3. Aquatic Habitat Baseline Conditions

The project is located in the Lake Washington watershed, which comprises 13 major drainage sub-basins and numerous smaller drainages, totaling about 656 miles (1,050 kilometers) of streams, two major lakes, and numerous smaller lakes. Lake Washington and its major drainages (Issaquah Creek, the Sammamish River, and the Cedar River) are located in the Cedar-Sammamish Watershed Basin, or Water Resource Inventory Area (WRIA) 8.

The majority of the watershed is highly developed, with 63% of the watershed fully developed; WRIA 8 has the highest human population of any WRIA in Washington state (NMFS 2008a). Lake Washington is the second largest natural lake in Washington with 80 miles (128 kilometers) of shoreline. The lake is approximately 20 miles long (32 kilometers) with a mean width of approximately 1.5 miles (2.4 kilometers), has a circumference of 50 miles (80 kilometers), covers 22,138 surface acres (8,960 hectares), and has a mean depth of approximately 100 feet (30 meters) and a maximum depth of approximately 200 feet (60 meters) (Jones and Stokes 2005).

3.1 Lake Washington Hydrology

The Lake Washington watershed has been dramatically altered from its pre-settlement conditions primarily due to urban development and removal of the surrounding forest, as well as the lowering of the lake elevation and rerouting of the outlet through the Ship Canal. As a result, the Cedar River is now the major source of fresh water to Lake Washington, providing about 50% (663 cubic feet per second [cfs]) of the mean annual flow entering the lake (NMFS 2008a). The Cedar River drainage area is approximately 184 square miles (476 square kilometers), which represents about 30% of the Lake Washington watershed area.

The Lake Sammamish basin is also a substantial source of fresh water, providing about 25% (307 cfs) of the mean freshwater flow into Lake Washington. The Sammamish sub-basin has a drainage area of about 240 square miles (622 square kilometers) and represents about 40% of the Lake Washington basin. Tributaries to the Sammamish River include Swamp, North, Bear, and Little Bear creeks, as well as the surface waters of Lake Sammamish. Hydrology in the Lake Sammamish sub-basin is generally affected by the same factors that affect Lake Washington.

The remainder of freshwater flow into Lake Washington originates from a variety of small creeks located primarily along the northern and eastern shores. These smaller tributaries and sub-basins in the Lake Washington system include Thornton, Taylor, McAleer, Forbes, Juanita, Kelsey, Coal, and May creeks, and Mercer Slough. Within Lake Washington, the natural hydrologic cycle has been altered. Historically, lake elevations peaked in winter and declined in summer. Present operation of the Ballard Locks produces peak elevations throughout most of the summer.

USACE is mandated by Congress (Public Law 74-409, August 30, 1935) to maintain the level of Lake Washington between 20 and 22 feet (USACE datum) as measured at the locks. USACE operates this facility to systematically manage the water level in Lake Washington over four distinct management periods, using various forecasts of water availability and use. The four management periods are as follows:

- Spring refill – lake level increases to 22 feet between February 15 and May 1 (USACE datum).
- Summer conservation – lake level maintained at about 22 feet for as long as possible, with involuntary drawdown typically beginning in late June or early July.
- Fall drawdown – lake level decreasing to about 20 feet from the onset of the fall rains until December 1.
- Winter holding – lake level maintained at 20 feet between December 1 and February 15.

Operation of the locks and other habitat changes throughout the Lake Washington basin have substantially altered the frequency and magnitude of floods in Lake Washington and its tributary rivers and streams. Historically, Lake Washington's surface elevation was nearly 9 feet higher than it is today, and the seasonal fluctuations further increased that elevation by an additional 7 feet annually (Williams 2000). In 1903, the average lake elevation was recorded at approximately 32 feet (USACE datum) (NMFS 2008a).

3.2 Lake Washington Shoreline Habitat

Lowering the lake elevation after completion of the Ship Canal in 1917 transformed about 1,334 acres (540 hectares) of shallow water habitat into upland areas, reducing the lake surface area by 7% and decreasing the shoreline length by about 13% (10.5 miles or 16.9 kilometers) (Chrzastowski 1983). The most extensive changes occurred in the sloughs, tributary delta areas, and shallow portions of the lake. The area of freshwater marshes decreased about 93%, from about 1,136 acres (460 hectares) to about 74 acres (30 hectares) (Chrzastowski 1983). The vast majority of existing wetlands and riparian habitatcurrently associated with Lake Washington, developed after the lake elevation was lowered 9 feet. Currently, this habitat occurs primarily in Union Bay, Portage Bay, Juanita Bay, and Mercer Slough (Dillon et al. 2000).

Lake level regulation by USACE has eliminated the seasonal inundation of the shoreline that historically shaped the structure of the riparian vegetation community. Winter lake drawdowns expose the roots of riparian vegetation in the drawdown zone to winter temperatures (rather than being protected by the standing water during this dormant period). This, in turn, produces a vegetation-free zone between the high and low lake levels (2 feet vertically, with variable horizontal distance depending on shoreline slope). Lake level regulation and urban development have replaced much of the hardstem bulrush- and willow-dominated community with developed shorelines and landscaped yards, and this affects the growth of many species of native terrestrial and emergent vegetation. In addition, lake level regulation indirectly buffers the shorelines from potential winter storm wave effects. The loss of natural shoreline has also reduced the historic complex shoreline features such as overhanging and emergent vegetation, woody debris (especially fallen trees with branches and/or rootwads intact), and gravel/cobble beaches. The loss of native shoreline vegetation and wetlands has reduced the input of terrestrial detritus and insects that support the aquatic food web.

These natural shoreline features have been largely replaced with armored banks, piers, and floats, and limited riparian vegetation. A survey of 1991 aerial photos estimated that 4% of the shallow water habitat within 100 feet (30.5 m) of the shore was covered by residential piers (ignoring coverage by commercial structures and vessels) (USFWS 2008). Later studies report about 2,700 docks in Lake Washington as well as armoring of more than about 80% of the shoreline (Warner and Fresh 1998; City of Seattle 2000; Toft 2001; DNR 2010).

An even greater density of docks and shoreline modifications occurs throughout the Ship Canal, Portage Bay, and Lake Union (City of Seattle 1999; Weitkamp et al. 2000). Areas that have some amount of undeveloped shoreline include Gas Works Park, the area south of SR 520 (in Lake Union and Portage Bay), and a protected cove west of Navy Pier at the south end of Lake Union. Vegetation within these areas is limited, with the area south of SR 520 possessing the highest abundance of natural riparian vegetation, consisting primarily of cattails (*Typha* spp.) and small trees (Weitkamp et al. 2000). The loss of complex habitat features (i.e., woody debris, overhanging riparian and emergent vegetation) and shallow water habitat in Lake Washington has reduced the availability of prey refuge habitat and forage for juvenile salmonids. Dense growths of introduced Eurasian milfoil and other aquatic macrophytes effectively isolate much of the more natural shoreline from the deeper portions of the aquatic habitat.

Portage Bay is lined by University of Washington facilities, commercial facilities, and houseboats. The southeastern portion of Portage Bay has an area of freshwater marsh habitat and naturally sloped shoreline, while the remainder of the shoreline is developed, with little natural riparian vegetation. The Montlake Cut is a concrete-banked canal that connects Portage Bay to Union Bay, which extends eastward to Webster Point and the main body of Lake Washington.

Prior to construction of the Ship Canal, Union Bay consisted of open water and natural shorelines extending north to 45th Street. The lowered lake levels resulting from the Ship Canal construction produced extensive marsh areas around Union Bay, with substantial portions of this marsh habitat subsequently filled, leaving only the fringe marsh on the southern end (Jones and Jones 1975). The south side of the bay is bordered by the Arboretum, with a network of smaller embayments and canals, and extensive marsh habitats. The north side of Union Bay contains a marshy area owned by the University of Washington; the area was previously filled with landfill material. Numerous private residences with landscaped waterfronts and dock facilities dominate the remainder of the shoreline.

Development and urbanization have also altered base flow in many of the tributary systems (Horner and May 1998). Increases in impervious and semi-impervious surfaces add to runoff during storms and reduce infiltration and groundwater discharge into streams and rivers. A substantial amount of surface water and groundwater is also diverted into the City of Seattle and King County wastewater treatment systems and is eventually discharged to Puget Sound.

Although the frequency and magnitude of flooding in the lake and the lower reaches of tributary streams have declined due to the operation of the locks, flooding has generally increased in the upstream reaches of tributary rivers and streams. This change is largely because of the extensive development that has occurred within the basin over the last several decades (Moscrip and Montgomery 1997).

No measurable changes in shoreline habitat condition are expected to occur in the near future, although gradual changes (both positive and negative) are likely to occur. Therefore, the existing degraded habitat in the greater Lake Washington watershed is expected to continue to affect salmonid species in the watershed for the foreseeable future.

3.3 Lake Washington Water Quality

The water quality and sediment quality in the Lake Washington basin are degraded as a result of a variety of current and historic point and non-point pollution sources. Historically, Lake Washington, Lake Union, and the Ship Canal were the receiving waters for municipal sewage, with numerous shoreline area outfalls that discharged untreated or only partially treated sewage directly into these waterways. Cleanup efforts in the 1960s and 1970s included expanding the area's wastewater treatment facilities and eliminating most untreated effluent discharges into Lake Washington. Although raw sewage can no longer be discharged directly into Lake Washington waters, untreated, contaminated flows in the form of combined sewer overflows occasionally enter these waterways during periods of high precipitation (NMFS 2008b). For example, a recent incident resulted in the accidental discharge of an estimated 6.4 million gallons of sewage into Ravenna Creek, which discharges into Union Bay (King County 2008).

In addition to point source pollution, a variety of non-point sources continue to contribute to the degradation of water and sediment quality. Non-point sources include stormwater and subsurface runoff containing pollutants from road runoff, failing septic systems, underground petroleum storage tanks, gravel pits/quarries, landfills and solid waste management facilities, sites with improper hazardous waste storage, and commercial and residential sites treated with fertilizers and pesticides.

Historical industrial uses in the basin, such as those around Lake Union and southern Lake Washington, Newcastle, Kirkland, and Kenmore, have contaminated sediments with persistent toxins; these toxins include polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and heavy metals (King County 1995). The expanding urbanization in the basin has also increased sediment input into the Lake Washington system water bodies.

Along with the physical changes to the Lake Washington basin, substantial biological changes have occurred. Non-native plant species have been introduced into Lake Washington, and years of sewage discharge into the lake increased phosphorus concentration and subsequently led to extensive eutrophication. Blue-green algae dominated the phytoplankton community and suppressed production of zooplankton, reducing the available prey for salmonids and other species. However, water quality improved dramatically in the mid 1960s as sewage was diverted from Lake Washington to Puget Sound; at this time, dominance by blue-green algae subsided and zooplankton populations rebounded.

The Ship Canal and Lake Union are listed on the Ecology 303(d) list of impaired water bodies for exceeding water quality criteria for total phosphorous, lead, fecal coliform, and aldrin (Ecology 2008). In addition, portions of Lake Washington are listed on the 303(d) list for exceeding water quality criteria for fecal coliform, as well as the tissue quality criteria for 2,3,7,8 TCDD (dioxin), PCBs, total chlordane, 4,4’ DDD (metabolite of DDT) and 4, 4’ DDE (breakdown product of DDT) in various fish species (Ecology 2008). Therefore, the overall water quality conditions in the project vicinity are degraded compared to historical conditions.

3.4 Dissolved Oxygen and Temperature Conditions

Despite reversing the eutrophication trend in the lake, the introduction of Eurasian milfoil to Lake Washington in the 1970s caused additional localized aquatic habitat and water quality problems. Milfoil and other aquatic vegetation dominate much of the shallow shoreline habitat of Lake Washington, Lake Sammamish, Lake Union, Portage Bay, and the Ship Canal. Dense communities of aquatic vegetation, or floating mats of detached plants, can adversely affect localized water quality conditions. Dense communities can reduce dissolved oxygen (DO) to below 5 ppm (parts per million), and the decomposition of dead plant material increases the biological oxygen demand, further reducing DO and pH (DNR 1999). Under extreme conditions, these localized areas can become anoxic.

In addition to the substantial modification aquatic vegetation has made to habitat in the water column, excessive accumulation and decomposition of organic material has overlain areas of natural sand or gravel substrate with fine muck and mud. Substantial shoreline areas of Lake Washington, the Ship Canal, and the project vicinity have soft substrate, with substantial accumulations of organic material from the decomposition of milfoil and other macrophytes. The dense vegetation also reduces the currents and wave energy in these areas, which encourages the accumulation of fine sediment material. As microorganisms in the sediment break down the organic material, they consume much of the oxygen in the lower part of the lake. By the end of summer, concentrations of DO in the hypolimnion (the lowest water layer in the lake) can be reduced to nearly 0.0 milligrams per liter (mg/L). Despite these effects in some shallow nearshore habitats, mean hypolimnetic DO levels recorded at long-term monitoring sites in the lake between 1993 and 2001 ranged from 7.7 to 8.9 mg/L (King County 2003). However, it should be noted that water depths in the hypolimnion extend well below the photic zone, to more than 200 feet. Also, the portions of the hypolimnion closer to the shoreline, which show the lowest DO concentrations, support outmigrating and rearing juvenile salmonids to a greater degree than do deep water habitats.

The thermal stratification of Lake Washington and Lake Union can produce surface temperatures in excess of 68°F (20°C) for extended periods during the summer. In addition, there is a long-term trend of increasing summer and early fall water temperatures (Goetz et al. 2006; Newell and Quinn 2005; Quinn et al. 2002; King County 2007). From 1932 to 2000, there was a significant increase in mean August water temperature from about 66° to 70° Fahrenheit (F) (19° to 21° Celsius [C]) at a depth of 15 feet (Shared Strategy 2007). If this trend continues, surface water temperatures could exceed the lethal threshold (22° to 25° C) for returning adult salmon in some years.

Lake Washington Ship Canal

Saltwater intrusion occurs in the Ship Canal above the locks, but very little of the deeper, heavier salt water mixes with the lighter freshwater surface layer. Consequently, this area lacks the diversity of habitats and brackish water refuges characteristic of most other (unaltered) river estuaries. Usually, this saltwater intrusion extends to the east end of Lake Union, but can extend as far as the University Bridge in an extremely dry summer. The extent of this intrusion into the Ship Canal and into Lake Union is primarily controlled by outflow at the locks and the frequency of large and small lock operations.

Historical data indicate that reduced mixing of the water column due to the saltwater layer likely produced year-round anaerobic conditions in the deeper areas of Lake Union and the Ship Canal (Shared Strategy 2007). The lack of mixing, along with a significant oxygen sediment demand, can reduce dissolved oxygen levels to less than 1 mg/L, and could prevent fish from using the water column below a 33 foot (10-meter) depth. This condition was likely more severe before about 1966, when a saltwater barrier was constructed at the locks, thereby improving water quality conditions upstream. Water quality in Lake Union has also improved since the 1960s because of the reduction in direct discharges of raw sewage and the closure of the Seattle Gas Light Company gasification plant, along with the upland cleanup activities at the gas plant and other industrial sites. However, Lake Union still experiences periods of anaerobic conditions that typically begin in June and can last until October (Shared Strategy 2007).

Adult fish returning through the Ship Canal and project area contend with anoxic conditions in the hypolimnion from July through October (King County 2009). High temperatures in the epilimnion generally restrict adult salmonid distribution, including Chinook salmon, to depths below 5 to 10 meters, while anoxic conditions below depths of 50 to 65 feet (15 to 20 meters) prevent Chinook use, thus concentrating them in the relatively narrow [16 to 32 feet (5 to 10 meters)] metalimnion. These physical restrictions can also affect juvenile outmigrants, limiting foraging opportunities and exposing juvenile fish to predators occupying habitat in the metalimnion.

3.5 Fish and Aquatic Resources in Lake Washington and the Ship Canal

A diverse group of native and non-native fish species inhabit the Lake Washington watershed, including several species of native salmon and trout such as Chinook, coho (*Onchorhynchus kisutch*), and sockeye (*O. nerka*) salmon; and steelhead *(O. mykiss*), rainbow (*O. mykiss irideus*), and cutthroat trout (*O. clarki clarki*). Most of these species are likely to occur at least occasionally in the project vicinity. The following section describes the various species of salmonids (the primary species of concern for compensatory mitigation) in the project area, and pertinent information on their habitat requirements and life history trajectories. In addition, information is presented on fish species that are significant predators on salmonids in Lake Washington, including bass and pikeminnow.

3.5.1. Salmonid Species and Life Histories

Salmonids in the Lake Washington watershed are a mix of native and non-native species, and sometimes a single species can include both native and non-native stocks. For example, recent evidence for sockeye indicates that the Cedar River and Issaquah Creek spawners are likely descendents of introduced fish (Baker Lake stock), while those spawning in Bear Creek may be native fish (Hendry et al. 1996). Man-made changes to the historical drainage patterns in the Lake Washington basin— such as the connection of the Cedar River, disconnection of the Black River, and creation of the Ship Canal—have had a significant effect on salmonid populations, including species distribution, within the Lake Washington system.

Chinook Salmon

Small numbers of Chinook fry begin migrating into Lake Washington from the Cedar River in January, while most Chinook fry enter the lake in mid-May. Initially, the Cedar River Chinook fry tend to concentrate in the littoral zone at the south end of Lake Washington between February and mid-May until they grow large enough to move offshore (Fresh 2000; Tabor et al. 2004a; Tabor et al. 2006). Therefore, the lakeshore area near the Cedar River mouth appears to be an important nursery area for juvenile Chinook salmon. Tabor et al. (2004a) found that the mean abundance of juvenile Chinook from February through May was positively related to proximity to the Cedar River mouth, but there was no difference by June. Juveniles migrate away from the Cedar River mouth and along the Lake Washington shorelines as they grow.

After entering the lake, the juvenile Chinook salmon rear in the shallow littoral zone (1 to 2 feet deep) as they gradually migrate to Union Bay and the Ship Canal. Juvenile Chinook salmon tend to prefer gradually sloping, sand-silt substrate habitat less than 1.6 feet deep (Tabor et al. 2006). They also congregate at the mouths of small tributary streams, possibly attracted by flow, shallow-water depths, benthic invertebrate or terrestrial insect food sources, fine particle substrate accumulated at the stream delta fans, or by some combination of these factors (Shared Strategy 2007). Juvenile Chinook salmon tend to increase their use of deeper-water habitat areas as they get larger, likely as a response to prey availability, reduced predation risks, and possibly more favorable water temperature conditions (Warner and Fresh 1998; Celedonia et al. 2008a).

Chinook fry typically rear in the lake from 1 to 4 months before migrating through the Ship Canal to Puget Sound (Seiler et al. 2004; Tabor et al. 2006). The larger fingerlings enter the lake between mid-May and June after spending up to 6 months rearing in the rivers and streams. Little information is available on the timing of north Lake Washington Chinook in the project vicinity.

Recent observations in the Ship Canal show that young Chinook salmon tend to be relatively uniformly distributed over a range of depths in this area (Celedonia et al. 2008b). Smaller juvenile Chinook salmon appear to prefer shallow areas with over-water cover, particularly during the day (Tabor et al. 2006), but tend to avoid overhead cover areas as they grow (Tabor et al. 2004a). While riparian vegetation tends to be the preferred over-water cover habitat, docks and piers are sometimes used as substitute cover, particularly during the day (Tabor and Piaskowski 2002). The large number of piers and docks lining the Lake Washington shoreline is expected to substantially affect the natural behavior of juvenile Chinook salmon and other salmonids rearing and migrating through the lake.

Celedonia et al. (2008b) determined that the response of juvenile Chinook salmon to the existing Evergreen Point Bridge was at least partially dependent on whether they were actively migrating or holding (remaining in one area). About two-thirds of actively migrating smolts appeared delayed by the bridge, while the remaining smolts appeared negligibly affected by the bridge. Delayed fish varied widely in the time of delay and distance traveled during delay. Nearly half (45%) of the delayed smolts took less than 3 minutes to pass beneath the bridge after the initial encounter, travelling less than 33 meters along the edge of the bridge during this time. Conversely, many smolts that exhibited holding behavior characteristics, as opposed to active migration behavior, appeared to selectively choose to reside in areas near the bridge for prolonged periods. This behavior was distinctly different from the apparent bridge-induced delay observed in some actively migrating smolts. Holding fish often crossed beneath the bridge to the north and were later observed returning to and holding in areas immediately adjacent to the bridge's southern edge (less than 20 meters from the edge of the bridge). The bridge did not appear to be a factor in delaying the migration of fish that displayed holding behavior prior to continuing their outmigration.

Artificial lighting associated with the proposed roadway and bridge also has the potential to affect the distribution and behavior of fish, depending on its intensity and proximity to the water. Adaptations and responses to light are not universal for all species of fish—some predatory fish are adapted for hunting in low light intensities, while others are attracted to higher light intensities; some species school and move toward light sources (Machesan et al. 2005).

Based on Lake Washington tagging data, Celedonia et al. (2009) indicate that juvenile Chinook salmon are attracted to areas where street lamps on the existing Evergreen Point Bridge cast light onto the water surface, suggesting that bridge lighting is at least partially responsible for the nighttime selection of near-bridge areas by Chinook salmon. It has been conjectured that the illuminated areas may allow juvenile Chinook salmon an opportunity to forage throughout the night when under normal, low light conditions they would normally stop feeding.

Each year, adult Chinook salmon pass through the Ship Canal and Lake Union from the end of July through the beginning of September (City of Seattle and USACE 2008). The total time of adult Chinook salmon migration from the Hiram M. Chittenden Locks (Ballard Locks) to arrival at tributary spawning grounds can take up to 55 days, but averages less than 30 days (Fresh et al. 2000). In general, migration time, both through the Ship Canal and to spawning grounds, decreases as the season progresses and could reflect maturation level of the fish.

Once Chinook leave the locks, most fish move through the Ship Canal in less than 1 day (varying from 4 hours to 7.7 days) (Fresh et al. 1999; Fresh 2000). Adult Chinook salmon may enter Lake Washington several days before moving into rivers for spawning, with the average time spent by adult Chinook in Lake Washington around 3 days for Cedar River fish and 5 days for Sammamish watershed fish (Fresh et al. 1999). Due to the short time most Chinook adults spend in the lake and the Ship Canal, the modified habitat in these areas may have a limited effect on returning adults, although the relatively short time spent in the lake may be related to the long-term trend of increasing late summer water temperatures.

Acoustic and temperature tags on adult Chinook salmon show that these fish inhabit lake waters ranging from 48º to 70º F (9º to 21º C) (F. Goetz in City of Seattle and USACE 2008). The adult Chinook do not seem to seek out cool waters, but will hold near the mouths of the Cedar and Sammamish rivers in warm, shallow waters.

Steelhead

Juvenile steelhead migrating out of the Lake Washington watershed will pass through the project area. No information is available that identifies the project area as a location specifically used by juvenile steelhead for rearing. Juvenile steelhead rear in fresh water, including the lake, for several years before migrating to Puget Sound; therefore, they are expected to be less dependent on the shallow nearshore habitat in the lake than are the smaller Chinook salmon fry.

