitat
- Agriculture

Habitat Polygons
- Forest Patch
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- Perch Nest Trees
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