Adult steelhead pass through the Ballard Locks to Lake Washington between December and early May (WDFW et al. 1993). Spawning occurs throughout the Lake Washington basin, including the lower Cedar River, the Sammamish River and its tributaries, and several smaller Lake Washington tributaries (WDFW 2006). Steelhead spawn primarily in the main stem Cedar River from March through early June (Burton and Little 1997), although there are historical records of steelhead spawning in Cedar River tributaries such as Rock Creek.

Bull Trout

Little is known about the historical distribution and abundance of bull trout in the Lake Washington system. A 1-year survey in the Lake Sammamish basin during 1982 and 1983 reported no char (a subset of the salmonids that includes bull trout and Dolly Varden) (WDFW 1998). While bull trout occasionally occur in Lake Washington, there are no indications of an adfluvial population in the lake, and bull trout are not expected to occur in the surface waters of Lake Washington during the summer when water temperatures typically exceed 59ºF (15ºC) for several months. Therefore, the apparent remnant anadromous population likely uses the lake primarily as a migration route to marine waters for foraging and rearing.

Although bull trout may occasionally occur in the project area, there is no known regular occurrence of bull trout in the lake. There have been only a few reports of bull trout and Dolly Varden in the entire Lake Washington watershed. No bull trout observations have been documented between October and December, likely because the fish are presumed to be on or near their spawning grounds during this time.

Several large native char (approximately 410 millimeters long) have been observed passing through the viewing chamber at the Ballard Locks, but only one was identified as bull trout

(Bradbury and Pfeifer 1992; USFWS 1998). Bull trout were caught in Shilshole Bay and the Ballard Locks during late spring and early summer in both 2000 and 2001, with up to eight adult and subadult fish caught in Shilshole Bay below the locks between May and July in 2000. In 2001, five adult bull trout were captured in areas within and immediately below the Ballard Locks. One bull trout was captured within the large locks and one in the fish ladder, as well as three adult bull trout captured below the tailrace during the peak of juvenile salmon migration in mid-June (USFWS 2008). Observations of bull trout near the Ballard Locks suggest migration of bull trout from other core areas to Lake Washington.

Anadromous adult and subadult bull trout likely occur in the project area throughout the year, most likely in spring and early summer during outmigration of juveniles. This observation is based on bull trout captured at the Ballard Locks and the Ship Canal between May and July. Bull trout likely use the project area for either foraging or migrating through the area to other marine or estuarine foraging habitats. Bull trout in the project area are likely originate from the core areas of the Stillaguamish, Snohomish-Skykomish, and Puyallup rivers.

Sockeye

Juvenile sockeye salmon commonly rear in the open-water habitat of the lake for a year before migrating to salt water, including the area along the floating portion of the Evergreen Point Bridge, although juvenile sockeye salmon use of Lake Washington varies. Smaller sockeye fry first entering the lake may inhabit shallow water areas such as river deltas at night (City of Seattle and USACE 2008) or other parts of the littoral zone (Martz et al. 1996), although the amount of time fry are present in this area is unknown. In general, sockeye fry travel in schools in limnetic areas (open-water areas of the lake away from shore) and are located below 66 feet in depth during the daytime, then ascend to shallower waters at dusk to feed during the night (Eggers et al. 1978). This diurnal difference in depth can be up to 43 feet. During summer lake stratification, sockeye are confined to deeper, cooler waters because during this period, sockeye are unable to access the high densities of zooplankton in the epilimneon (uppermost water layer in a lake) due to high water surface temperatures in Lake Washington.

Juvenile sockeye salmon begin to migrate out of Lake Washington in April and continue outmigration until June or early July. Sockeye are usually outmigrate at 1 year of age, after spending the previous summer and winter rearing in the lake, although some sockeye outmigrate within their first year. Outmigration behavior of sockeye has not been studied in Lake Washington.

In-lake survival for sockeye salmon, from fry entry to pre-smolts the following spring, was estimated to be about 2.91% over the 2000 to 2005 brood years (McPherson and Woodey 2009). This is a very low survival rate for this life history stage compared with that of other sockeye salmon populations. A hypothesis for this finding is based on timing of sockeye fry entry into Lake Washington, which often takes place before or early in the spring bloom period, potentially placing the fry at risk due to suboptimal food resources for large populations entering in the south end of the lake from the Cedar River (McPherson and Woodey 2009). However, studies of Lake Washington sockeye's pre-smolt to adult survival have indicated that survival is consistent with other sockeye stocks (Ames 2006).

Once adult sockeye have migrated through the Ballard Locks, they have a rapid migration through the Ship Canal, averaging about 4 days (Newell and Quinn 2005). As with Chinook salmon, timing of sockeye passage through the Ship Canal and Lake Union is thought to be influenced by several factors, including warm water temperatures in the Ship Canal.

All sockeye salmon tend to have similar life history patterns in the Lake Washington watershed, but the adult sockeye returning to spawn in the Cedar River tend to be larger and older than the Bear Creek spawners (Hendry and Quinn 1997). In addition to spawning in the Cedar River and other Lake Washington tributaries, sockeye salmon also spawn along Lake Washington's shoreline. This includes past spawning records for the existing and proposed east end of the Evergreen Point Bridge, based on WDFW map records (K. Buchanan, Fish Biologist, WDFW, Olympia, Washington, July 26, 2004. pers. comm.). However, no recent surveys have been conducted to determine whether sockeye salmon currently spawn in this location. This area is one of more than 85 shoreline spawning beaches and is less than 1% of the beach spawning habitat previously identified in Lake Washington on maps provided by WDFW (K. Buchanan, Fish Biologist, WDFW, Olympia, Washington, July 26, 2004, pers. comm.).

Estimated annual escapement of Lake Washington beach spawning sockeye (i.e., hatchery fish that spawn in natural areas versus returning to hatchery waters) varied from 54 to 1,032 fish from 1976 through 1991 (WDFW 2004). These sockeye spawn wherever suitable gravel beaches and groundwater upwelling occur around the lake, particularly along the north shore of Mercer Island and the east shore of Lake Washington. These spawning areas occur over a wide range of water depths. The estimated total beach spawning population ranged between 200 and 1,500 fish between 1986 and 2003 (WDFW 2004).

Coho Salmon

Not much information is known about coho salmon's use of Lake Washington habitats. In general, these fish enter Lake Washington at a larger size than Chinook salmon, which influences their habitat choice. In Lake Washington, smaller-sized coho salmon are likely to eat prey items similar to those consumed by Chinook and sockeye. However, as these fish grow larger, they may switch to piscivory (eating other fish).

Age 1+ coho outmigration occurs from late April until late May, usually peaking in early May (Fresh and Lucchetti 2000). As with steelhead, it is thought that coho generally move through the lake and into marine waters more quickly than Chinook salmon because of their large size upon entry into Lake Washington. Most coho salmon tagged and released in the

Ship Canal pass the Ballard Locks within 2 weeks. Habitat use and behavior during this period have not been studied in Lake Washington, and are largely unknown.

Returning adult coho salmon pass through the project area from late September through November. Little is known about adult coho behavior and habitat choice upstream of the Ballard Locks.

Cutthroat Trout

Lake Washington contains populations of cutthroat trout, both anadromous (migrating from fresh to salt water) and potamodromous (migrating only within freshwater areas). Most anadromous cutthroat trout juveniles move to salt water at age 2 if they migrate to sheltered saltwater areas, or age 3 or 4 if they migrate to the open ocean. Seaward migration peaks in May. Potamodromous forms migrate to main stem rivers or to lakes; otherwise, their life history characteristics are much like those of the anadromous form. Prey includes insects, crustaceans, and other fish including perch, coho smolts, minnows, and other young fish.

3.5.2. Salmonid Distribution and Densities: Salmonid Functional Zones

Anadromous salmonids in the project area are classified into several stocks, based on both geographical distribution of the fish and genetic similarities. Table 3-1 lists the identified stocks of anadromous salmonids in the Lake Washington basin. Based on geography, all anadromous juveniles originating in the Cedar River or along the southern shoreline of Lake Washington (for beach spawning sockeye salmon) must migrate through the project area to reach the Lake Washington Ship Canal, the only available route to the marine environment of Puget Sound. In some cases, a high percentage of a particular salmon species originates in the Cedar River. For example sockeye salmon from the Cedar River have accounted for approximately 85.3% of sockeye (1982 to 2002 range: 68 to 98%; Standard Deviation: 7.8%) estimated to have spawned annually in the Lake Washington watershed (McPherson and Woodey 2009).

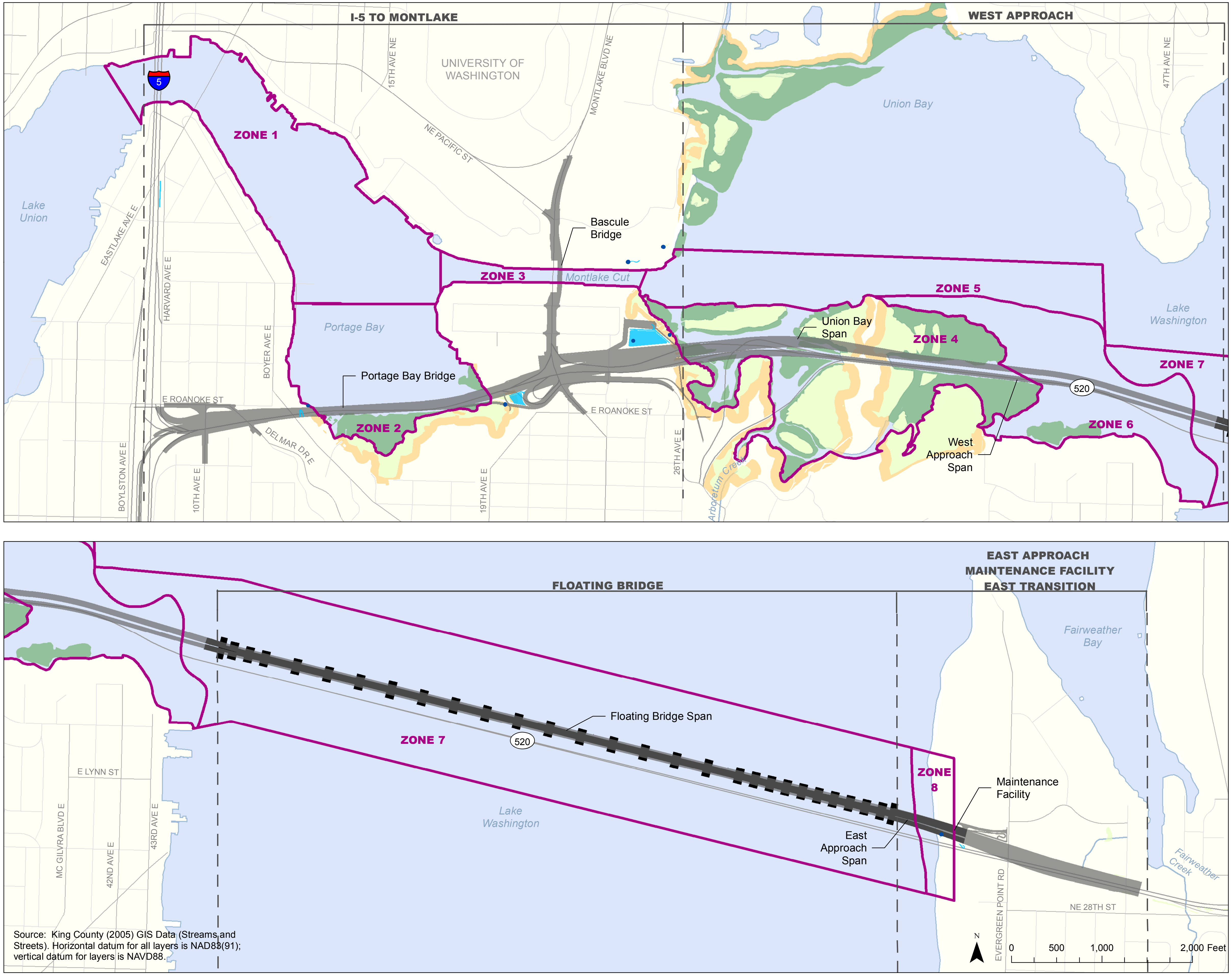
Table 3-1. Stock Summary of Lake Washington Basin Salmonids

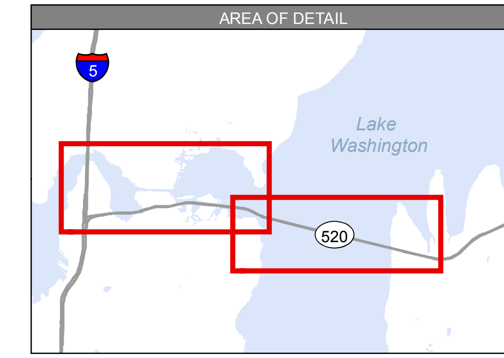
Species	Stock	Population Estimate Metric	1986–2003 Average (Max – Min)[b]
Chinook	Cedar River Chinook	Index escapement	525 (120 – 1540)
	Sammamish River[a]	Carcass counts and index escapement	3,438 (1,153 – 7,851)
Coho	Cedar River Coho	Cumulative fish-days	2,040 (128 – 9,204)
	Lake Washington/ Sammamish Tributaries Coho	Cumulative fish-days	4,120 (339 – 13,804)
Sockeye	Cedar River Sockeye	Run size	176,503 (30,084 – 512,257)
	Lake Washington Beach-Spawning Sockeye	Total escapement	1,895 (200 – 4,800)
	Lake Washington/ Sammamish Tributaries Sockeye	Total escapement	25,980 (2,080 – 81,090)
Steelhead	Lake Washington Winter Steelhead	Total escapement	158 (20 – 1,816)

[a] As defined by NOAA Fisheries Puget Sound Technical Recovery Team. This stock includes Issaquah Chinook and North Lake Washington Tributaries Chinook as listed in WDFW (2004). The stock includes substantial hatchery origin fish, including strays and fish allowed to spawn after egg taking goals have been achieved.
[b] Data from WDFW 2004

In other cases, salmonids spawn in the tributaries that enter the north end of the lake (e.g., Bear Creek, Issaquah Creek) or along Lake Washington's beaches to the north of the SR 520 bridge. Larger juvenile sockeye and Chinook salmon from these locations in Lake Washington inhabit deeper limnetic lake habitat prior to outmigration, although some outmigrants may cross back and forth through the bridge corridor during this time.

In addition to the geographic location of spawning areas, the density and distribution of salmonids in the project area are also determined by the physical, chemical, and biological conditions in the project area. To assess and discuss the salmonids' variable use of the project area, it is helpful to break the project area into smaller zones. Eight salmonid functional zones have been identified in Lake Washington and the Ship Canal (Figure 3-1) to characterize the ecological conditions, salmonid habitat functions, and salmonid species' use of each zone. The zones were defined, and fish use evaluated, by a team of technical experts on Lake Washington fisheries. The results identified by the team were then reviewed and approved by the NRTWG. Each zone is briefly described in more detail below.





Proposed Stormwater Outfall

Stream

Salmonid Use Ecological Zone

Zone 1. Ship Canal from Hiram M. Chittenden Locks to Portage Bay
All successful juvenile outmigrants and adult returns must pass through this zone during their life cycle.

Zone 2: Southern portion of Portage Bay
Highly used by University of Washington Hatchery fish. Sub-optimal rearing and migration habitat, believed to be little utilized by native salmonids.

Zone 3: Ship Canal Montlake Cut
Lack of suitable habitat. Shallow, warm and heavily armored on both sides makes residency times low, All juvenile outmigrants and returning adults must pass through this segment of the Ship Canal prior to entering Lake Union or Lake Washington, respectively.

Zone 4: Arboretum and Foster Island Waterways
Low habitat use by salmonids. Shallow, warmer environment with dense macrophytes. This is believed to provide habitat for bass and other species tolerant of warmer waters.

Zone 5: Union Bay
This area may be used by outmigrating juvenile Chinook salmon for extended time periods (multiple days) and it may provide rearing habitat or refuge to fish about to enter or just exiting the relatively hostile environs associated with the Ship Canal

Zone 6: SR 520 West Approach (Foster Island to 10 m depth)
Believed to be primary migration route for Cedar River juvenile outmigrants and returning adults. This area may be used by outmigrating juvenile Chinook salmon for extended time periods (multiple days) and it may provide rearing habitat (primarily in 2-6 m depths).

Zone 7: Floating Bridge (areas deeper than 10 m)
Deep water area believed to be of lower importance for juvenile salmonids, which are generally shoreline oriented, while adult salmonids may use this portion of the lake. Juvenile salmonids may migrate into deeper waters at night in pursuit of feeding opportunities or use pontoon edge as migration corridor.

Zone 8: East Approach (from 10-meter depth contour to shore)
The east shoreline of Lake Washington is believed to be of less importance to migrating juvenile salmonids, however some shoreline-oriented salmonids likely use this area. Lake spawning sockeye salmonids have been documented to spawn in the vicinity of the East Approach bridge structure.

Proposed Edge of Pavement

Aquatic Bed Wetland

Palustrine Wetland

Wetland Buffer

Proposed Stormwater Facility

Pontoon

Source: King County (2005) GIS Data (Streams and Streets). Horizontal datum for all layers is NAD83(91); vertical datum for layers is NAVD88.

Figure 3-1. **Project Scale - Salmonid Function Zones in Lake Washington**

I-5 to Medina: Bridge Replacement and HOV Project

\\JAFAR\PROJ\PARAMETRIX_400707\MAPFILES\WESTSIDE\DR\ECOSYSTEMS\WORKING\SDEIS_SR_NEWOPENWATERECOZONES.MXD 5/27/10

Salmonid Functional Zone 1 – Ship Canal West of Portage Bay

The Ship Canal is an 8.6-mile-long man-made navigation waterway connecting Lake Washington to Puget Sound in the city of Seattle. Lake Washington was isolated from Puget Sound until 1903, when the construction of the Ship Canal created a connection from Lake Washington to Puget Sound through Lake Union. From west to east, the Ship Canal passes through Shilshole Bay, Ballard Locks, Salmon Bay, the Fremont Cut, Lake Union, Portage Bay, the Montlake Cut, and Union Bay on the edge of Lake Washington. Although all successful juvenile outmigrants and adult returns must pass through this zone during their life cycle, project activities occurring in this area are minimal, and limited to the movement of barges and pontoons.

Salmonid Functional Zone 2 – Portage Bay

The project area crosses through the southern portion of Portage Bay, which is thought to be south of the primary salmonid migration route through the Ship Canal. This area is a shallow, quiescent bay with abundant aquatic macrophytes during the spring and summer months. It provides limited habitat for anadromous fish populations, which are believed to migrate relatively rapidly through this portion of the Ship Canal.

Salmonid Functional Zone 3 – Ship Canal at Montlake Cut

The Ship Canal at Montlake Cut is relatively shallow, warm, and heavily armored on both sides. The lack of suitable habitat makes fish residency times low; however, all outmigrating juveniles and returning adult salmonids must pass through this segment of the Ship Canal prior to entering Lake Union or Lake Washington. Construction activities to build a second bascule bridge will occur above the Montlake Cut, and will be conducted primarily from upland areas, with some periodic support from barges and tugboats anchored or positioned in the Montlake Cut.

Salmonid Functional Zone 4 – Arboretum and Foster Island

This zone includes the Washington Park Arboretum, Foster Island, and Union Bay. The area is generally characterized by shallow, quiescent waterways where dense growths of macrophytes are abundant during the spring and summer months. This zone contains a single stream, Arboretum Creek, which may have historically supported salmonids, although it has since been modified and degraded to the point where under current conditions it does not support any salmonids. While much of this zone is thought to provide habitat for bass and other species tolerant of warmer waters, it is not considered important or highly utilized salmonid habitat. A substantial amount of in-water construction will occur in this zone, including the installation of temporary work bridges and permanent bridge columns and superstructure.

Salmonid Functional Zone 5 – Union Bay

This area may be used by outmigrating juvenile Chinook salmon for extended time periods (multiple days). It may also provide rearing habitat and refuge to fish about to enter or just exiting the relatively hostile environment associated with the Ship Canal. As with Salmonid Functional Zone 1, project construction activities in this area will generally be limited to the movement of barges and pontoons.

Salmonid Functional Zone 6 – West Approach

This zone occurs east of the dense macrophyte communities associated with Foster Island, out to the 10-meter depth contour. This area is believed to be the primary migration route for Cedar River juvenile outmigrants and returning adults. Recent fish tracking studies (Celedonia et al. 2008b) suggest that this area may be used by outmigrating juvenile Chinook salmon for extended time periods (multiple days), and may provide rearing habitat (primarily in 2- to 6-meter depths). Fish travelling to or from the southern end of Lake Washington generally pass underneath the bridge in this zone. In addition, there will be a substantial amount of in-water and over-water construction in this zone, including the installation of temporary work bridges and permanent bridge columns and superstructure.

Salmonid Functional Zone 7 – Floating Bridge

The floating portion of the Evergreen Point Bridge resides in deeper water (greater than 10 meters deep) supported by floating pontoons. This zone is believed to provide limited habitat for the smaller juvenile salmonids, which are generally shoreline-oriented; however, adult and larger juvenile salmonids may use this portion of the lake. In addition, juvenile salmonids may migrate into deeper waters at night or in pursuit of feeding opportunities because a preferred food item, zooplankton, tends to be more abundant offshore.

Salmonid Functional Zone 8 – East Approach

This zone occurs along the east shoreline of Lake Washington, which is thought to be of less importance to migrating juvenile and adult salmonids because these fish are generally believed to pass through the project area closer to the western shoreline of the lake. It is likely that some shoreline-oriented salmonids use this area. Sockeye beach spawning has also been identified in this area (see Section 3.5.1). Construction activities in this zone include installation of permanent bridge columns and superstructure, and construction of the bridge maintenance facility and associated dock.

3.5.3. Salmonid Predators

Predation of salmonids by native and non-native predatory fishes is a substantial source of mortality in Lake Washington and the Ship Canal (Fayram and Sibley 2000; Warner and Fresh 1998; Kahler et al. 2000). However, current information does not indicate that the existing bridge structure has an influence on the predator–prey interactions associated with adult salmonids in Lake Washington; any effects on associated predator–prey distributions resulting from the existing bridge and associated structures are expected to apply mainly to juvenile salmon outmigration.

Fayram and Sibley (2000) and Tabor et al. (2004a, 2006) demonstrated that bass may be a risk factor for juvenile salmonid survival in Lake Washington. Celedonia et al. (2008a, b) found that larger bass tend to be present near shoreline structures and bridge piers, including areas where young salmon are likely to migrate and rear. Therefore, juvenile Chinook and steelhead may be particularly vulnerable to predation as they migrate through Lake Washington to marine waters, as well as through the relatively-confined Ship Canal. The highly modified habitat throughout the Ship Canal and the locks may also contribute to an increased potential of predation due to the reduced refuge habitat available.

The primary freshwater predators of salmonids in the lakes and waterways in the Lake Washington basin include both native and non-native species. Primary non-native predator fish include yellow perch (*Perca flavescens*), smallmouth bass (*Micropterus dolomieui*), and largemouth bass (*Micropterus salmoides*). Predominant native fish predators include cutthroat trout, northern pikeminnow (*Ptychocheilus oregonensis*), and prickly sculpin (*Cottus asper*). However, sampling in February and June of 1995 and 1997 found only 15 juvenile Chinook salmon in the stomachs of 1,875 predators (prickly sculpin, smallmouth and largemouth bass, and cutthroat trout) examined, with most of the predation by prickly sculpin (Tabor et al. 2004a). These data suggest predation of less than 10% of the Chinook salmon entering the lake from the Cedar River.

Smallmouth bass distribution in Lake Washington overlaps with that of juvenile Chinook salmon in May and June, when both species occur in shoreline areas. However, predation rates are also affected by physical conditions. For example, smallmouth bass do not feed as actively in cooler temperatures as they do in waters above 68ºF (20ºC) (Wydoski and Whitney 2003), while Chinook avoid the warmer-water areas. Chinook also avoid overhead cover, docks and piers, and the coarse substrate habitat areas preferred by smallmouth bass (Tabor et. al 2004a; Gayaldo and Nelson 2006; Tabor et al. 2006; Celedonia et al. 2008a, b).

Tabor et al. (2006) concluded that under existing conditions, predation by smallmouth and largemouth bass has a relatively minor effect on Chinook salmon and other salmonid populations in the Lake Washington system. However, predation appears to be greater in the Ship Canal than in the lake. Tabor et al. (2000) estimated populations of about 3,400 smallmouth and 2,500 largemouth bass in the Ship Canal, with approximately 60% of the population occurring at the east end at Portage Bay. They also observed that smallmouth bass consume almost twice as many Chinook salmon smolts per fish as largemouth bass (500 smolts versus 280 smolts annually, respectively). This consumption occurs primarily during the Chinook salmon outmigration period (mid-May to the end of July) when salmon smolts represented 50 to 70% of the diet of smallmouth bass (Tabor et al. 2000). An additional study estimated the overall consumption of salmonids in the Ship Canal at between 36,000 and

46,000 juvenile salmon, corresponding to mortality estimates ranging from 0.5 to 0.6% (Tabor et al. 2006).

Although smallmouth bass showed an affinity for the bridge columns, information suggests that their overall abundance is no greater at the bridge than in other suitable habitat types (Celedonia et al. 2009). Also, a study of the stomach contents of predators under the existing bridge found that predator diets near the bridge include a similar proportion of salmonids as the diets of predators studied in other locations of Lake Washington (Celedonia et al. 2009).

In addition to selecting the bridge columns as part of their migration route, smallmouth bass were found to have an affinity for a depth of 4 to 8 meters and often sparse vegetation or edge habitat associated with macrophytes. Moderately dense to dense vegetation was used only occasionally. Neither pikeminnow nor smallmouth bass have been shown to have an affinity for the shading (i.e., overhead cover) provided by the overhead bridge structure.

As noted previously, artificial lighting associated with the proposed roadway and bridge could affect the distribution and behavior of fish. Any increased abundance of salmonids around illuminated areas may then also attract visual predators. Neither smallmouth bass nor northern pikeminnows appeared to be particularly attracted to the artificially illuminated area adjacent to the existing bridge. Other studies, however, suggest that predation rates by other salmonids such as cutthroat trout and rainbow trout may be higher due to increased visibility of the prey species in illuminated areas, even if the predators on the whole do not select these areas (Mazur and Beauchamp 2003; Tabor et al. 2004b). No information was presented regarding increased potential for predator detection by prey in artificially illuminated areas.

While there has been an obvious increase in the number of non-native predators in the lake in the twentieth century, changes in the number of native predators have been less apparent. However, there is some anecdotal evidence that the number of cutthroat trout has increased considerably over time (Nowak 2000). In addition, Brocksmith (1999) concluded that the northern pikeminnow population increased by 11 to 38% between 1972 and 1997. Brocksmith (1999) also found evidence that larger northern pikeminnows are more numerous than they were historically, indicating that the pikeminnow population is currently not limited by density dependence. The greater number and the larger size of pikeminnows suggest an overall increase in predation mortality of anadromous juvenile salmonids, compared with historical conditions. The incidence of freshwater predation by fish in Lake Washington and the Ship Canal may also be increasing due to the increasing water temperatures that favor these species (Schindler 2000).

Data suggest that northern pikeminnow do not select areas near the bridge over other habitat types. Northern pikeminnow were primarily concentrated at 4- to 6-meter depths during all periods, and moderately dense vegetation was the most commonly used habitat type. Limited attraction to nighttime lights was noted, although this was inconsistent from year to year (Celedonia et al. 2008a, 2008b, 2009).

In general, the amount of predation currently occurring in the project area is likely to be primarily a function of the overlap in available predator and prey habitat areas and selection preferences. Assuming smallmouth bass are selecting the bridge columns as preferential habitat for predation, and that migrating Chinook show no preference where they cross in the primary migration corridor, predation is likely to occur adjacent to the in-water structure (columns) of the existing bridge structure.

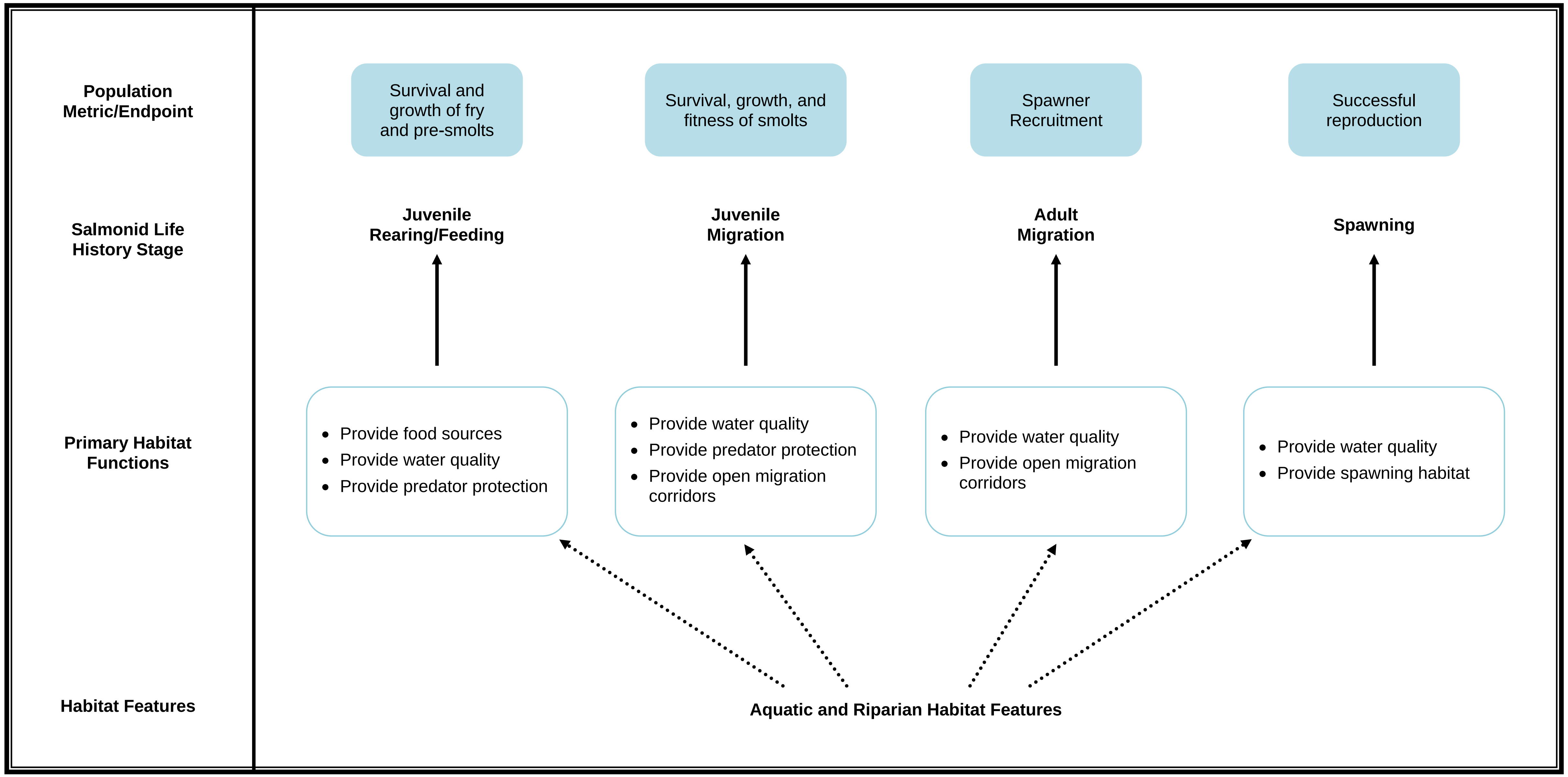
Aside from potential changes in predator distribution, the information suggests that migrating juvenile salmonids that exhibit a holding behavior in association with the bridge are more likely to be susceptible to increased predation rates. The increased residence time around the structure may simply result in prolonged exposure to bridge-associated predators.

3.6 Lake Washington Salmonid Conceptual Model

A conceptual model was developed to characterize the interaction between anadromous salmonids and aquatic habitat in the project area. The model (Figure 3-2), based on literature on salmonid habitat functions and features in Lake Washington, uses the primary life history stages of anadromous salmonids as surrogates for related population-level metrics (i.e., survival, growth, fitness, and reproductive success). To simplify the model, the life history stages have been generalized, and serve to represent all anadromous salmonids within the Lake Washington system, although the importance of specific habitat features varies by species. For example, natural shoreline habitat is extremely important to Chinook fry when they enter the lake from the Cedar River, while sockeye salmon, which are generally larger upon lake entry, rely somewhat less on shoreline habitat and for a shorter period.

This page intentionally left blank.

Figure 3-2. Conceptual Model of Anadromous Fish in Lake Washington



This page is intentionally left blank.

The aquatic habitat functions listed in the model also apply to all species of anadromous salmon in the project area. These functions, listed in Figure 3-2 and listed in more detail in Table 3-2, are based on scientific literature on salmonid habitat requirements and limiting factors (City of Seattle and USACE 2008; Kerwin 2001; Wydoski and Whitney 2003) and directly relate to specific life history stages.

Table 3-2. Aquatic Habitat Functions and Related Salmonid Life History Stages

Aquatic Habitat Function	Primary Salmonid Life History Stage(s) Affected
Provide adequate food sources (macroinvertebrate and zooplankton)	Juvenile Rearing/Feeding Juvenile Migration
Provide water quality with constituents within acceptable levels for salmonids (DO, temperature, TSS, contaminants, etc.)	All stages
Provide protection from predator species (piscivorous and avian)	Juvenile Rearing/Feeding Juvenile Migration
Provide migration corridors free from obstruction and disturbance	Juvenile Migration Adult Migration
Provide accessible spawning habitat of suitable quantity and quality	Adult Spawning

DO = Dissolved oxygen
TSS = Total suspended solids

The model relates these general population metrics to specific habitat functions that support salmonid life stages. Each habitat function is supported by a number of physical, biological, and chemical habitat features that can be affected by project actions. Alteration of these habitat features can influence habitat functions, which then can affect salmonid life history stages and result in population-level effects. Since this methodology looks at salmonid life history and related population-level effects, it can be used to either assess project impacts (negative effects) or project mitigation (positive effects), and allows evaluation and comparison of both types of effects, using identical metrics.

The potential project impacts and mitigation actions may affect different habitat features, but the overall aquatic functions, and in turn, life history elements affected, are similar. The discussion below summarizes general information on the life histories of salmonids, and the relationship of several habitat features to these life stages.

3.6.1. Juvenile Salmonid Rearing and Feeding

Rearing

Juvenile salmonids require habitat that provides refuge from predatory, physiological, and high-energy challenges. High-quality freshwater refuge habitat, limited in Lake Washington and the Ship Canal (Tabor and Piaskowski 2002; Weitkamp et al. 2000), consists of unarmored, shallow-gradient littoral zone with large woody debris (LWD) and overhanging vegetation (Tabor and Piaskowski 2002). Low-quality refuge habitat is prevalent in most Lake Washington shoreline areas due to shoreline development, lack of LWD, and the proliferation of non-native predatory fish species. Shoreline modifications that preclude shallow water habitat comprise most of the Lake Washington shoreline (Toft 2001; Toft et al. 2003). In Lake Washington, pilings and riprap likely contribute to increased energy expenditure and risk of predation on juvenile salmonids by bass and northern pikeminnow (Celedonia et al. 2008 a, b). Riprap areas have been shown in other lakes to exhibit higher water velocities, depths, and steep slopes compared with unaltered habitats (Garland et al. 2002). Due to littoral zone activities and modifications including dredging, filling, bulkheading, and construction, very little native vegetation remains on the Lake Washington shoreline (Weitkamp et al. 2000; Toft 2001; Toft et al. 2003).

Refuge is limited in the Lake Washington basin near the fresh/saltwater transition at the Ballard Locks due to the limited natural habitat and sharp osmotic gradient. Juvenile salmonids exiting Lake Washington may seek tributary mouths as refuge habitats because overhead vegetative cover and the water from these tributaries provide refuge from higher salinities or temperatures (Seattle Parks and Recreation 2003). In nearshore shallow and/or marine areas, features considered to be high-quality refuge habitat are aquatic and marine riparian vegetation, LWD, and larger substrates (City of Seattle 2001). In Puget Sound, this habitat is limited due to the prevalence of bulkheads and over-water structures, and extensive filling, dredging, and grading in shoreline areas (Weitkamp et al. 2000; City of Seattle 2001).

Foraging

Juvenile salmon require habitat that provides and supports the production of ample prey resources; this habitat includes unaltered shorelines with organic inputs and small substrates. Juvenile Chinook in Lake Washington prey on insects and pelagic invertebrates, namely chironomids and *Daphnia* spp. (Koehler 2002). Juvenile salmonids in Puget Sound feed on forage fish larvae and eggs as well as on other pelagic, benthic, and epibenthic organisms from nearshore, intertidal, and eelgrass/kelp areas (Simenstad and Cordell 2000). Although the literature generally concludes that prey resources are not a limiting factor for juvenile salmon (Kerwin 2001), in-water construction activities have the potential to temporarily affect the juveniles' foraging behavior by decreasing primary productivity, changing water clarity (sedimentation), or creating in-water noise and disturbance. Because the proposed project has the potential to temporarily affect the foraging ability of juvenile outmigrant salmonids, this life history element was incorporated into the conceptual model.

3.6.2. Juvenile Migration

Lake habitat that is generally considered favorable for migration includes gently sloping beaches with no over-water structures restricting light penetration of the water. Juvenile salmonids require habitat with few barriers to their seaward migration. Lake Washington is free of these barriers, but concern exists among biologists that over-water structures such as docks and piers may indirectly act as a barrier to alter migration patterns (Weitkamp et al. 2000). Juvenile salmon readily pass under small docks and narrow structures under which darkness is not complete, but studies have indicated that under some conditions, large over-water structures with dark shadows can alter migration (Fresh et al. 2001). However, juvenile migration of salmonids is complex and influenced by a variety of factors. In a study of the effects of the existing SR 520 bridge, Celedonia et al. (2008a) observed no apparent holding behavior of juvenile Chinook at the existing bridge during year 1 of the study, while in another year minutes to hours of holding were observed for about half the fish (Celedonia et al. 2008a). Some juveniles pass directly under the bridge without delay, while others spend up to 2 hours holding close to the bridge. Overall, these short delays are unlikely to result in detectable changes in survival of Chinook or other juvenile salmon as they migrate through Lake Washington and the Ship Canal.

Several studies have shown that in nearshore areas of the Duwamish estuary and Elliott Bay, over-water structures do not have a detrimental effect on juvenile salmonid migration patterns, unlike some larger docks and piers on Lake Washington. However, this has been attributed to the difference in size and construction of similar structures along the Lake Washington and Lake Union shorelines (Weitkamp et al. 2000). Some studies have shown that drastic changes in ambient underwater light environments may alter fish migration behavior (Nightingale and Simenstad 2001).

The migratory corridor is severely modified at the Ballard Locks, as the fresh- to saltwater transition occurs rather abruptly within the salt wedge and mixing zone near the locks.

3.6.3. Adult Migration

Adult salmonids returning to spawn in the Lake Washington basin must pass through the Ship Canal and the lake. Details on migration timing through the Ship Canal are discussed in Section 3.5.1. Adult Chinook salmon may enter Lake Washington days before moving into rivers for spawning. The average time spent by adult Chinook in Lake Washington in 1998 was 2.9 days (Fresh et al. 1999). For Sammamish watershed fish, the average was 4.9 days. Acoustic and temperature tags on adult Chinook salmon show that these fish inhabit waters of varying depths and temperatures. Temperature tag studies show that areas in the lake occupied by fish range in temperature from 48 to 70º F (9 to 21º C) (F. Goetz unpublished data in City of Seattle and USACE 2008). Adult sockeye salmon enter Lake Washington well before spawning. Freshwater entry occurs in the summer and the fish spawn in October and November (Newell and Quinn 2005). A fish tracking study conducted in 2003 indicated that 25 of 29 adult sockeye salmon that were initially detected south of the existing Evergreen Point Bridge were subsequently detected south of the bridge (Newell 2005). Of these, 10 fish exhibited back-and-forth behavior, meaning they swam under the bridge at least three times. Fish remained in the lake for an average of 83 days (range of 57 to 132 days) before migrating upstream to spawn; however, there was no apparent correlation between freshwater arrival date and spawning date. Most adult sockeye spend their time in Lake Washington below the thermocline, where temperatures are cooler. Over 90% of temperature detections in the lake were between 48° and 52° F (9° and 11°C), corresponding to water depths of 18 to 30 meters, with the fish rarely occupying available cooler and warmer waters (Newell 2005).

Ship Canal Water Quality Conditions and Adult Salmon Migration

Upstream of the Ballard Locks, water quality parameters such as temperature and DO may inhibit adult salmon movement away from the cool water refuge. The results of previous tagging studies indicate inter-annual variability in the duration of Chinook salmon holding just upstream of the locks, resulting in annual average delays of 2 days to 19 days (K. Fresh in City of Seattle and USACE 2008; Timko et al. 2002). These studies identified 19ºC as a temperature that most fish move through and 22ºC as the boundary beyond which fish do not migrate. In general, water temperatures above 19ºC correlate with fish staying longer at the locks.

This suggests that the Ballard Locks have been delaying the entry of some fish into Lake Washington, potentially based on elevated water temperatures. Water temperatures in the Ship Canal and Lake Union consistently exceed values that are physiologically stressful to salmon (i.e., greater than 20ºC) and can greatly exceed this threshold, as in 1998, when the daily average temperature peaks were 23.5ºC in early August (City of Seattle and USACE 2008).

Adult salmon passage through the Ship Canal and Lake Union is thought to be influenced by warm water temperatures in the Ship Canal, among other things. Both sockeye and Chinook salmon may be affected by these high temperatures. Sockeye tend to spend longer in the Ship Canal, but also keep to a tighter temperature range than Chinook. Chinook enter the Ship Canal later in the season when temperatures are higher, however.

The combined effect of the locks and the stratification of the water column contribute to water quality conditions that may adversely affect adult salmon, especially in years of high summer temperature. The potential biological effects on individual adult salmon from these degraded water quality conditions in the Ship Canal are not well documented; however, it is possible that physical conditions in the Ship Canal are a stress to holding or migrating adults that could cause pre-spawning mortality and reduced egg survival for those adults that survive to spawn, or make affected fish more susceptible to other stressors encountered during their migration.

This page intentionally left blank.

4. Impact Assessment

The purpose of this section is to characterize impacts on aquatic habitat and species from construction and operation of the SR 520 bridge replacement in Lake Washington and the Ship Canal, as part of the SR 520, I-5 to Medina Project. The characterization of impacts (and related mitigation benefits) required the development of impact assessment and mitigation methodologies that are applicable to the unique site conditions, impact types, and mitigation limitations of the proposed project, and that relate to the conceptual model presented in Section 3.6. The development of these methodologies was necessary to accurately describe and characterize those aquatic functions and values that will be negatively affected as a result of the project.

WSDOT recognizes that the mitigation benefits will almost certainly be of a different type than the impacts (based on the location and type of impacts); therefore, any methodology developed must be based on a framework that characterizes the aquatic functions and values lost at the impact site, as well as the aquatic functions and values enhanced at the mitigation sites.

In addition, some of the impact types for this project are unique and require a methodology that can accurately characterize and sum such impacts. One limitation to the methodology as proposed is that it is somewhat limited in its ability to characterize the benefits of minimization measures (such as bridge height) on impacts (e.g., shading).

An overriding goal of developing a conceptual framework and associated methodology was to create a relatively simple and tractable method for assessing impacts and benefits while acknowledging its limitations. Therefore, WSDOT developed a framework and associated methodology for impact assessment and mitigation evaluation that addresses the following key factors:

- **Biologically-Relevant Common Endpoints –** The methodology can sum a variety of stressors and impact mechanisms, as well as beneficial actions (e.g., mitigation actions) into several biologically-relevant endpoints, including life history stage effects and associated population endpoints/metrics. Endpoints were chosen based on their direct relation to important aquatic functions and values in the project area.

- **Spatial Sensitivity –** The methodology differentiates between the biological importance of specific geographic areas, and relates the physical impacts to the biological functions these areas support. The sensitivity includes the habitat/functional differences between various locations along the bridge alignment (floating bridge versus west approach) as well as differences between the project site and other sites (potential mitigation site locations) in the larger Lake Washington basin.

- **Temporal Sensitivity –** The methodology is able to integrate the overlap of temporary spatial impacts over time, which allows an assessment of the biological importance of impacts to specific fish life history stages.

The methodology described below was developed based on these key factors and was presented to resource agencies participating as part of NRTWG process. The final impact assessment methodology was formulated and refined incorporating NRTWG input.

The sections below describe the methodology in detail, including its direct application to the site-specific impacts of the SR 520, I-5 to Medina Project.

4.1 Impact Assessment Methodology

This section summarizes the project's approach to characterizing temporary and permanent aquatic impacts resulting from the project's construction and operation. The approach is applied to those impacts that cannot otherwise be avoided or minimized, and that are of a scale that will potentially negatively affect aquatic resources to a degree that will require compensatory mitigation. WSDOT has applied specific avoidance and minimization measures to potential impacts; these measures are discussed in detail in Section 5.The methodology focuses on those project impacts that deleteriously affect fish habitat, either directly or in most cases, indirectly (degradation of habitat functions), without full habitat displacement.

The use of such a habitat-based methodology is consistent with the guidance in WDFW Policy M-5002, which states that a project will not result in a net loss of aquatic habitat or habitat functions. The methodology was not designed to calculate other types of potential impacts that are disturbance-based or chemical in nature (e.g., pile driving or turbidity-related impacts) and that are generally related to construction activities. However, construction-related impacts do not result in a loss of habitat or function and their effect ceases almost immediately upon cessation of the activity. Furthermore, potential construction impacts, including in-water noise, temporary lighting, in-water turbidity/contaminants, and barge operation and moorage, have been avoided and/or minimized (see Section 5) to the extent that compensatory mitigation is not required. Similarly, potential non-habitat operational effects such as stormwater discharge and permanent bridge lighting (see Section 2) have been minimized through project design to a degree such that any residual effects will not rise to a magnitude that requires compensatory mitigation.

The primary metrics for both impact characterization and subsequent calculation of functional uplift resulting from mitigation activities are based on the two-dimensional area of affected habitat. These metrics are then modified by a geographic (spatial) factor to account for differences in fish use. The methodology calculates temporary impacts by integrating the temporal aspect of the impact structures, and therefore results in impacts based on the concept of service-acre years (the sum of impacted acres over time).

The methodology is used to calculate both permanent and temporary impacts. It uses three area metrics, based on (1) the amount of shading, (2) benthic fill, and (3) habitat complexity. These metrics were deemed the best representation of the project impacts that have the greatest potential to affect aquatic habitat functions. Thus, these project impacts have the most potential effect on salmonid life history stages and populations.

Figure 4-1 presents the primary functions in the aquatic habitat that will be affected by project construction and operation, and also shows the subsequent aquatic functions and salmonid life history stages affected. Habitat features will primarily be changed by physical mechanisms (e.g., alterations in benthic fill or daylight/shade-intensity), that in turn negatively affect aquatic habitat functions that support juvenile salmon migration and rearing. Based on an analysis of those habitat features substantially altered as a result of project construction and operation, three impact mechanisms were identified that produce the greatest effects on aquatic functions:

1. Artificial shading produced by project structures.
2. Changes in the number, size, and spacing of in-water structures all affect salmonid habitat complexity, which has the potential to attract salmonid predators.
3. Displacement of benthic habitat by in-water structures.

This impact assessment methodology is designed to calculate effects from habitat-based impacts. A detailed discussion of these three impact mechanisms is presented in Section 4.2.

This page intentionally left blank.

Figure 4-1. Conceptual Model of Project Impacts

Population Metric/Endpoint	Survival and growth of fry and pre-smolts	Survival, growth, and fitness of smolts	Spawner Recruitment	Successful reproduction
Salmonid Life History Stage	**Juvenile Rearing/Feeding**	**Juvenile Migration**	**Adult Migration**	**Spawning**
Primary Habitat Functions	• **Provide food sources** • Provide water quality • **Provide predator protection**	• Provide water quality • **Provide predator protection** • **Provide open migration corridors**	• Provide water quality • Provide open migration corridors	• Provide water quality • **Provide spawning habitat**
Affected Habitat Features	Benthic substrate that supports healthy/diverse macroinvertebrate assemblages Access to full spectrum of vertical and horizontal depth strata including hypolimnion. Shallow water beach habitat Aquatic habitat with low levels of point and non-point contaminants Shade levels adequate to provide for regulation of water temperatures Natural shoreline and open-water habitat free from in-water and over-water physical structures that serve as preferred fish predator habitat (including both anthropogenic and natural features) Shoreline and open-water habitat free from behavioral or physical obstructions (e.g., vertical bulkheads and piers)	Access to full spectrum of vertical and horizontal depth strata including hypolimnion. Shallow water beach habitat Aquatic habitat with low levels of point and non-point contaminants Shade levels adequate to provide for regulation of water temperatures Natural shoreline and open-water habitat free from in-water and over-water physical structures that serve as preferred fish predator habitat (including both anthropogenic and natural features) Shoreline and open-water habitat free from behavioral or physical obstructions (e.g., vertical bulkheads and piers) Natural shoreline and open-water habitat free from in-water and over-water physical structures that serve to alter or delay migration (either directly through obstruction, or indirectly through light-dark interfaces)	Access to full spectrum of vertical and horizontal depth strata including hypolimnion Aquatic habitat with low levels of point and non-point contaminants Shade levels adequate to provide for regulation of water temperatures Shoreline and open-water habitat free from physical and behavioral obstructions	Aquatic habitat with low levels of point and non-point contaminants Shade levels adequate to provide for regulation of water temperatures Suitable sized, stable, spawning substrate not subject to erosion and deposition Spawning areas with clean, cold, oxygenated water (includes groundwater upwelling for beach spawning sockeye salmon)

** **Bold text** denotes those metrics with a substantial effect.*

This page intentionally left blank.

Fish Function Modifier

The impact assessment methodology applies a geographic (spatial) modifier to the impact metrics in order to characterize ecological function. This modifier (called the Fish Function Modifier) accounts for differing levels of fish use at various sites throughout Lake Washington. It is used to calculate the potential exposure of salmonid species to temporary and permanent stressors from project construction. Fish Function Modifiers were assigned based on (1) the number of fish use (i.e., the number of fish that likely use a specific geographic area); (2) the type of fish use (i.e., the life stages that are likely present); and (3) the duration of fish use (i.e., the temporal distribution of fish in the area throughout the year).

Project impacts were separated into eight geographically-distinct Salmonid Functional Zones that were based on salmonid utilization (as described in Section 3.5.2). Each zone was assigned an individual Fish Function Modifier, scaled to a number between 0 and 1. The modifier scores were based on the abundance and distribution factors listed above, and were scaled to represent the range of fish utilization in the Lake Washington basin. Table 4-1 describes the criteria used to determine the modifiers.

Two zones that have the highest fish use are Zones 3 and 6, which serve as the primary juvenile outmigration corridor for most (Zone 6) or all (Zone 3) salmonids spawned in the Lake Washington basin. These two zones were assigned the highest possible Fish Function Modifier, of 1.0. Zone 8, the East Approach Area, has some historical beach spawning use by sockeye salmon, as well as some use by shoreline-oriented juvenile outmigrants from the Cedar and Sammamish basins; therefore, the Fish Function Modifier is 0.8. Zone 2 (Portage Bay) has low to moderate use by Chinook and potentially by coho salmon outmigrants, although fish distribution is generally oriented away from the aquatic macrophytes beds on the zone's southern edge. Nonetheless, the entirety of the zone was assigned a Fish Function Modifier of 0.6. Zone 4 (Arboretum and Foster Island) was assigned a Fish Function Modifier of 0.1 based on the very low densities of Chinook and other juvenile salmonids present in this relatively shallow habitat that is heavily impacted by invasive aquatic macrophytes.

Zone 7 (Floating Bridge) represents deep-water and open-water habitat (depths greater than 30 feet). Although this zone has moderate use by rearing and outmigrating juvenile salmonids, it was assigned a relatively low Fish Function Modifier for several reasons. The mechanism of effect on salmonids is unique in this area (as discussed in Section 4.3.1), and does not fit well into the project effects analysis, which uses calculations based entirely on area. Therefore, the Fish Function Modifier in Zone 7 was adjusted downward for impact analysis purposes.

Furthermore, the Fish Function Modifier also takes into account the vertical distribution of fish in the water column in Zone 7. When considering Zone 7 from a plan view perspective (the entire water column bounded by the zone limits), the use of the entire zone by salmonids could be considered moderate. However, the majority of these fish are generally not present at the water depths potentially affected by the project elements (in this case, the floating bridge). Due to thermal stratification and habitat preferences, the larger juvenile Chinook, sockeye, and coho that utilize the open-water portions of the lake stay at depths greater than the 8 meters (the bottom of the pontoons) and substantially less than the lake bottom (where pontoon anchors will be placed). Thus, their exposure to the project structures in the zone is fairly low. Likewise, returning adult salmonids are also able to use much of the water column during their spawning migrations, not only the portions of the water column containing the pontoons or their anchors. Therefore, the distribution of salmonids within Zone 7 that have the potential to be affected by the project is low in comparison with other habitat types. For these reasons, Zone 7 was assigned a Fish Function Modifier of 0.1.

Table 4-1. Proposed Scaling Factors and Criteria

Fish Function Modifier Score	Fish Function Modifier Criteria	Potential Impact Zones Within Category[1]
1 – Very High	Aquatic sites that are defined as critical migration or rearing areas for multiple species and stocks of juvenile salmon, or that serve as critical migration areas for multiple species and stocks of returning adults.	Zone 3 – Montlake Cut Zone 6 – West Approach
0.8 – High	Aquatic sites that are known to support documented spawning of at least one salmonid species, or Aquatic sites that serve as migration or rearing areas of considerable importance for one or more species of juvenile salmon, or that serve as migration areas of considerable importance for returning adults.	Zone 8 – East Approach
0.6 – Moderate	Aquatic sites that do not support salmon spawning, and where juvenile migration or rearing areas for juvenile salmonid species occurs, but where fish density, or temporal distribution of fish is lower compared to that of other sites.	Zone 2 – Portage Bay
0.1 – Low	Aquatic sites that do not support salmon spawning, and that have low or nominal use by salmonids for migration or rearing.	Zone 4 – Arboretum and Foster Island Zone 7 – Floating Bridge

[1] Zones 1 (north Portage Bay) and 5 (Union Bay) do not have structural impacts; therefore, no Fish Function Modifiers were assigned to these zones.

This page intentionally left blank.

4.2 Impact Characterization and Impact Mechanisms

The mitigation team calculated preliminary effects on aquatic ecological habitat by overlaying the proposed design onto the project base maps of aquatic features. The team then determined affected habitat areas as the area of intersection of the two sets. Effects were calculated based on the project action that will cause the effect, and were broken down by the type of ecological stressors that the project action will affect. Specifically, impact characterization is based on areal cover of over-water structures (representing shading, which has potential impacts to fish migration and predator–prey relationships) and in-water structures (representing habitat complexity, which has potential impacts to fish predator–prey relationships).

The existing bridge structure likely has some effect on fish due to these mechanisms, and its removal will eliminate those effects. Therefore, the methodology for assessing permanent impacts estimates the change in effects to fish as a result of the project. Impact calculations are based on the net change (future conditions minus existing conditions) of area affected by the project to account for the ecological benefits of removing the existing structures.

Unlike the regulatory process for wetland mitigation, federal and state regulations and guidance do not prescribe calculation metrics or mitigation formulas for the majority of the effects to aquatic habitat. In addition, many of the potential effects to fish and other aquatic species will be indirect, and will result from effects to organism behavior patterns or effects to fish predators or prey resources. For example, partial shading effects from the new bridge structures could alter the migration patterns or timing of juvenile salmon, or influence the distribution of their predators. These effects could ultimately change the success rate of juvenile salmon migrating to marine waters.

Salmon, in particular Chinook salmon, were chosen as key indicator species when studying the impact mechanisms of the SR 520, I-5 to Medina Project, because these species are the most studied in the watershed, and a comprehensive data set is available that links habitat variables in the watershed to salmonids (City of Seattle and USACE 2008; King County 2005). The key salmonid life history functions that will be affected are directly related to the life history phases of the affected fish. These functions are juvenile/feeding, juvenile migration, adult migration, and beach spawning (sockeye) (se Figure 4-2).

The measurable impacts that affect the life history functions of salmonids are benthic habitat loss (e.g., fill), and those mechanisms that can alter fish behavior or predator–prey interactions (e.g., over-water and in-water structures, which can both increase predation and result in migration alterations or delays). It is important to note that the only impact category that includes complete habitat loss is the benthic habitat impact category. All other impact mechanisms are affecting, but not displacing fish and their use of habitat. The following text describes each of these impact mechanisms in more detail.

4.2.1. Benthic Habitat Impacts

Biological effects to fish and benthic organisms come from the following:

- Temporary reduction in water quality associated with the installation and removal of temporary piles.
- Temporary loss of benthic organisms and other prey due to disturbance of the lake substrate.
- Permanent loss of benthic habitat from the installation of support columns and floating bridge anchors.

Sediment plumes are likely to arise from some of these project activities, although the distribution of the plumes will be limited due to the low-velocity water currents in the area. The size of the sediment particles is typically correlated with the duration of sediment suspension in the water column. Larger particles, such as sand and gravel, settle rapidly, but silt and very fine sediment may be suspended for several hours.

Sediment put into suspension by bottom disturbance may adversely affect salmonids' migratory and social behavior as well as their foraging opportunities (Bisson and Bilby 1982; Sigler et al. 1984; Berg and Northcote 1985). However, this impact pathway is considered temporary, and will be minimized by appropriate BMPs, as listed in Section 5.

Disturbed substrate sediments could have indirect effects on benthic flora and forage organisms, including the elimination or displacement of established benthic communities and thus a reduction in prey available for juvenile salmon. Suspended sediments can clog the feeding structures of filter-feeding benthic organisms; this reduces their feeding efficiency and increases their stress levels (Hynes 1970). However, benthic communities are expected to recover relatively quickly after the disturbance, resulting in a short-term loss rather than long-term loss. Also, there is no indication that prey abundance is a limiting factor in Lake Washington for salmonids. Some of the highest recorded juvenile sockeye growth rates have been observed in Lake Washington compared with the growth rates in other lacustrine systems (Eggers et al. 1978; Edmondson 1994), and Chinook salmon exhibit exceptional growth compared with growth in other populations (Koehler et al. 2006). Therefore, benthic habitat disturbance and displacement are expected to have potential effects only on those areas directly disturbed, and impacts to salmonid populations in Lake Washington and the Ship Canal will be minor.

4.2.2. Shading Impacts

Numerous factors are believed to affect the migration of salmonids through Lake Washington. It is unlikely that the presence of the existing bridge substantially affects most of these factors. Such factors include physiological development (smoltification) of migrating juvenile salmonids, overall water temperature of the lake and Ship Canal, and the size and condition of the migrating fish. However, the bridge and in-water bridge structures do present unnatural conditions in the migration corridor, which have the potential to alter the behavior of migrating fish. Alteration of migratory behavior could cause the fish to occupy or migrate through areas that are more or less productive than habitats they would otherwise occupy, require different energy expenditure levels, or subject the fish to more or less viable survival conditions.

The placement of permanent over-water structures will alter in-water shading intensities and patterns. Shade effectively creates a different habitat type that contrasts with the adjacent aquatic environment (lacking shade). In particular, the transition between light and shade (described as the edge effect) is considered a potential influence on fish behavior and habitat selection. The shadow cast by an over-water structure affects both the plant and animal communities below the structure.

Factors that influence in-water shade levels include the width and over-water height of new bridge decks, light diffraction (bending of light around an object) around the structures, light refraction (change in speed and direction of light when travelling from one medium to another, e.g., air to water), and the spatial alignment of the structures in relation to the path of the sun.

These factors are expected to change during project construction as temporary structures (e.g., work bridges) are built to facilitate construction, as the new bridge is constructed, and as the existing bridge is removed. Therefore, the overall extent and duration of over-water and in-water structures in the migration corridor will change over time, as will the potential effects of these changing features on migration behavior throughout the construction and operation phases of the SR 520, I-5 to Medina Project. Past studies of Lake Washington have indicated that the influence of in-water shading on fish behavior is complex and variable, and it may vary by species, time of year, and other factors.

New permanent fixed bridge structures will replace the existing Portage Bay Bridge and west approach. When the impact of shading from permanent bridge structures is considered, it is important to note that although these structures will be wider than the existing structure, they will also be substantially higher. The Portage Bay Bridge will be 7 to 11 feet higher (moving west to east) than the existing structure, and the new west approach structure will range in height above the water surface from approximately 18 feet just east of Foster Island to approximately 48 feet near the west transition span. Approximately 65% of the existing structure (western portion) is less than 10 feet above the surface water elevation at high water. This increase in height for the proposed structures will allow more ambient light under the structures, and although they will be wider, the intensity of the light-dark transition will be reduced overall.

Likewise, temporary over-water structures (work bridges) will also result in increased shading in the work area, although recovery to non-shaded conditions will be instantaneous and coincident with the removal of the structures. Furthermore, although work bridges tend to be very low to the water (5 to 10 feet), they are relatively narrow (about 30 feet) and in the case of the west approach, will extend only to approximately 10 feet of water depth. This means that much of the primary migratory corridor will be free of obstruction by work bridges, allowing fish to migrate around the work bridges, as fish have been documented to do for docks and other structures.

Shading and Effects on Outmigration

Shading from the bridge may affect several different salmonid species and stocks, including all anadromous salmon produced in the Cedar River, because the proposed bridge will cross the migratory path of all juvenile fish from the river's spawning grounds. The bridge will cross the southeast edge of Union Bay, which serves as a migration corridor and as a short-term (less than 24 hours) holding area (Celedonia et al. 2008a). The new bridge will have an over-water approach structure at the edge of Union Bay, similar to the existing structure in this area. Studies of site-specific migration in this area focused on juvenile Chinook salmon, and these studies do not indicate that the existing bridge substantially alters the migration paths or timing of Chinook juveniles (Celedonia et al. 2008a, 2008b, 2009). In addition, some juvenile Chinook have been observed moving along the edge of the over-water approach structure before passing under the bridge, and this does not appear to adversely affect their survival. As previously mentioned, the proposed bridge structure will be wider and higher above the lake surface than the existing bridge. Current information does not indicate that these differences are likely to substantially change the behavior of juvenile Chinook migrating under the bridge.

Some juveniles pass directly under the bridge without delay, while others spend up to 2 hours holding close to the bridge. These short delays are unlikely to result in detectable changes in survival of Chinook or other juvenile salmon as they migrate through Lake Washington and the Ship Canal. In-water and over-water structures could affect the rate and/or route of juvenile outmigration. However, the specific effect will differ by species and by the particular behavior patterns exhibited by individual fish. For some species and behavior patterns (e.g., Chinook juveniles exhibit active migration behavior), migration rates could be slowed slightly if fish tend to hold under a wider bridge deck for longer periods than they do under existing conditions. This change is not readily quantifiable; it is expected to be unmeasurable relative to existing conditions. Based on past studies, overall migration routes are unlikely to change significantly because individuals will encounter a transition point (i.e., shadow boundary) similar to that of the baseline condition and are expected to react in a similar manner. Therefore, the fish will pass through relatively quickly, move to deeper water to pass, or will be inclined to hold and/or rear for some period of time. Because salmonids can see in dim conditions, the information suggests that contrast in the boundary of shade may be the primary factor affecting behavior. Once the transition is made, fish either appear to move quickly through or hold in the shaded areas.

Celedonia et al. (2008b, 2009) showed that actively migrating fish demonstrated the three commonly observed behavior types: (1) minimal response, (2) paralleling, or (3) meandering or milling near the bridge after paralleling. The majority of fish that exhibited a holding behavior crossed multiple times or were observed milling under the bridge. None of these observations suggests that the width of the bridge shadow is influencing behavior. Spatial frequency data suggest that the majority of fish are not selecting for habitat under the bridge, so increased bridge width is not likely to result in a meaningful benefit in holding habitat. The data suggest that the transition between light and shade and the sharpness of that contrast may have the greatest influence on migration behavior.

Biological Effects of Outmigration Delays

A number of factors affect the migration rate and route of juvenile and adult salmonids through Lake Washington. Such factors include depth preferences, temperature gradients, macrophyte density, and size of the migrating fish. Although the project could incrementally affect fish behavior in terms of these innate biological factors, information on fish behavior in the project vicinity suggests that the existing structures do not result in substantial alterations of migration behavior. The location of new bridge will overlap the location of the existing bridge for a substantial portion of the primary juvenile migration route through the project area (near the west high-rise). Therefore, individuals will encounter a similar transition point (i.e., shade boundary) and similar depth conditions, although the extent and density of aquatic macrophytes could change slightly due to the wider bridge structure.

Studies indicate that active migration behavior is predominant in juvenile Chinook as opposed to holding behavior. Alteration of migration rate or migration route may result in increased energy expenditures by actively migrating fish that exhibit paralleling behavior. Relative to the overall energy expenditure (using time as a surrogate) of outmigration, actively migrating juvenile Chinook are adding only minutes to a migration typically lasting days to weeks. This change in the migration rate should not represent a significant disruption to migration behavior. Gauging any potential increase in energy expenditure in actively holding fish is speculative because they are likely taking advantage of foraging benefits during the holding period. Current information suggests that holding fish will likely behave in a manner similar to the current condition; moreover, the primary potential residual effect on migration behavior for holding fish may result in exposure to increased mean water temperatures from a later migration. The extent to which this effect may reduce survival is likely highly variable and speculative.

The project team concluded that a relatively minor migration delay may result from the increased shade from the new bridge structure. In many cases, this delay will have an insignificant effect on juvenile survival and fitness. In other cases, slight reductions to juvenile survival or fitness may result. However, several factors suggest that effects on migration patterns will be moderated:

1. Data do not indicate that the existing bridge has a detrimental influence on the migration behavior associated with adult or juvenile salmonids in the Lake Washington system.

2. Although the new structure will be wider, it will also be higher and will contain fewer columns than the existing structure. This will produce narrower, more diffuse shadows than the existing structure.

3. Adult salmon migration mainly occurs away from the proposed bridge, within deeper waters.

4.2.3. Habitat Complexity-Predation Impacts

The placement of temporary and permanent in-water structures will alter the structural complexity of the aquatic habitat. The effects of these structures on benthic habitat are discussed above; this section addresses the structures' effects on water column habitat.

Habitat complexity influences the behavior and distribution of fish, including both salmonids and their predators. Project-related factors that influence this complexity are primarily the amount of in-water structure per unit area and the spatial alignment of the structures in relation to one another, such as distance between shafts (or columns) and the distance between piers (span length).

Current information does not indicate that the existing bridge structure has any influence on adult salmonids' predator–prey interactions in Lake Washington. Because the new structures will be sufficiently similar in arrangement and size to the existing structures, they are not likely to have a different influence on these predator–prey interactions.

Therefore, any effects on associated predator–prey distributions requiring compensatory mitigation are expected to apply mainly to juvenile salmon outmigration. Any such effects will likely be much reduced for older age classes and larger-size fish (such as residual Chinook, steelhead, or coho). During outmigration, these larger fish are generally not exposed to predation because of their limnetic distribution; they do not show the same affinity for the shoreline as do smaller migrants such as 0-age Chinook salmon and sockeye.

The work bridges, and the replacement bridge will result in substantial increases in shading and habitat complexity in the project area. These conditions are expected to provide additional predator habitat in the area during the proposed construction period, although the long-term habitat conditions are expected to be similar to existing conditions.

Species known to prey on juvenile salmon include northern pikeminnow and smallmouth bass. The data suggest that northern pikeminnow do not select areas near the bridge over other habitat types. Studies found that this species was primarily concentrated at 4- to 6-meter depths, and most commonly used habitat with moderately dense vegetation. Some attraction to nighttime lights was noted, although this was inconsistent from year to year (Celedonia et al. 2008a, 2008b, 2009). Although smallmouth bass showed an affinity for the bridge columns, information suggests that their overall abundance is no greater at the bridge than in other suitable habitat types. In addition to selecting the bridge columns as part of their migration route, smallmouth bass were found to prefer a depth of 4 to 8 meters and often sparse vegetation or edge habitat associated with macrophytes. Moderately dense to dense vegetation was used only occasionally. Neither pikeminnow nor smallmouth bass have been shown to prefer the shade or cover provided by the overhead bridge structure.

The fewer and more widely spaced in-water columns of the proposed permanent bridge structures are expected to generally reduce habitat complexity in the immediate area of the bridge, although the columns will extend out. This alteration is not expected to substantially affect the quality of predator and prey habitat provided by the permanent bridge structures. With the exception of Zone 7 (Floating Bridge), the increased habitat complexity associated with temporary structures will occur primarily in shallow water areas, which already contain substantial complexity from aquatic macrophyte beds. An increase in bridge height could allow more ambient light under the bridge and an increase in macrophyte density, particularly along the southern exposure. An increase in height will also reduce the intensity of cover caused by shading. This increase could in turn positively affect northern pikeminnow habitat and negatively affect smallmouth bass habitat. Therefore, while the project may slightly increase the quality of the available predator habitat in the project area, this increase will generally be minor.

However, some proportion of outmigrating juvenile Chinook salmon (and possibly other salmonid species) is likely to exhibit a holding behavior, resulting in increased residence time around the west approach structure. Of those fish exhibiting holding behavior, some may experience direct mortality via predation while holding near the structure, or a reduction in overall fitness as suggested by later saltwater entry (Celedonia 2009).

Although impacts to the aquatic habitat are expected to occur due to increased shade and structural complexity, several factors suggest that associated changes to predator–prey relationships will be low:

1. The new bridge will represent an improvement over the baseline conditions because the bridge is higher (although wider) and has fewer and more widely spaced in-water structural elements, reducing the overall complexity per unit area.
2. Current data do not indicate that the existing bridge has an influence on predator–prey relationships associated with adult salmonids.
3. Adult Chinook salmon mainly migrate away from the existing bridge approaches, within deeper waters.

4.2.4. Potential Effects on Adult Salmon

The impact mechanisms of shading/migration effects, predation, and benthic fill apply to juvenile salmonids, specifically to outmigrating fish. However, returning adults will be migrating through the project area during a time when relatively intensive in-water construction activities occur. Avoidance and minimization measures will limit or eliminate direct construction effects.

Data are insufficient to assess the potential influence of the existing west approach bridge structure on the migration behavior of adult salmonids as they return to the Lake Washington watershed to spawn. Adults are believed to migrate in the deeper water areas adjacent to the west approach, where fish will have ready access to cool, deep water refuge, including adequate temperature and dissolved oxygen conditions. Because the physical characteristics and locations of the new structures will be similar to those of the existing structures, they are unlikely to have a different influence than existing structures. For these reasons, potential effects to adult fish do not require direct compensatory mitigation. However, WSDOT recognizes that returning adult fish in the Lake Washington Ship Canal are exposed to potential stress due to degraded water quality conditions in this area (see Section 3.6.3 for discussion). Therefore, while the proposed mitigation activities are generally focused on offsetting impacts to juvenile salmonids, several mitigation actions are included that will also directly and indirectly benefit adult fish in the unlikely event that adult fish are affected by project construction activities.

4.3 Impact Assessment

4.3.1. Shading Impacts

To calculate the shading impacts of the permanent and temporary over-water structures, WSDOT first determined the total net acreage of (plan view) over-water structure resulting from construction and operation of the project (Figure 4-2; Tables 4-2 and 4-3). This calculation did not include the column and footing areas because these impacts were calculated as a separate impact type (see Section 4.3.2, Benthic Habitat Impact). For each impact type (permanent and temporary), the impacts were then sorted by Salmonid Functional Zone and multiplied by the appropriate Fish Function Modifier (see Section 4.1).

Impacts to juvenile salmonids, if any impacts occur in this zone, are believed to be generally limited to slight migration delays in the deep water habitat. Therefore, WSDOT used the total area of the pontoon structures to calculate the shading (migration) impact. WSDOT believes that this approach is a conservative approximation of environmental risks from the floating bridge, which are insignificant and discountable.

For permanent shading, the modified acreages were then summed to produce a total impact number (6.94 acres) that will require offsetting mitigation (see Table 4-2). For temporary shading impacts, a similar process was used, but the modified acreage was calculated by year (based on the area of over-water structure present during each construction year), and then summed to yield a time-weighted impact number of 21.38 acre-years (see Table 4-3). One acre-year is defined as one acre of impact over one year. This calculation takes into account the cumulative temporal effect of multiple structures present for specific time periods. A conservative approach to calculating shading impacts was taken where temporary over-water structures overlapped with future permanent bridge structures. In these cases, the impacts were counted separately for both permanent and temporary shading where these separate types of over-water structures overlap.

As noted in Section 4.1, impact calculation for shading (as a surrogate for migration impacts) in Zone 7 represents a special case, because unlike the other zones, any migration effects in this area would be caused by an obstruction in open water habitat and not shading on an open water column. Although the draft of the new pontoons will be slightly deeper than that of the existing pontoons, migrating fish could still move under the structure, and/or orient along the structure.

Additional over-water structure (potential shading impact) will result from construction of the new maintenance dock. However, this impact is considered self-mitigating because construction will require removal of two existing docks located directly under the new east approach bridges. Removal of the southern dock will eliminate about 860 square feet of over-water structure, while removal of the northern dock will benefit about 545 square feet of lake habitat. These docks are constructed of creosote-treated timber and have wooden decking with little to no space between the deck planks, both factors that are known to degrade habitat quality for salmonids. Therefore, removal of these two structures (totaling 1,405 square feet in over-water area) will fully offset construction of the maintenance facility dock, which although slightly larger in area (about 1,500 square feet over water), will be constructed using fish-friendly methods. The methods include the use of decking that allows a significant amount of ambient light to pass through, and materials that do not negatively affect water quality. These actions will maintain or improve aquatic habitat conditions along the shoreline area of the east approach.

Preliminary project design did not include full engineering of temporary work bridges, a task which will be undertaken during future design phases. Preliminary design resulted in estimates of the general location and size of the work bridges, as well as the approximate number of piles and their diameters. However, preliminary design does not include the exact size, configuration, or location of individual piles. Therefore, for the purposes of temporary impact calculations shown in Table 4-3, shading and benthic impacts were combined and classified as the entire area underneath the work bridge superstructure.

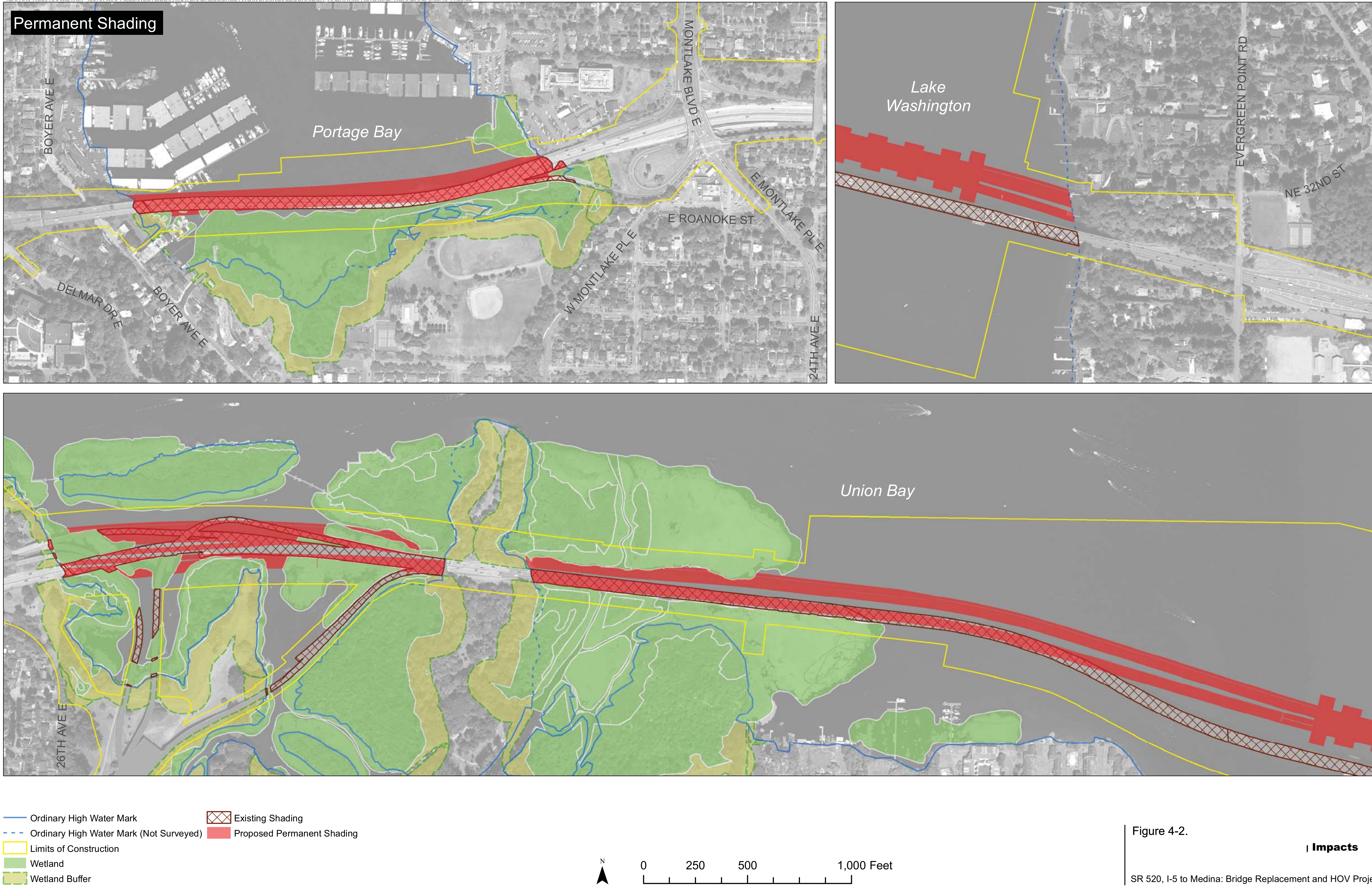


Figure 4-2.
Impacts

SR 520, I-5 to Medina: Bridge Replacement and HOV Project

Table 4-2. Permanent Project Impacts

Salmonid Use Ecological Zone	Existing Acreage	Proposed Acreage	Net Acreage	Fish Function Modifier	Permanent Impacts (acres)[1]
Permanent Shading Impacts					
Zone 8: East Approach	0.30	0.65	0.35	0.8	0.28
Zone 7: Floating Bridge	12.09	26.59	14.50	0.1	1.45
Zone 6: West Approach	2.61	5.28	2.67	1.0	2.67
Zone 4: Arboretum and Foster Island	7.22	8.50	1.28	0.1	0.13
Zone 3: Montlake Cut	0.14	0.18	0.18	1.0	0.18
Zone 2: Portage Bay	3.13	6.85	3.72	0.6	2.23
		Total Permanent Shading Impacts			**6.94**
Permanent Benthic Impacts (includes impacts to sockeye spawning beach habitat)					
Zone 8: East Approach	0.01	0.05	0.04	0.8	0.03
Zone 7: Floating Bridge	0.02	1.00	0.98	0.1	0.10
Zone 6: West Approach	0.03	0.09	0.05	1.0	0.05
Zone 4: Arboretum and Foster Island	0.11	0.09	-0.02	0.1	0.00
Zone 2: Portage Bay	0.04	0.34	0.30	0.6	0.18
		Total Permanent Benthic Impacts			**0.37**
Permanent Habitat Complexity Impacts					
Zone 8: East Approach	0.03	0.01	-0.03	0.8	-0.02
Zone 7: Floating Bridge	0.11	0.07	-0.04	0.1	0.00
Zone 6: West Approach	0.46	0.36	-0.10	1.0	-0.10
Zone 4: Arboretum and Foster Island	1.08	0.48	-0.60	0.1	-0.06
Zone 2: Portage Bay	0.37	0.25	-0.12	0.6	-0.07
	Total Permanent Habitat Complexity Impacts				**0**[2]
			Grand Total Permanent Impacts		**7.30**

[1] The sum of individual impact numbers may not equal the totals due to rounding.

[2] The negative values for each zone are negative, as is the total. Therefore, permanent habitat complexity habitat conditions will improve, and no impact will result.

Table 4-3. Temporary Project Impacts

Salmonid Use Ecological Zone	Sequence (Calendar Year)	Acreage	Fish Function Modifier	Modified Acreage	Impact Duration (Years)	Temporary Impacts (Acre-Year)
Shading and Benthic Impacts[1]						
Zone 8: East Approach	2012	0.60	0.8	0.48	1	0.48
	2013	0.60	0.8	0.48	1	0.48
	2014	0.60	0.8	0.48	1	0.48
	2015	0.0	0.8	0	1	0
	2016	0.0	0.8	0	1	0
	2017	0.0	0.8	0	1	0
					Subtotal	**1.44**

Salmonid Use Ecological Zone	Sequence (Calendar Year)	Acreage	Fish Function Modifier	Modified Acreage	Impact Duration (Years)	Temporary Impacts (Acre-Year)
Zone 7: Floating Bridge	2012	0.23	0.1	0.02	1	0.02
	2013	0.23	0.1	0.02	1	0.02
	2014	0.23	0.1	0.02	1	0.02
	2015	0	0.1	0	1	0
	2016	0	0.1	0	1	0
	2017	0	0.1	0	1	0
					Subtotal	**0.07**
Zone 6: West Approach	2012	0	1.0	0.00	1	0.00
	2013	1.57	1.0	1.57	1	1.57
	2014	1.57	1.0	1.57	1	1.57
	2015	2.65	1.0	2.65	1	2.65
	2016	2.65	1.0	2.65	1	2.65
	2017	1.08	1.0	1.08	1	1.08
					Subtotal	**9.53**
Zone 4: Arboretum and Foster Island	2012	0	0.1	0.00	1	0.00
	2013	2.67	0.1	0.27	1	0.27
	2014	2.67	0.1	0.27	1	0.27
	2015	5.56	0.1	0.56	1	0.56
	2016	5.56	0.1	0.56	1	0.56
	2017	2.89	0.1	0.29	1	0.29
					Subtotal	**1.93**
Zone 2: Portage Bay	2012	0	0.6	0.00	1	0.00
	2013	3.42	0.6	2.05	1	2.05
	2014	3.99	0.6	2.40	1	2.40
	2015	3.99	0.6	2.40	1	2.40
	2016	1.59	0.6	0.95	1	0.95
	2017	1.02	0.6	0.61	1	0.61
					Subtotal	**8.41**
					Total Shading and Benthic Temporary Impacts	**21.38**
Habitat Complexity/Predator Impacts						
Zone 6: West Approach	2012	0	1.0	0	1	0
	2013	0.55	1.0	0.55	1	0.55
	2014	0.55	1.0	0.55	1	0.55
	2015	1.00	1.0	1.00	1	1.00
	2016	1.00	1.0	1.00	1	1.00
	2017	0.44	1.0	0.44	1	0.44
					Subtotal	**3.54**
					Grand Total Temporary Impacts	**24.92**

[1] Based on the absence of design information on the location of piles to support temporary work trestles, benthic habitat impacts were combined with shading impacts and reflect the entire over-water structure area of the work bridge decks.

4.3.2. Benthic Habitat Impact

To calculate the benthic habitat impacts of the permanent over-water structures, WSDOT first determined the total net acreage of benthic structures at all water depths less than 60 feet (see Figure 4-3, and Tables 4-2 and 4-3). This depth cut-off is appropriate based on the life history of salmonids in the project area because these salmonids do not use benthic habitat in these greater depths.

For permanent benthic habitats, the modified acreages were then summed to produce a total impact number (0.37 acre) that will require offsetting mitigation (see Table 4-2). As discussed above, temporary benthic impacts were included in the calculation of temporary shading impacts (see Table 4-3).

Based on preliminary geotechnical investigations (WSDOT 2011b), the underdrain associated with the maintenance facility under the east approach could result in a slight reduction in the aquifer pressure, which may result in a slight decrease in upwelling rates within benthic habitat areas that support sockeye salmon spawning. However, the potential reduction is of very small magnitude (a worst case estimate is about a 7% reduction in hydraulic head, which relates to flow velocity), and therefore no substantial reduction in either the distribution or success of spawning sockeye salmon is expected. Based on the geotechnical information, this potential impact is considered insignificant, and does not require compensatory mitigation.

4.3.3. Habitat Complexity Impacts

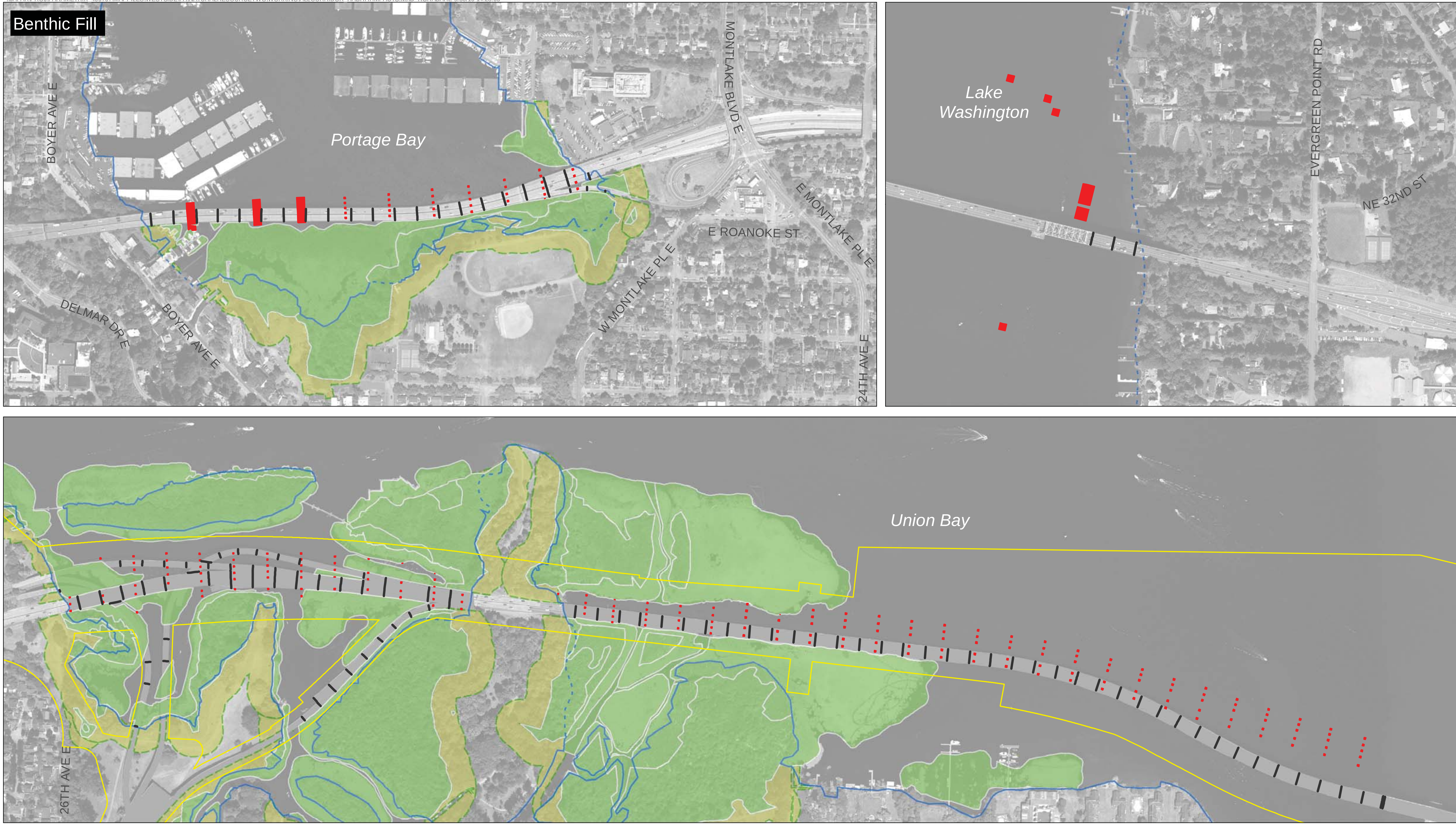
To calculate the shading impacts of the permanent in-water structures (columns and piers) on habitat complexity (predation), WSDOT first determined the area of the predation zone around each in-water structure. The predation zone area is based on data describing predator behavior (discussed in Section 3) and is defined as the plan view distance of the portion of the water body extending from the outside edge of a column or pier to a distance of 5 feet.

The 5-foot distance was chosen based on field observations and scientific studies of the visual detection and reaction distances in picivorous fish. For example, Sweka and Hartman (2003) measured a maximum reactive distance for smallmouth bass of 65 centimeters (cm) (2.1 feet) in clear water. The reactive distance decreased exponentially with increasing turbidity. Similar reactive distances (between 0.8 and 6.6 feet) have been measured for largemouth bass (Howick and O'Brien 1983; Savino and Stein 1989), with the vast majority of strikes occurring within a distance of 5 feet. Based on these data, a predation zone of 5 feet was applied to each bridge column. For each Salmonid Functional Zone, the net change in predation area was calculated and then multiplied by the appropriate Fish Function Modifier (see Table 4-2).

For permanent habitat complexity impacts, all modified acreages for each Salmonid Functional Zone were negative. This indicates that the net predation area will decrease under future conditions. Therefore, no compensatory mitigation is required (see Figure 4-4 and

Table 4-2). For temporary habitat complexity impacts, an identical method was used for impact calculation, although temporary predation was calculated only for Zone 6, the west approach. The modified acreage was calculated by year (based on the area of over-water structure present during each construction year), and then summed to yield a time-weighted impact number of 3.54 acre-years (see Table 4-3).

\\JAFAR\PROJ\PARAMETRIX_400707\MAPFILES\WESTSIDE\PA\NATURALRESOURCETWG\WORKING\ALLCORRIDOR_HABITATIMPACTS.MXD RGRABARE 9/30/10 14:28:05



Ordinary High Water Mark
Ordinary High Water Mark (Not Surveyed)
Limits of Construction
Wetland
Wetland Buffer
Existing Benthic Fill
Proposed Benthic Fill

N

0 250 500 1,000 Feet

Figure 4-3.
Proposed and Existing Impacts

SR 520, I-5 to Medina: Bridge Replacement and HOV Project

\\JAFAR\PROJ\PARAMETRIX_400707\MAPFILES\WESTSIDE\PA\NATURALRESOURCETWG\WORKING\ALLCORRIDOR_HABITATIMPACTS.MXD RGRABARE 9/30/10 14:28:05

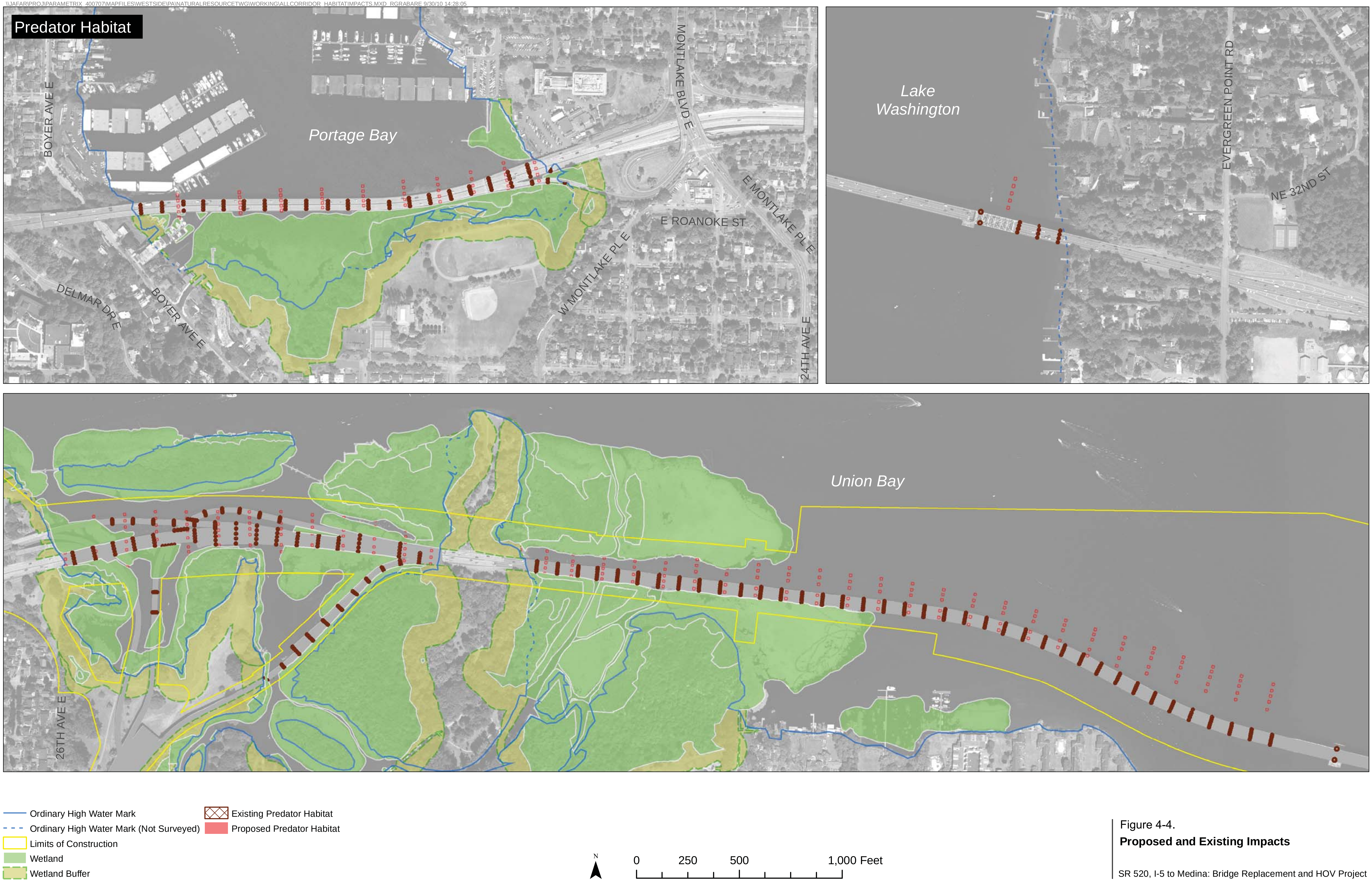


Figure 4-4.
Proposed and Existing Impacts

SR 520, I-5 to Medina: Bridge Replacement and HOV Project

4.3.4. Impact Summary

To determine overall project mitigation needs, the mitigation team summed the impact calculations for shading, benthic fill, and structural complexity (see Tables 4-2 and 4-3). Using the methods discussed above, permanent project impacts are 7.30 acres, while temporary project impacts equate to 24.92 acre-years. The impact numbers were derived using the habitat function and life history stage model presented in Section 3 (see Figure 3-2).

Conservative Impact Analysis Assumptions

The mitigation team believes these methods are appropriate to describe the primary impact mechanisms, and that the methodology uses generally conservative assumptions and rules, which tend to err on the side of overstating the potential impacts to fishery resources. Some of the conservative assumptions used in impacts analysis are listed below.

Over-water and structural complexity: Under the methodology, over-water and structural complexity impacts from temporary and permanent structures are effectively treated as affecting 100% of both the available habitat and the associated habitat functions (for the time frame they are physically present). That is, they are treated as if the affected habitat was being removed or filled. In reality, although aquatic habitat functions will be affected, the habitat will generally be available for use and will support salmonid life histories, albeit at a somewhat reduced level. For example, juvenile salmonids will still migrate under the permanent bridge and temporary work bridges, with many of these fish experiencing no negative effects to survival or fitness. Also, although some increase in predation rate may occur in the vicinity of the temporary and permanent structures compared to existing conditions, the vast majority of rearing and migrating juveniles will not likely become prey due to these structures.

Shading impacts: Under the methodology, permanent shading impacts are assessed using a metric of net increase of over-water structure. This does not account for the net increase of height, and therefore of light intensity, under the new bridge structure compared to the existing structure. In addition, the gap between the north and south superstructures will also allow a greater amount of light under the bridge. Although the exact change in light intensity over the project area cannot be accurately calculated (and thus was not used for analysis purposes), it is likely that under future conditions, light intensity will be equal to or less than under existing conditions, at least in key areas such as the west approach (Zone 6) or Portage Bay (Zone 3).

At all permanent structures and temporary work bridges in the west approach area (Zone 6), shading and structural complexity impacts were double-counted in cases where they overlapped (each impact type was counted separately and summed). This approach is conservative because an individual fish cannot be affected on multiple endpoints (e.g., both survival and growth).

In addition, a conservative approach to calculating shading impacts was taken where temporary over-water structures overlapped with future permanent bridge structures. In these cases, the impacts were counted separately for both permanent and temporary shading impacts where these impacts overlap.

Fish Function Modifier: Furthermore, in several cases the methodology took a conservative approach to the assignment of Fish Function Modifiers. For example, in Zone 2 (Portage Bay), the entire zone was assigned a modifier of “moderate”, even though past studies have shown only minor use of the zone’s shallower southern portion by juvenile and adult salmonids (City of Seattle and USACE 2008).

Benthic impacts: Permanent impact calculations for benthic impacts were also conservative because they included the area of column footings. Although the footings will initially displace benthic habitat, over time the mudline will form over the footings as sediment is redistributed. Although the footing area will provide at least some important benthic habitat functions over time, these areas were counted in the total impact area.

Temporary work bridges: Preliminary engineering on the configuration and extent of the temporary work bridges was based on relatively conservative assumptions. Once final engineering on the work bridges is complete and a contractor is chosen, there is a likelihood that the extent (length) of the work bridges, and the associated over-water and in-water structures associated with the work bridges will substantially decrease for reasons including potential materials cost savings, schedule savings, and/or the use of different construction methods.

5. Mitigation Framework

The overall goal of WSDOT mitigation measures is to achieve no net loss of habitat functions and values. Mitigation for impacts to aquatic functions and values from the proposed project activities will be considered and implemented, where feasible, in the following sequential order:

1. Avoiding the impact altogether by not taking a certain action or parts of an action.
2. Minimizing impacts by limiting the degree or magnitude of the action, and restoring temporary impacts.
3. Compensating for the impact by replacing or providing substitute resources or environments.

5.1 Avoidance of Aquatic Impacts – Design Features

The structures included in this project have been designed to avoid and minimize aquatic impacts whenever practicable. Specific design features to avoid and minimize effects on aquatic habitat are listed in the 2009 Ecosystems Discipline Report (WSDOT 2009b) and described in the following sections.

5.1.1. In-water Structures

An increased span length has reduced the number of in-water structures, relative to the existing condition. The use of precast girders will eliminate the need for falsework in most locations. Columns will be spaced farther apart, relative to the existing condition. Span lengths that require footers will be avoided, when possible. When structure foundations require footings, mudline footings will be installed. Mudline footings will result in a reduction of in-water structure and shading compared to waterline footings. The footings will be installed below the mudline, allowing for natural deposition on top of the footing. Finally, the length and over-water coverage of the maintenance dock was designed with the minimum dimensions necessary to provide its required function. The size and number of pilings have been minimized to the most practicable extent. A detailed description of in-water structures in each project area is in section 2.1 and the biological assessment (WSDOT 2010a).

5.1.2. Shading

Shading from over-water structures can delay juvenile salmonid migration by invoking a behavioral response such as milling, paralleling, or holding, and because a shade edge provides a foraging opportunity (see Section 4.2.2 for a discussion). Piscivorous fishes also use this shade edge to forage, thereby increasing the risk of predation on juvenile salmonids.

The shading intensity and sharpness of the shade edge is attenuated by increasing bridge height and reducing bridge width (see Section 4.2.2 for discussion).

The Portage Bay, west approach, and east approach bridges will be wider, but significantly higher than the existing structures (see Table 5-1, and Figures 2-2, 2-3, and 2-4). Increasing bridge width can increase shading intensity. The proposed widths of the Portage Bay, west approach, and east approach bridge structures are greater than the existing widths, even though the number of lanes and shoulder widths have been minimized. The west approach bridge will have a gap between eastbound and westbound lanes, further minimizing shading intensity. A detailed description of bridge height and width for each project area is in section 2.1 and the biological assessment (WSDOT 2010a).

Table 5-1. Proposed Changes to Bridge Height Over Water (feet)

Statistic	Portage Bay		West Approach		East Approach	
	Existing	Proposed	Existing	Proposed	Existing	Proposed
Minimum	6	16	4	12	52	66
25th Percentile	8	19	5	21	ND[1]	ND[1]
75th Percentile	37	35	21	42	ND[1]	ND[1]
Maximum	63	63	45	49	64	78

[1]Percentiles were based on bridge height at pier locations. The proposed East Approach structure only has two piers. Therefore, no percentiles were calculated.

Stormwater Discharge

Stormwater discharge impacts will be minimized because of outfall location and design. New outfalls will be located at or near existing outfalls. Outfall discharge and energy dissipation will occur above the OHWM. Discharged stormwater will be conveyed to the lake. Revegetation will occur between outfalls and water bodies.

Enhanced stormwater treatment will occur where possible. Stormwater treatment includes the combined sewer system, conventional treatment BMPs, and—in the case of the floating bridge portion of the project—an innovative stormwater treatment approach identified in an "all known, available, and reasonable technology" (AKART) study (WSDOT 2010c).

All new pollutant-generating impervious surface (PGIS) will receive stormwater quality treatment. Existing areas that will not receive post-construction treatment are primarily areas associated with restriping activities in the I-5 interchange. Project-related stormwater will be treated by facilities designed on the basis of the requirements in the 2008 WSDOT Highway Runoff Manual (HRM) and the WSDOT Hydraulics Manual. New and replaced PGIS requires stormwater treatment to a basic level of treatment for Lake Union and Lake Washington. The project will also be providing enhanced treatment for stormwater discharge from SR 520 into Lake Washington to further minimize any effects on the lake due to dissolved metals. A detailed description of operational stormwater treatment and management is in section 2.3.1 and the biological assessment (WSDOT 2010a).

5.1.3. Lighting

Cut-off light fixtures with shielding will be used when fixtures are adjacent to water. Cut-off lights are shielded or directional lights that limit the light to the target area. Cut-off lights reduce the amount of light that shines outside the bridge roadway onto the water surface. Lights will be placed on the center median whenever possible to limit light spillage. During bridge operation, nighttime lighting on water surfaces will be avoided or minimized where feasible. A detailed description of proposed roadway lighting is in section 2.32 and the biological assessment (WSDOT 2010a).

5.2 Avoidance of Aquatic Impacts – Construction Timing

WSDOT has been collaborating in research that improves our understanding of juvenile Chinook distribution, movement, and transit time through the project area (Tabor et al. 2010a; Celedonia et al. 2008a; 2008b). Juvenile Chinook are the most vulnerable to the presence of in-water structures and construction impacts because of their small size during migration. These tracking studies confirmed the benefit of previously published work periods, and also contributed to the basis of the project impact assessment (see Section 4).

The construction schedule has been optimized to limit the number of construction years. Seasonal restrictions (i.e., work windows) will be applied to the project to avoid or minimize potential impacts to fish species based on the Hydraulic Project Approval (HPA) issued by WDFW. The in-water work windows vary between water bodies (Table 5-2). The in-water work window is timed to protect peak abundances of juvenile and adult salmonids.

In-water construction will adhere to the proposed in-water construction timing shown in Table 5-2. The proposed dates were developed through a series of in-water construction Technical Work Group meetings attended by representatives from WSDOT, the United States Fish and Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS), the Washington Department of Fish and Wildlife (WDFW), the Muckleshoot Indian Tribe, and local fish experts. Each in-water construction period is predicated on the nature of the construction activity, the habitat function zones described in Section 3.5.2, and the expected timing of fish use in the habitat function zone.

Table 5-2. Proposed In-Water Construction Periods for the Various Project Elements

Project Element	Proposed In-Water Construction Timing
Portage Bay [a]	
Work bridge/falsework pile installation	September 1 to April 30
Work bridge deck	N/A
Cofferdam – vibratory	August 16 to April 30
Mudline footings in cofferdam	N/A
Drilled shaft – vibratory	August 16 to April 30
Bridge superstructure	N/A
Materials transport	N/A
Column demolition	N/A
Pile removal	August 16 to April 30
Cofferdam removal	August 16 to April 30
Union Bay and West Approach – Salmonid Habitat Zone 4 [b]	
Work bridge pile installation	September 1 to April 30
Work bridge deck	N/A
Drilled shaft – vibratory	N/A
Bridge superstructure	N/A
Materials transport	N/A
Column demolition	N/A
Pile removal	N/A
West Approach – Salmonid Habitat Zone 6 [b]	
Work bridge pile installation	October 1 to April 15
Work bridge deck	N/A
Drilled shaft -–vibratory	August 1 to March 31
Bridge superstructure	N/A
Materials transport	N/A
Column demolition	N/A
Pile removal	August 1 to March 31
West Approach Connection Bridge [b]	
Work bridge deck	N/A
Drilled shaft – vibratory	August 1 to March 31
Bridge superstructure	N/A
Materials transport	N/A
Column demolition	N/A
Floating Bridge [b]	
Temporary pile anchors – vibratory	July 16 to March 15
Gravity or shaft anchor installation – west end	July 16 to March 15
Gravity or shaft anchor installation – east end	September 1 to May 15
Fluke anchor installation	N/A

Project Element	Proposed In-Water Construction Timing
Pontoon assembly	N/A
Bridge outfitting/superstructure	N/A
Materials transport	N/A
Pile removal	July 16 to March 15
East Approach [c]	
Work bridge/falsework pile installation	August 16 to March 15
Work bridge deck	N/A
Cofferdam – vibratory	September 1 to May 15
Mudline footings in cofferdam	N/A
Drilled shaft – vibratory	September 1 to May 15
Bridge superstructure	N/A
Materials transport	N/A
Column demolition	N/A
Pile removal	July 1 to March 15
Cofferdam removal	July 1 to March 15

[a] Published In-Water Construction Timing October 1 to April 15
[b] Timing July 16 to March 15 north of bridge and July 16 to April 30 south of existing bridge
[c] Published In-Water Construction Timing July 16 to March 15
N/A = not applicable

5.3 Minimization of Impacts during Construction

BMPs will be used during all construction activities to eliminate or minimize potential environmental effects. Many of these BMPs are standard and will apply universally to many project construction activities, including upland staging areas. The following section discusses provisional BMPs that WSDOT anticipates will be included as construction commitments for the project. A detailed description of construction methods that avoid or minimize aquatic impacts is described in the project biological assessment (WSDOT 2010a).

Monitoring will occur during construction. Activities will be adjusted as necessary, depending on monitoring results. Environmental performance (e.g., turbidity, underwater noise, water quality) will be reviewed during initial construction activities. Turbidity, DO, and noise will be monitored before and during construction. If environmental results are unsatisfactory during construction, subsequent similar activities will be implemented in a more conservative fashion to minimize these impacts.

5.3.1. Temporary Stormwater Management Strategy

The project's temporary stormwater management strategy is to reduce the risk of potential pollutants being discharged to a watercourse that may cause or contribute to the exceedances of water quality standards during construction and demolition activities. The strategy is to use BMPs and adhere to regulatory requirements to manage construction-related stormwater runoff and thereby minimize environmental impacts. The plan will include planning system design and water quality monitoring and sampling. The components of the temporary stormwater management strategy are listed below.

Stormwater Pollution Prevention Plan

A Stormwater Pollution Prevention Plan (SWPPP) is prepared to meet National Pollutant Discharge Elimination System (NPDES) permit requirements for stormwater discharges at construction sites. The SWPPP will address the following elements:

- Planning and organization
- Formation of a pollution prevention team
- Building on pre-existing plans
- Assessment
- Development of a site plan
- Material inventory
- Record of past spills and leaks
- Non-stormwater discharges
- Site evaluation summary
- BMP identification
- Preventive maintenance
- Spill prevention and response
- Sediment and erosion control
- Management of runoff
- Implementation
- Implementation of appropriate controls
- Employee training

- Evaluation and monitoring
- Annual site compliance evaluation
- Recordkeeping and internal reporting
- Plan revisions

Temporary Erosion and Sediment Control Plan

A Temporary Erosion and Sediment Control (TESC) Plan will be prepared and implemented to minimize and control pollution and erosion from stormwater runoff. Temporary erosion and sediment control is required to prevent erosive forces from damaging project sites, adjacent properties, and the environment. The TESC plan will address the following elements:

- Marking clearing limits
- Establishing construction access
- Controlling flow rates
- Installing sediment controls
- Stabilizing soils
- Protecting slopes
- Protecting drain inlets
- Stabilizing channels and outlets
- Controlling pollutants
- Controlling dewatering
- Maintaining BMPs
- Managing the project

Spill Prevention Control and Countermeasures Plan

WSDOT requires the implementation of a Spill Prevention Control and Countermeasures (SPCC) Plan on all projects to prevent and minimize spills that may contaminate soil or nearby waters. The plan is prepared by the contractor as a contract requirement and is submitted to the project engineer prior to commencement of any on-site construction activities.

Spill avoidance and containment BMPs will include the following:

- Maintain all construction equipment to minimize the risk of fuel and fluid leaks or spills.
- Implement spill control and emergency response plans for fueling and concrete activity areas. All spill-control materials will be present on the site prior to and during construction.
- If a leak or spill should occur, cease all work until the source of the leak is identified and corrected and the contaminants have been removed from the site.
- Clean all equipment that is used for in-water work prior to operations waterward of the OHWM. Remove external oil and grease as well as dirt and mud. Prohibit the discharge of untreated wash and rinse water into local waters. Ensure that all construction equipment working in the water, particularly pile-driving machines, use vegetable-based hydraulic fluid.
- Conduct refueling activities within a designated refueling area away from the shoreline, streams, or any designated wetland areas.
- Minimize refueling activities on work bridges whenever feasible, and ensure that appropriate spill containment and cleanup equipment is on hand and in use as needed during any refueling of equipment on work bridges.
- Inspect daily all vehicles operating within 150 feet of any water body for fluid leaks before vehicles leave the staging area. Repair any leaks detected before the vehicle resumes operation. When vehicles are not in use, store them in the vehicle staging area.
- Modify off-pavement construction entrances according to WSDOT standard plans to reduce the spread of dirt from the project site.

Concrete Containment and Disposal Plan

A Concrete Containment and Disposal Plan will be developed to maintain water quality when handling and managing concrete. The plan will be used during construction of bridge columns and their footings, and also during demolition of the existing bridge.

Water Quality Sampling, Recording, and Reporting Procedures

All projects with greater than 1 acre of soil disturbance, except federal and tribal land, that may discharge construction stormwater to Waters of the State are required to seek coverage under the NPDES Construction Stormwater General Permit. Sampling guidance for meeting permit requirements is listed in WSDOT's HRM (2008), Section 6-8.

5.3.2. Land-Based Construction – Best Management Practices

The following BMPs and procedures are to be implemented for the proper use, storage, and disposal of materials and equipment on land-based construction limits, staging areas, or similar locations that minimize or eliminate the discharge of potential pollutants to a watercourse or Waters of the State. These procedures will be implemented for construction materials and wastes (solid and liquid), soil or dredging materials, or any other materials that may cause or contribute to exceedance of water quality standards.

Upland construction BMPs will involve the following:

- Clearly define construction limits with stakes and a high visibility fence before beginning ground-disturbing activities. No disturbance will occur beyond these limits.
- Minimize vegetation and soil disturbance to the extent possible.
- Avoid or reduce adverse impacts to critical areas during project construction, including shoreline buffers. These measures will include clearing, grading, and stormwater management.
- Protect designated sensitive areas, including the shoreline, with silt fencing. All silt fencing will be removed when construction is completed.
- Control all stormwater discharges from construction sites and ensure that NPDES permit requirements are met.
- Use construction BMPs to control dust and limit impacts to air quality; these BMPs include the following:
    - Wet-down fill material and dust on-site.
    - Ensure adequate freeboard to prevent soil particles from blowing away during transport.
    - Remove dirt, dust, and debris from the roadway on a regularly scheduled basis in accordance with final permitting requirements.
    - Minimize potential erosion from areas of disturbed soil by stabilizing and/or revegetating cleared areas in accordance with the TESC Plan.
    - Wet-down concrete structures during demolition activities.

5.3.3. Over-Water Work – Best Management Practices

The following BMPs and procedures are expected to be implemented at a minimum for the proper use, storage, and disposal of materials and equipment on barges, boats, temporary construction pads (e.g., work bridges), or at similar locations that minimize or eliminate the discharge of potential pollutants to a watercourse or to Waters of the State. These procedures will be implemented for construction materials and wastes (solid and liquid), soil or dredging materials, or any other materials that may cause or contribute to exceedance of water quality standards.

Construction Lighting

Construction lighting will be limited to areas of active work and directed at work surfaces.

Watertight Curbs, Bull Rails, or Toe Boards

Watertight curbs, bull rails, or toe boards will be installed around the perimeter of a work bridge, platform, or barge to contain potential spills and prevent materials, tools, and debris from leaving the over-water structure. These applications will be installed with a minimum vertical height of 10 inches.

Oil Containment Boom

An oil containment boom is a floating barrier that can be used to contain oil, and aids in preventing the spread of an oil spill by confining the oil to the area in which it has been discharged. The purpose of containment is not only to localize the spill and thus minimize pollution, but to assist in the removal of the oil.

Floating Sediment Curtain

These barriers can aid in controlling the settling of suspended solids (silt) in water by providing a controlled area of containment. This condition of suspension (turbidity) is usually created by disrupting natural conditions through construction or dredging in the aquatic environment. The containment of settleable solids is desirable to reduce the impact area.

Tie-Downs

Tie-downs can be used to secure all materials, which can aid in preventing discharges to receiving waters via wind.

Absorbent Materials

Absorbent materials will be placed under all vehicles and equipment on docks, barges, or other over-water structures. Absorbent materials will be applied immediately on small spills, and promptly removed and disposed of properly. An adequate supply of spill cleanup materials, such as absorbent materials, will be maintained and available on-site.

Equipment Maintenance and Inspection

- Vehicle and construction equipment inspection will occur daily. Vehicles will be inspected prior to entering any over-water work zone. Vehicles and equipment will be kept clean of excessive build-up of oil and grease.
- Land-based fueling stations will be used to the extent practicable.
- Off-site repair shops will also be used to the extent practicable. These businesses are better equipped to properly handle vehicle fluids and spills. Performing this work off-site can also be economical by eliminating the need for a separate maintenance area. If a leaking line cannot be repaired, the equipment will be removed from over-water areas.
- If maintenance must take place on-site, only designated areas away from drainage courses will be used. Dedicated maintenance areas will be protected from stormwater run-on and runoff.

Cover and Catchment Measures

Portable tents, drop cloths, tarps, blankets, sheeting, netting, and plywood panels will be used to cover work areas, temporary stockpile materials, or demolition debris. Nets, tarps, platforms, scaffolds, blankets, barges, and/or floats will be used to contain and control debris beneath structures being constructed or demolished. Vacuums, diverters, squeegees, absorption materials, holding tanks, and existing drainage systems will be used to control and contain concrete-laden water. These BMPs will also facilitate the suppression and dispersal of fugitive dust generated from the demolition process.

Construction Water Treatment Systems

These systems generally consist of temporary settling storage tanks, filtration systems, transfer pumps, and an outlet. The temporary settling storage tank provides residence time for the large solids to settle out. The filtration system will be provided to remove additional suspended solids below an acceptable size (typically 25 microns). The pumps provide the pressure needed to move the water through the filter and then to an acceptable discharge location. Once the solid contaminants are filtered out, the clean effluent is then suitable for discharge to a municipal storm drain or an acceptable discharge location. These systems will be located on work bridges and barges.

Spill Containment Kits and Containment Products

These pre-manufactured products will aid in spill containment and cleanup. These kits and products will be kept on-site and within construction vehicles for easy deployment.

Alternative Lubricants and Fuels

Eco-friendly lubricants and fuel sources (e.g., vegetable-based) will be used for in-water and over-water construction where practicable.

Barges and Floats

Barges and floats can be used to store stockpiled materials, store construction equipment, transport demolition debris, and store water containment systems and water storage tanks. The barges and floats can also be used as a catchment for demolition debris if located below a proposed demolition activity.

Protection will be required to prevent debris or water from entering adjacent live traffic lanes and prevent the spread of such material over a larger area. The prevention of such occurrences can be accomplished by using temporary barriers and protective panels, and containing or vacuuming water from concrete saw usage.

5.3.4. In-Water Work – Best Management Practices

In addition to applicable BMPs described above for over-water work, the following BMPs apply where demolition or construction activity will occur in Waters of the State. These procedures will be implemented to contain construction materials and wastes (solid and liquid), soil or dredging materials, or any other materials that may cause or contribute to the exceedances of water quality standards. Equipment that enters waterways will be maintained such that no visible sheen from petroleum products appears within waterways. If a sheen appears around equipment in the water, the equipment will be contained within an oil boom and shall be removed from the water, cleaned, and/or maintained appropriately.

Construction Work Bridges and Barges

Work over open water will be accomplished from work bridges or barges. Construction will be done from barges where feasible, because of their relatively small impact. The impacts are relatively small because (1) they do not require in-water pile driving; (2) they will result in only limited disturbance of the substrate; and (3) they will remain in any one place for a shorter time than the work bridges.

The extent of work bridges has been estimated with an assumption that construction barges cannot travel into waters less than 10 feet deep. However, contractors will be allowed to use barges at shallower depths (potentially to a 6-foot depth) if they have equipment capable of safely navigating and operating in shallow waters (WSDOT 2010d). Where the lake depth is too shallow for barges to operate, temporary work bridges will be constructed. Portage Bay, Union Bay, and the west approach areas all have shallow waters that are inaccessible by barge and will require work bridges. In addition, a work bridge across Foster Island will be constructed instead of temporary work roads, thereby reducing temporary clearing. The over-water height of the work bridges has been maximized to the furthest extent practicable, thereby minimizing shading impacts. Piles will be installed with a vibratory hammer, but proofed with an impact hammer. These structures will be removed at the earliest possible date, even if removal occurs outside of the in-water work window. The piles will be removed with a vibratory hammer and simultaneous lifting of the pile (WSDOT 2010d).

Underwater Containment System/Temporary Cofferdam

These systems will be implemented to prevent sediment, concrete, and steel debris from mixing with Waters of the State. Examples include a temporary cofferdam, an oversized steel casing, or another type of approved underwater containment system. This application will allow demolition work to be completed on and around an underwater structure, and will allow the work zone to be isolated. The system will also allow work to be completed at or below the mudline as determined by the state or contractor's removal requirements. Construction water and slurry within the containment system will be removed, treated, and pumped to an acceptable discharge location when demolition is complete. Fresh concrete will be prevented from coming in contact with Waters of the State.

Noise Attenuation

The Fisheries Hydroacoustic Working Group (FHWG) defined interim criteria for injury to fish from pile driving activities. The criteria identify sound pressure levels (SPLs) of 206 decibels (dB) peak and 187 dB accumulated sound exposure level (SEL) for all listed fish except those that are less than 2 grams. For the fish less than 2 grams, the criteria for the accumulated SEL is 183 dB.

To compare these criteria with the proposed pile driving activities, WSDOT initiated a Pile Installation Test Program (WSDOT 2010e). During this program, a vibratory hammer and an impact hammer were used on test piles, and WSDOT measured the peak and attenuated noise. Three minimization measures were employed and measured for effectiveness. Bubble curtains were very effective at reducing noise down to acceptable levels and will be installed during in-water impact pile driving for the SR 520, I-5 to Medina Project. The use of a bubble curtain is expected to substantially minimize the area affected by above-threshold sound levels. In-water pile driving in the Union Bay area will occur during the fish work window to further avoid noise disturbance to fish.

Several factors suggest that the project's noise will have a relatively low impact to fish:

- Few juvenile or adult Chinook salmon are likely to occur in the project area during this construction period. The in-water work period is outside of the peak of Chinook outmigration from the Cedar River into Lake Washington (begins in January, but most fry enter the lake in mid-May), and is also outside of the adult migration period.

- Adult Chinook salmon are believed to migrate through deeper waters, away from behavioral and injury disturbance areas.

- The use of a bubble curtain (confined or unconfined) is expected to substantially minimize the area affected by above-threshold sound levels.

The underwater SPLs from in-water impact pile driving will be monitored by the contractor, per a forthcoming and agreed-upon monitoring plan. If the recorded SPLs exceed the thresholds agreed upon by the National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NOAA Fisheries), the U.S. Fish and Wildlife Service (USFWS), FHWA, and WSDOT, appropriate energy reduction measures shall be deployed by the contractor to attenuate the SPLs.

If a fish kill occurs or fish are observed in distress from pile driving, the contractor will immediately cease the activity and WSDOT will be notified. WSDOT will notify the WDFW Habitat Program immediately. The contractor will ensure that a project inspector/biologist is on-site during all in-water pile driving operations to monitor for distressed fish. The contractor will ensure that this inspector has full authority to stop work in the event that dead or distressed fish are observed.

5.3.5. Water Quality Monitoring

Discharges from construction and operation activities will be monitored per the contractor's Construction Water Quality Protection and Monitoring Plan (WQPMP) approved by Ecology. The contractor will submit the WQPMP to WSDOT for submittal to Ecology at least 30 calendar days prior to beginning construction. The purpose of the WQPMP is to assess compliance with water quality standards during the project's construction and operation activities. The WQPMP will identify all the construction and operation activities at the site that may have a discharge (e.g., dewatering water, construction stormwater, channel dredging, operational stormwater, etc.) to surface water or groundwater. Specific locations of proposed discharge points to be monitored and their water quality parameters will be defined in the WQPMP. If any of the monitoring parameters exceed the water quality standards, the contractor will cease construction activities in the vicinity and notify WSDOT until appropriate measures are taken to bring the project back into compliance. In the event that a violation of the state water quality standards occurs or if a revision from the permitted work is needed, WSDOT will immediately notify Ecology.

5.4 Compensatory Mitigation

Given the measures described in Sections 5.1–5.3, many potential impacts to the aquatic environment will be effectively avoided or minimized. However, some project elements and activities will require compensatory mitigation for impacts to aquatic habitat, or habitat functions will still be degraded after avoidance and minimization measures have been applied (see Section 4.1).

Many of the construction-related impacts will not result in a long-term impact to aquatic habitats or functions because the effect ceases almost immediately upon cessation of the activity (see Table 5-3). Furthermore, potential construction impacts, including in-water noise, temporary lighting, in-water turbidity/contaminants, stormwater discharge, and barge operation and moorage, will be effectively avoided and/or minimized (see Sections 5.1–5.3) to the extent that compensatory mitigation is not required. On an operational basis, the bridge lighting and stormwater impacts will be minimized through the implementation of design elements and BMPs.

Three types of activities will cause habitat function degradation (see Table 5-3). These functional effects will occur on both a temporary and a permanent basis. The bridge superstructure and temporary work bridges will alter the quality of migratory habitat for juvenile salmonid by projecting a shade edge onto the water. The bridge columns and temporary work bridge piles will result in permanent and temporary displacements of benthic habitat. The columns and temporary work bridge piles will also increase vertical habitat complexity, thereby attracting smallmouth bass, a juvenile salmonid predator. These impacts have the greatest potential to affect aquatic habitat functions, particularly in terms of salmonid life history stages and populations. A detailed discussion of these impact mechanisms is provided in Sections 4.1–4.2.

Table 5-3. Potential Impacts and Compensatory Mitigation Requirements

	Potential Impact	Avoided/ Minimized	Compensatory Mitigation
Temporary	In-water noise	X	
	Lighting	X	
	Turbidity	X	
	Construction stormwater	X	
	In-water work	X	
	Barge Operation	X	
	Barge Moorage	X	
	Over-water Shading (work bridges)		X
	Benthic fill (piles)		X
	Habitat complexity (piles)		X
Permanent	Lighting	X	
	Stormwater	X	
	Over-water Shading (work bridges)		X
	Benthic fill (piles)		X
	Habitat complexity (piles)		X

5.5 Compensatory Mitigation Framework

The following agencies have authority to require compensatory mitigation for aquatic (i.e., non-wetland) impacts that were not sufficiently avoided or minimized:

- USACE
- WDFW
- City of Seattle

The aquatic mitigation framework for the SR 520, I-5 to Medina Project is commensurate with the mitigation policies of these agencies. The WDFW policy “Requiring or Recommending Mitigation”, POL-M5002, has stated goals to “…achieve no loss of habitat functions and values” and “to maintain the functions and values of fish and wildlife habitat in the state.”

The following WDFW policy language applies to infrastructure projects:

"WDFW may not limit mitigation to on-site, in-kind mitigation when making decisions on hydraulic project approvals for infrastructure development projects. The State Legislature has declared that it is the policy of the state to authorize innovative mitigation measures by requiring state regulatory agencies to consider mitigation proposals for infrastructure projects that are timed, designed, and located in a manner to provide equal or better biological functions and values compared to traditional on-site, in-kind mitigation proposals. For these types of projects, WDFW may not limit the scope of options in a mitigation plan to areas on or near the project site, or to habitat types of the same type as contained on a project site. When making a permit decision, WDFW shall consider whether the mitigation plan provides equal or better biological functions and values, compared to the existing conditions, for the target resources or species identified in the mitigation plan…"

The City of Seattle has a similar policy goal on maintaining habitat functions and values. Policy SMC 25.09.200, Section B.3.b pertains to over-water structures and states that the "Mitigation is provided for all impacts to the ecological functions of fish habitat on the parcel resulting from any permitted increase in or alteration of existing over-water coverage."

Unlike the regulatory process for wetland mitigation, federal and state regulations and guidance do not prescribe calculation of metrics or mitigation formulas for the majority of the effects to aquatic habitat. In addition, many of the potential impacts to fish and other aquatic species will be indirect. For example, partial shading impacts from the new bridge structures could alter juvenile salmon migration patterns or timing, or influence the distribution of salmonid predators in the project area. These potential impacts could reduce the number of juvenile salmon completing successful outmigration to marine waters. Impacts on individual fish, or populations of fish, resulting from habitat alterations are generally mitigated by increasing the quality and quantity of habitat for the species of interest.

Since on-site, in-kind opportunities were not feasible, WSDOT sought off-site mitigation opportunities that addressed the same functions and values that could be affected by the project. Aquatic functions and values were defined in terms of the following fish species and their life history requirements:

- Fall Chinook
- Sockeye
- Coho
- Steelhead

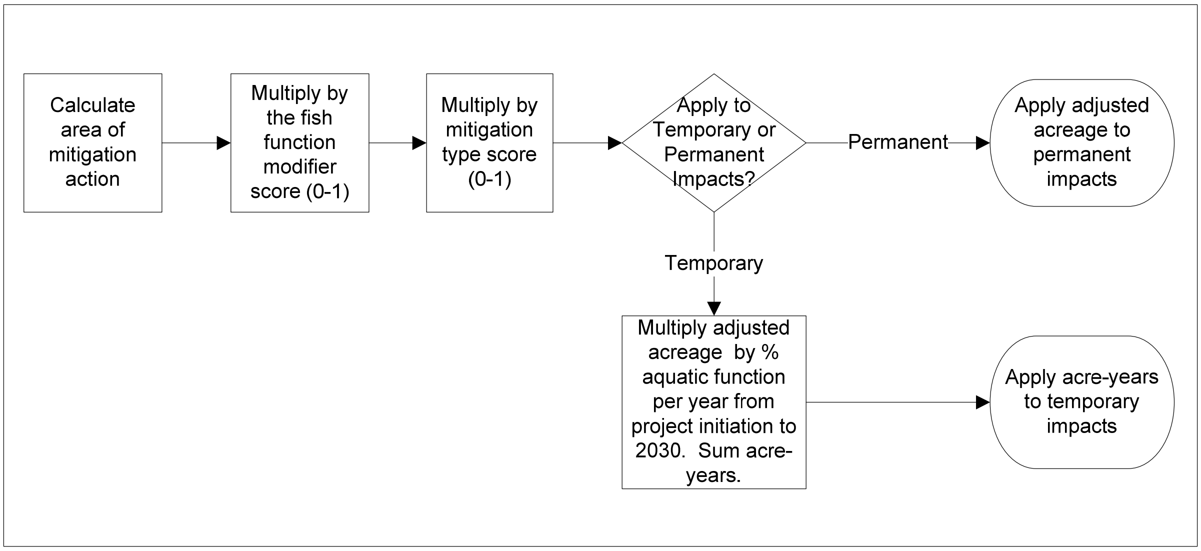
The spatial locations of project impacts and mitigation sites were classified in terms of their importance to these species, and assigned a score commensurate to their value to the focal fish. These Fish Function Modifier scores were assigned to impact and mitigation sites, in the form of a 0-1 weighting factor. Section 4.1 describes criteria and rationale for the Fish Function Modifier scoring. The acreage of a given mitigation action is multiplied by the applicable Fish Function Modifier score (Figure 5-1). Next, the mitigation acreage (adjusted by Fish Function Modifier score) is weighted in terms of the "Project Type" score (Figure 5-1).

Using this framework, all in-water mitigation activities (riprap removal, shoreline grading, levee removal, dredging) were assigned a Project Type score of 1.0. A score of 1.0 is indicative of the direct and immediate aquatic benefits that these projects produce. Riparian and floodplain restoration projects received a score of 0.2, to recognize the delay in achieving full function/and or the indirect nature of these projects to functioning aquatic habitat. While riparian function along the shoreline may directly benefit fish (e.g., fish cover), the functional value becomes indirect farther from the shoreline (e.g., pollutant filtration, shading, etc.). Floodplains provide indirect fish benefits by attenuating flood flows, performing water quality functions, maintaining riverine wetlands, providing off-channel salmonid habitat, and providing the opportunity for dynamic channel creation over time. Mitigation areas that improve both riparian and floodplain functions received a Project Type score of 0.4 to reflect the additive value of riparian and floodplain functions. After adjusting the mitigation acreages by Fish Function Modifier and Project Type scores, the adjusted acreage can be applied to permanent impacts (see Section 4.1).

If the adjusted mitigation acreage is applied to temporary impacts instead of permanent impacts, an additional step is required. Temporary impacts are calculated in terms of weighted acre-years (see Section 4.1). Restoration actions that are intended to mitigate for these temporary impacts must also be valued in terms of their temporal contribution to aquatic functions and values. The acreage of each mitigation action (adjusted by Fish Function Modifier and Project Type scores) is multiplied by the percent aquatic function that the project provides on an annual basis for the first 18 years after project completion. For example, if a mitigation project was completed in 2012, temporary mitigation credit will be counted until 2030 (18 years).

Projects that have full and immediate benefits are multiplied by 1.0 (i.e., 100% function) for all 18 years. Projects that take time to realize full function are multiplied by an increasing proportion (i.e., percent function) over time. Riparian restoration projects are assumed to realize 10% function during years 1 through 5, 50% function during years 6 through 10, and 100% function thereafter. The acre-years for all 18 years are summed to yield a total mitigation value that can be credited toward temporary impacts.

Figure 5-1. Process for Determining Value of Mitigation Actions



This page intentionally left blank.

6. Aquatic Mitigation Sites

6.1 Rationale for Site Selection

The goal of the mitigation screening and ranking process was to select a suite of habitat restoration projects that increase aquatic functions and values enough to offset the SR 520, I-5 to Medina Project's effects on similar functions and values. Chinook salmon, sockeye salmon, coho salmon, and winter steelhead were chosen as key indicator species because they are the most studied species in the watershed and a comprehensive data set is available linking salmonids to habitat variables in the watershed (City of Seattle and USACE 2008; King County 2005).

The project will affect four key life history functions of Lake Washington salmonids: juvenile rearing/ feeding, juvenile migration, adult migration, and lakeshore beach spawning. The mitigation screening approach looked at habitat features and ecological functions that supported these key life history phases in Lake Washington, and linked them with potential enhancements of such features.

Mitigation opportunities were sought from throughout WRIA 8, specifically in the marine nearshore, the Ship Canal, and throughout Lake Washington, and were organized through a screening plan (WSDOT 2009c). However, the results of this plan were substantially adjusted through agency input, coordination, and further field work.

Mitigation Opportunities in the Marine Nearshore and Ship Canal

Mitigation opportunities along the marine nearshore (and in proximity to the Ship Canal) were extremely limited. WSDOT continues to work with the resource agencies and tribes in identifying mitigation measures that might be applied to the Lake Washington Ship Canal to benefit adult fish survival and migration into the Lake Washington system. Opportunities being evaluated focus on increasing the quantity of fish habitat available to fish and improving water quality by reducing water temperatures in the Ship Canal during the mid- to late-summer time period (June – October). WSDOT is working on evaluating the feasibility of these mitigation opportunities and will provide updates during this evaluation phase. If a feasible opportunity is identified and pursued, it would replace one or more mitigation measures identified in this report.

Mitigation Opportunities in Lake Washington

The objectives of the Lake Washington General Investigation (City of Seattle and USACE 2008) include habitat improvement for juvenile salmon in Lake Washington. The Lake Washington General Investigation prescribed management actions to support this objective, including the following:

- Continue to remove shoreline armoring and create shallow-water habitat with overhanging vegetation. These actions will improve rearing conditions for Chinook fry. Focus these activities in the southern portion of Lake Washington.

- Continue to improve habitat around over-water structures by removing structures, reducing their footprint, or by improving light penetration.

- Remove in-water solid waste debris (e.g., concrete, asphalt, and scrap metal) and riprap to reduce available predator habitat.

- Prioritize the restoration of tributaries and tributary mouths in south Lake Washington tributaries.

Some project opportunities in Lake Washington are located along juvenile salmonid migration routes; these opportunities were prioritized, because of the relatively high fish benefits. Juvenile Chinook (and sockeye to a lesser extent) use the lake shoreline for foraging, rearing, and refugia from predators (Tabor and Piaskowski 2002). They also slowly migrate along the shoreline toward the Ship Canal during this time. As noted above, once juvenile salmonids have migrated into the Ship Canal, holding and foraging is not desirable because of rapidly-degrading water quality in the late spring and the presence of warm-water predators. However, opportunities for habitat improvement along the more desirable Lake Washington migration corridors are extremely limited because the overwhelming majority of opportunities are on private residential land (WSDOT 2009c). These private residential lots were not pursued, because restoration of the narrow shoreline on a typical residential lot would not result in a large habitat gain. Projects on individual parcels would be surrounded by adjacent bulkheads, piers, and docks. Acquiring multiple contiguous residential properties was considered very unlikely. Out of the limited public property with shoreline that has fisheries value, the following sites have been prioritized for restoration by the WSDOT 520 Program:

- Seward Park

- Magnuson Park

- Taylor Creek

- South Lake Washington Shoreline Restoration (DNR Parcel)

- East approach

These mitigation sites are described in the subsequent sections of this section. The site locations are shown at the landscape scale in Figure 6-1. The known salmonid uses of each site, as well as their Fish Function Modifier scores, are shown in Table 6-1.

Mitigation Opportunities in Lake Washington Tributaries

Habitat improvement in the WRIA 8 Lake Washington tributaries is also an objective defined in the WRIA 8 watershed management plans. The WRIA 8 Chinook Salmon Conservation Plan (King County 2005) prioritizes the Lower Cedar River for restoration with a focus on actions that protect water quality, restore riparian zones, increase LWD and pools in the river (via installation and natural recruitment), and set back levees to increase floodplain function and off-channel habitat. The Chinook Salmon Conservation Plan also recommends restoration actions on Lower Bear Creek, Upper Bear Creek, and Cottage/Cold Creeks. However, the plan indicates that Lower Bear Creek has the poorest habitat function of these three water bodies.

WSDOT will address these restoration priorities by implementing restoration projects at the following riverine locations:

- Cedar River/ Elliott Bridge reach
- Lower Bear Creek, near the mouth

The current and potential use of these mitigation sites by the focal fish species is discussed in detail in subsequent sections. Although none of the sites meet the “very high” fish function criteria (Table 6-1), they are all important locations in the watershed and will provide ecological functions that are priorities for fish recovery.

These sites have undergone a basic screening for fatal flaws such as site access, landowner consent, hazardous materials, and cultural resources. However, if it becomes apparent during advanced design that a site is no longer feasible due to technical constraints, the site will be removed from this plan and replaced with another appropriate mitigation site. A mitigation site may also be replaced with another if WSDOT develops a new site concept that is of higher ecological value or has more ecological value per monetary cost for the State of Washington.

This page intentionally left blank.

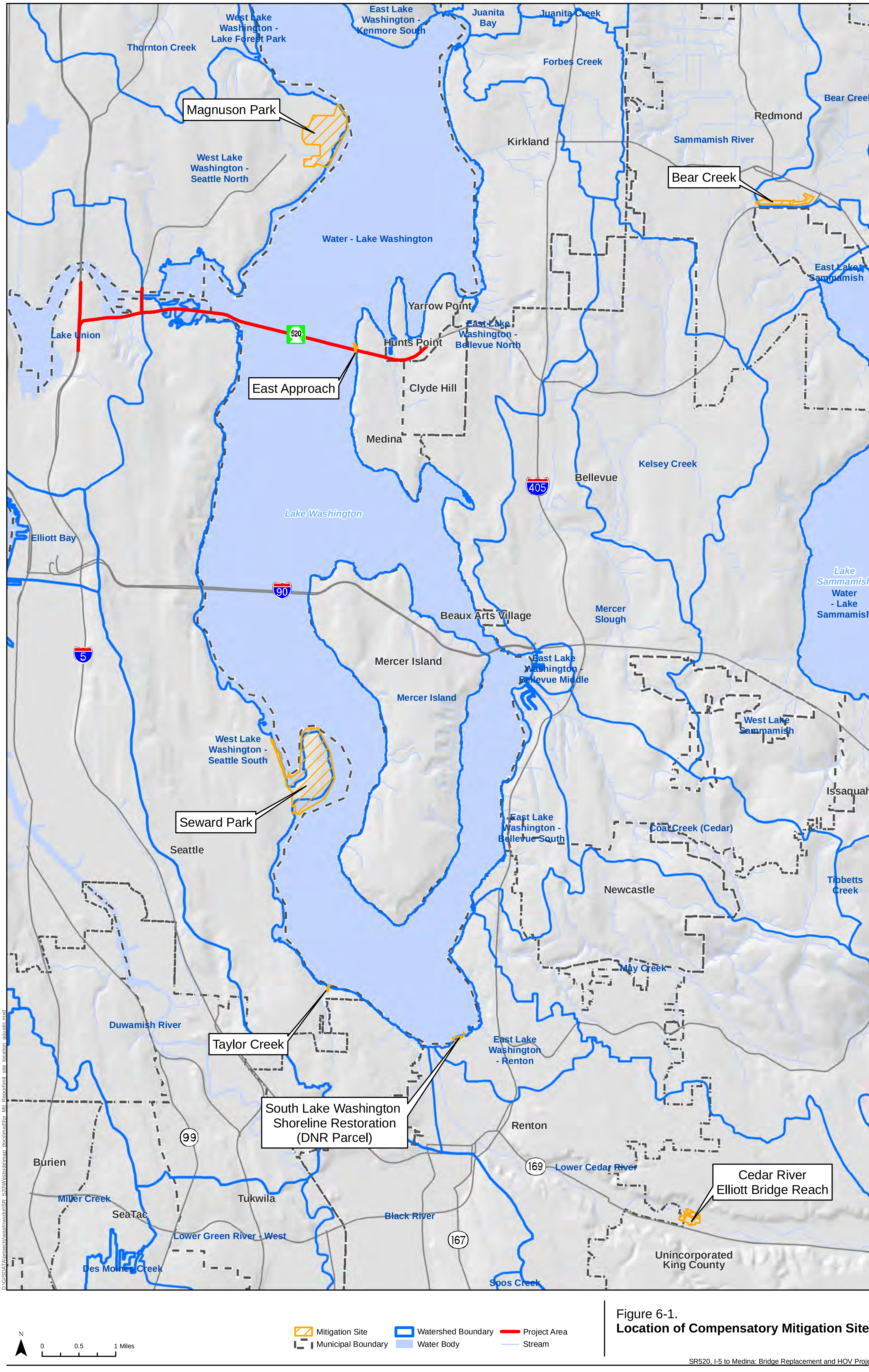


Figure 6-1.
Location of Compensatory Mitigation Sites

SR520, I-5 to Medina: Bridge Replacement and HOV Project

Table 6-1. Mitigation Site Fish Use and Fish Function Modifier Scores

Fish Function Modifier Score	Proposed Mitigation Site Classification	Adult Salmonid Use	Juvenile Salmonid Use	Stocks Affected
0.8 – High and 0.6 – Medium	**Seward Park** Shoreline Enhancements	Sockeye (Spawning)	Chinook (Rearing) Sockeye (Rearing/Feeding)	Taylor Creek Cedar River Lake Washington
0.8 – High	**Magnuson Park** Shoreline Enhancements	Sockeye (Spawning)	Chinook (Rearing) Sockeye (Rearing/Feeding)	North Lake Washington Issaquah Lake Washington
0.8 – High	**Taylor Creek** Restoration	Coho (Spawning) Sockeye (Spawning)	Coho (Rearing) Chinook (Rearing) Sockeye (Rearing/Feeding)	Taylor Creek Cedar River
0.8 – High	**South Lake Washington Shoreline Restoration (DNR Parcel)** Shoreline Enhancements		Chinook (Rearing/Feeding) Chinook (Migration) Sockeye (Rearing; Feeding)	Cedar River
0.8 – High	**Cedar River/ Elliott Bridge Reach** Enhancements	Coho (Spawning) Sockeye (Spawning) Chinook (Spawning) Steelhead (Spawning	Coho (Rearing/Feeding) Steelhead (Rearing/Feeding) Chinook (Rearing/Feeding	Cedar River
0.8 – High	**Bear Creek** Restoration	Sockeye (Spawning) Chinook (Spawning)	Sockeye (Rearing/Feeding) Chinook (Rearing/Feeding) Coho (Rearing/Feeding)	North Lake Washington
0.8 – High	**East Approach** Spawning Beach Enhancement	Sockeye (Spawning)		Lake Washington

This page intentionally left blank.

6.2 Seward Park Site

6.2.1. Site Location

Seward Park is in the City of Seattle, along the western shore of Lake Washington, as shown on Figure 6-1.

6.2.2. Mitigation Site Existing Conditions and Fish Use

Shoreline Conditions

Seward Park has an extensive shoreline. The shoreline has discontinuous segments that vary by the presence of bank height, bank slope, bulkheads, native vegetation, or nuisance aquatic vegetation. Many of these shoreline segments were armored as early as 1916, and in many places the rock used for armoring has been displaced into the nearshore, creating a cobble substrate. Some segments of the park shoreline were restored in 2001 and 2006 by re-grading the bank to a lower slope, importing gravel to the re-sloped beaches, installing LWD for fish cover, and re-vegetating narrow riparian zone strips immediately adjacent to the shoreline.

Ecological Condition of Adjacent Parcels

Parcels adjacent to Seward Park are residences with bulkheads and docks (to the south), and include a marina (to the north).

Fish Use

The Seward Park shoreline is used by juvenile Chinook for feeding, rearing, and migration from the Cedar River toward the Ship Canal, though Chinook abundance is lower here than along the South Lake Washington shoreline (Tabor and Piaskowski 2002). The shoreline segments with shallow water and vegetative cover provide food resources (invertebrates) and protection from piscivorous fish and avian predators. The absence of piers, ramps, and floats along the park's natural shorelines allows unhindered migration along the area's littoral zone. Historical records document sockeye spawning along the Seward Park nearshore (WDFW map records; K. Buchanan, Fish Biologist, WDFW, Olympia, Washington. July 26, 2004. Pers. Comm.).

6.2.3. Rationale for Site Selection

Seward Park was selected for shoreline and riparian restoration because of documented use of this shoreline by Chinook salmon juveniles for foraging, rearing, and outmigration. Sockeye salmon may use the Seward Park shoreline for spawning. Some adjacent shoreline segments were restored in 2001 and 2006 by providing shallow water habitat and sediment that will support both juvenile rearing and spawning. Recent effectiveness monitoring of these shoreline restoration projects concluded that the shallow habitat was functioning for juvenile Chinook refugia and migration. However, the gravel supplementation did not significantly increase epibenthic prey preferred by juvenile Chinook (Armbrust et al. 2009). This monitoring study recommended incorporating organic material into the gravel. The proposed restoration project will be very similar to these past projects, and will also cover eroded quarry spall along the shoreline with appropriate substrate. The size and amount of organic material in the new substrate will be determined by the erosive potential along the shoreline. Past gravel supplementation projects on adjacent shoreline segments have determined that wave exposure and lake currents will mobilize and erode pea gravel and finer sediments (Seattle Parks, pers. comm.). Covering the quarry spall with coarse gravel, however, will have multiple benefits, including reducing predator (e.g., sculpin) habitat and providing suitable substrate for sockeye spawning. The Seattle Parks Department owns this property and will allow WSDOT to implement the projects. Seward Park will be owned by the City of Seattle into the foreseeable future.

6.2.4. Mitigation Site Design

Seward Park Project 1

There are four discrete mitigation opportunities on the Seward Park property. Project 1 is located on the southern portion of the peninsula, due east of the parking lot (Figure 6-2). This segment is approximately 550 feet long, has a vertical concrete bulkhead (2.5 feet high, 3 feet wide) along its length, and has very little riparian vegetation (Figure A-1). The vertical elevation gain between the uplands and the lake water level is approximately 6 to 7 feet (Appendix B). Mitigation actions at this site will include bulkhead removal, bank regrading, gravel installation, and riparian revegetation (Figure 6-2). Revegetation will include a mixed willow/emergent community near high lake level elevation and transition to a riparian upland community. Proposed planting palettes for revegetation are included in Appendix C. Specific planting plans will be based on site-specific conditions and constraints. The shoreline east of Project 1 has been previously restored.

Seward Park Project 2

Seward Park Project 2 is located on the northeastern portion of the peninsula (Figure 6-3). The sum of the two lengths of this segment is approximately 500 feet. The segment has a riprap bulkhead along its length, and has very little riparian vegetation (Figures A-2 and A-3 in Appendix A). The vertical elevation gain between the uplands and the lake water level is approximately 5 feet (Appendix B). Mitigation actions at this site will include gravel installation, and riparian revegetation (Figure 6-3). Because the riprap is largely above the managed lake levels and thinly applied, plants will be installed through the riprap matrix. Revegetation will include a mixed willow/ emergent community near high lake level elevation and transition to a riparian upland community. Riparian plantings will be installed along the riprap face and adjacent uplands. Proposed planting palettes for revegetation are included in Appendix C. Specific planting plans will be based on site-specific conditions and constraints. A previously-restored segment of the shoreline is adjacent and to the southeast of Project 2. A heavily-used swimming area is located adjacent and to the west of Project 2.

Seward Park Project 3

Seward Park Project 3 is located on the northwestern portion of the peninsula (Figure 6-3). The sum of the two lengths of this segment is approximately 800 feet, and the segment has very little riparian vegetation. A small restoration project occurred between the two portions of this segment, and included bank re-sloping and LWD installation along the shoreline. Mitigation actions at this site will include riparian revegetation. The northern portion of this segment will require only underplanting (enhancement) under existing trees. The southern portion of this segment will require full revegetation. The park path is very close to the shoreline along both portions of this segment and will limit revegetation to a 5- to 10-foot width. Revegetation will include a mixed willow/emergent community near high lake level elevation and transition to a riparian upland community. Proposed planting palettes for revegetation are included in Appendix C. Specific planting plans will be based on site-specific conditions and constraints.

Seward Park Project 4

Seward Park Project 4 is located on the western portion of the peninsula (Figure 6-2). The length of this segment is approximately 500 feet and the segment has sporadic trees and no understory vegetation. Mitigation actions at this site will include only underplanting (enhancement) under existing trees. The average width of enhancement will be 15 feet. The adjacent nearshore is infested with water lilies; these non-native plants will be removed to provide viable habitat for juvenile salmonids. Revegetation will include a mixed willow/ emergent community near high lake level elevation and transition to a riparian upland community. Proposed planting palettes for revegetation are included in Appendix C. Specific planting plans will be based on site-specific conditions and constraints.

This page intentionally left blank.

Seward Park Project 1+4	
Mitigation Action	Acreage
Shoreline Enhancement + Hard Structure Removal	0.47
Riparian Enhancement	0.74

D:\GISDATA\projects\wash\wsdot\SR 520\Westside\map docs\mxd\Aquatic\Final Sites\SewardPark2.mxd

Figure 6-2.
Conceptual Restoration Plan at the Seward Park Mitigation Site, Projects 1 and 4

This page intentionally left blank.

Seward Park Project 2+3	
Mitigation Action	Acreage
Shoreline Enhancement	0.59
Riparian Restoration	0.57

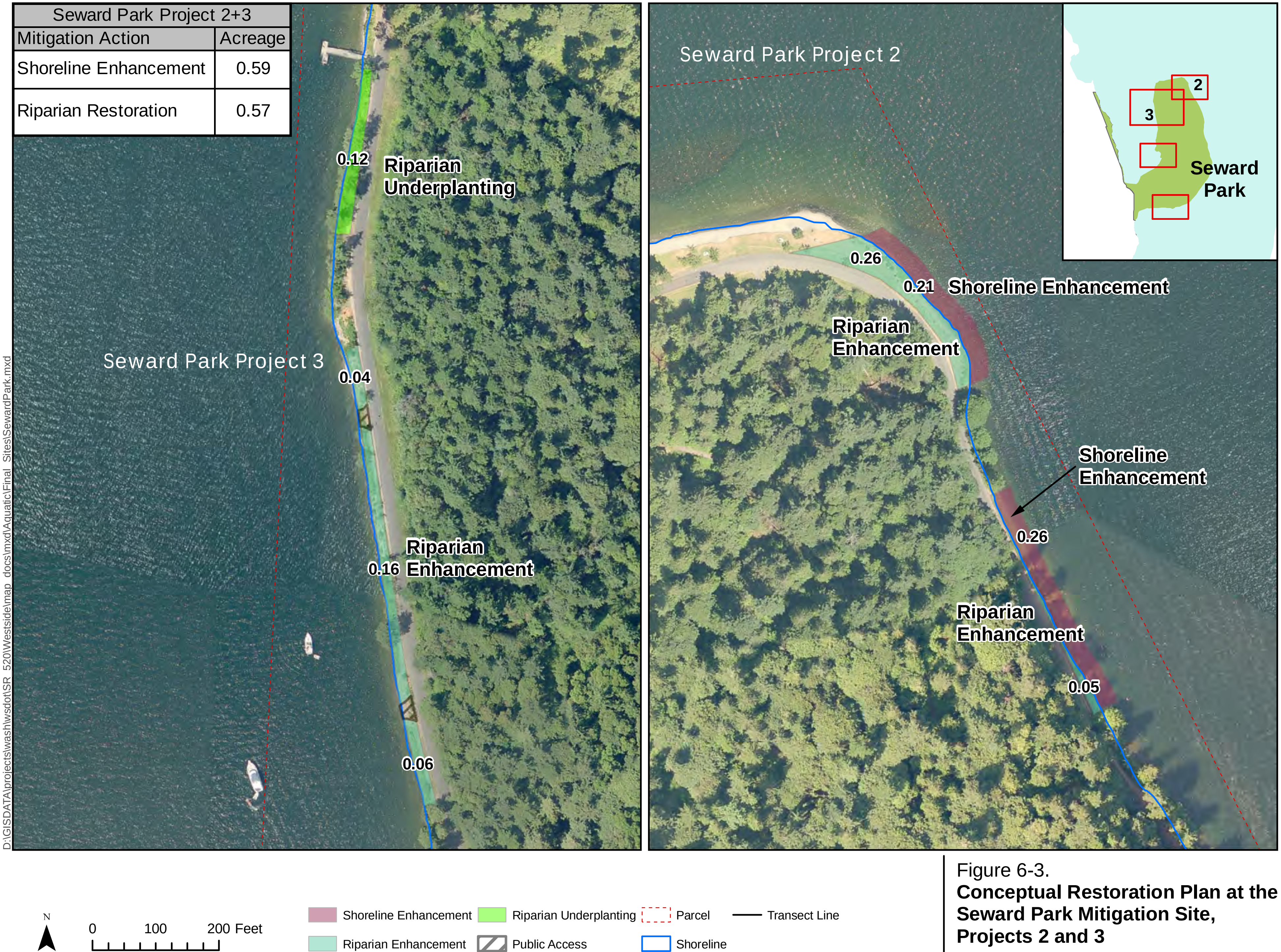


Figure 6-3.
Conceptual Restoration Plan at the Seward Park Mitigation Site, Projects 2 and 3

This page intentionally left blank.

6.2.5. Ecological Functions and Benefits

The mitigation actions at Seward Park will benefit the Cedar River Chinook juveniles and lake spawning sockeye salmon (Table 6-2). The juvenile Chinook will benefit from the conversion of shorelines with bulkheads to a gradual, sloping natural condition with functional riparian vegetation. These improved habitat features will provide an unobstructed migratory pathway, protection from piscivorous and avian predators, and enhanced food sources from the natural sediments and overhanging vegetation. Sockeye salmon could benefit from the gravel supplementation along the shoreline at projects 1 and 2 (Table 6-2). Sockeye salmon are known to spawn along the Seward Park shoreline, particularly where there is sufficient current to move water through the gravels. Sockeye fry use the shoreline less than Chinook juveniles. However, since fry have been documented using the littoral zone during very early rearing (Martz et al. 1996), a functional littoral zone adjacent to suitable lake spawning habitat may be important.

The acreages of each mitigation type were weighted per the fish function and mitigation type modifiers (Table 6-1). Seward Park Projects 1 and 2 were assigned a Fish Function Modifier of 0.8 because of known migration and rearing of juvenile Chinook and historical documentation of sockeye beach spawning. Projects 3 and 4 were assigned a Fish Function Modifier of 0.6 because of known, but limited rearing of juvenile Chinook, and no documented sockeye spawning. The mitigation value of Seward Park will be credited toward temporary impacts associated with the temporary work bridge (see Section 6.10.1). Temporary shading, fill, and predator habitat will disproportionately affect juvenile Chinook, relative to other species and stocks. The mitigation actions will benefit survival of outmigrating juvenile Chinook by increasing habitat function along their migratory path toward the Ship Canal.

Table 6-2. Seward Park Mitigation Benefits

<table>
<tr><th>Mitigation Action</th><th>Acreage</th><th>Habitat Features Improved</th><th>Habitat Functions Improved</th><th>Species/Life Stage Addressed</th></tr>
<tr><td>Shoreline Enhancement + Hard Structure Removal</td><td>0.94</td><td>Gradual, sloped bank
Suitable sediment
Prey input</td><td>Protection from predators
Migratory corridor
Spawning habitat</td><td rowspan="2">Chinook
(Juvenile Rearing/Feeding)
Chinook
(Juvenile Migration)
Sockeye
(Juvenile Rearing/Feeding)
Sockeye (Spawning)</td></tr>
<tr><td>Riparian Restoration</td><td>1.42</td><td>Vegetative cover
Prey input</td><td>Protection from predators
Food sources</td></tr>
</table>

6.3 Magnuson Park Site

6.3.1. Site Location

The Magnuson Park mitigation site is located on the northwest shore of Lake Washington (Figure 6-1). Four separate reaches are proposed for mitigation actions (Figure 6-4).

6.3.2. Mitigation Site Existing Conditions and Fish Use

Shoreline Conditions

Magnuson Park has an extensive shoreline. The shoreline has discontinuous segments that vary by presence of bulkheads, presence of native vegetation, bank height, and bank slope. Similar to Seward Park, some segments of the Magnuson Park shoreline have been restored by regrading the bank to a lower slope, importing gravel to the re-sloped beaches, and revegetating narrow riparian zone strips immediately adjacent to the shoreline. A boat launch on the southern end of the park has a heavily armored shoreline at approximately 50 feet on either side of the ramps, and is incompatible with shoreline restoration. Two swimming areas are also incompatible with restoration.

Ecological Condition of Adjacent Parcels

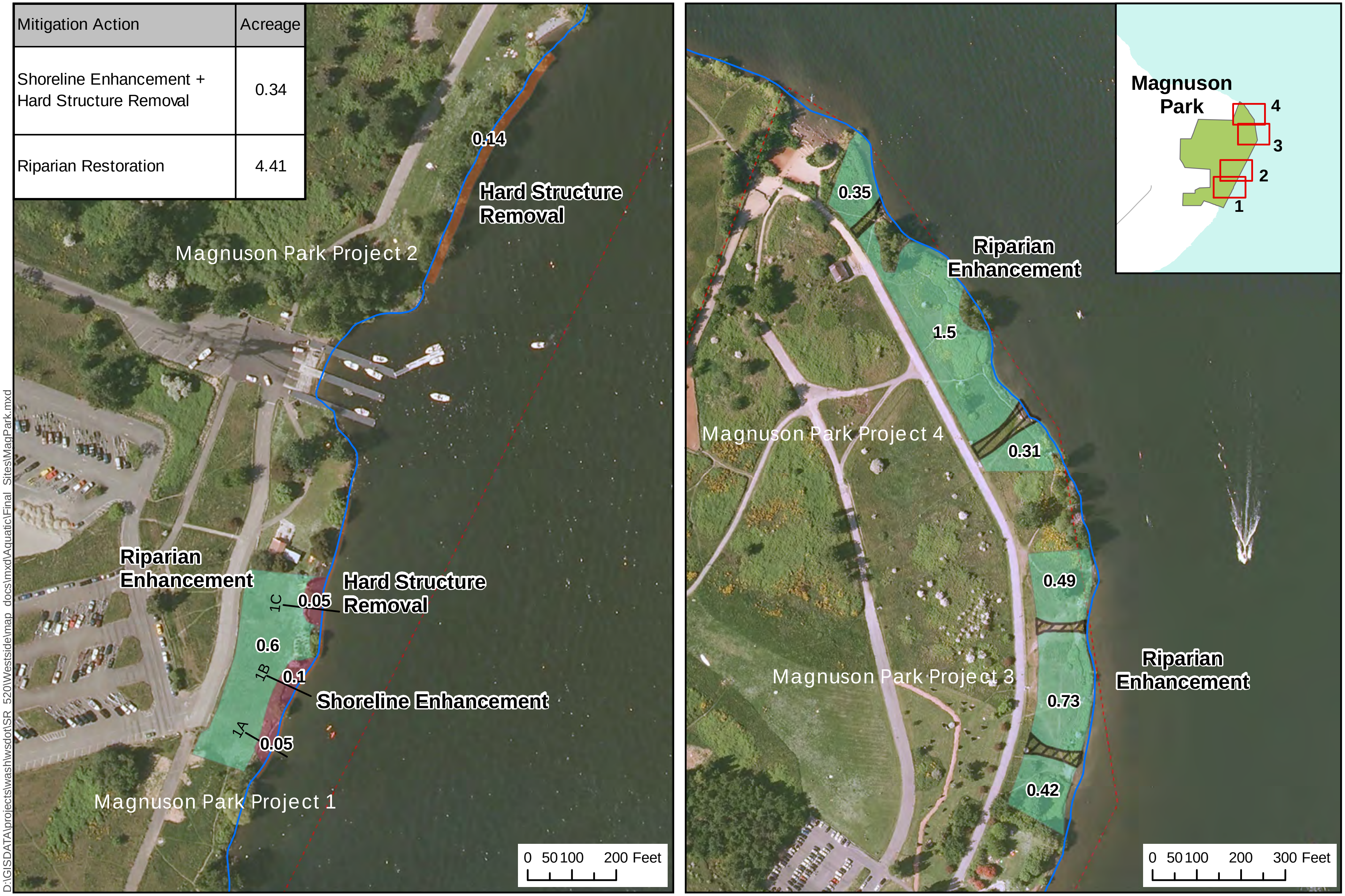
The adjacent parcels south of Magnuson Park are residences with bulkheads and docks. The adjacent parcels to the north and west belong to the National Oceanic and Atmospheric Administration (NOAA). The adjacent NOAA shoreline has a character similar to that of the Magnuson Park shoreline.

Fish Use

The Magnuson Park shoreline is used by juvenile Chinook from the North Lake Washington tributaries and the Sammamish/Issaquah Creek system as they migrate toward the Ship Canal. The shoreline segments with shallow water and cover are used by the juvenile Chinook for rearing, foraging, and refugia. North Lake Washington Chinook juveniles have bimodal migration timing, with a some 0+ juveniles migrating out of their natal streams toward the lake as newly emerged fry (35–40 millimeter [mm] fork length) in early spring and others as smolts (85–95 mm fork length) in late May–June (Seiler et al. 2003). The early fry probably use the Magnuson Park shoreline and other nearshore areas in Lake Washington for rearing, foraging, and migration. The larger Chinook juveniles reside in waters between 3 and 18 feet deep during the day, primarily over sand-gravel substrates. These larger juveniles will use the shoreline features for fish cover on an infrequent basis (King County 2005).

Historical records document sockeye spawning along the Magnuson Park nearshore (WDFW map records; K. Buchanan, Fish Biologist, WDFW, Olympia, Washington. July 26, 2004. pers. comm.). Sockeye fry originating from adults spawning on the Magnuson Park shoreline may use the littoral zone for very early rearing.

Mitigation Action	Acreage
Shoreline Enhancement + Hard Structure Removal	0.34
Riparian Restoration	4.41



N

Hard Structure Removal
Shoreline Enhancement
Shoreline Enhancement +Hard Structure Removal
Riparian Enhancement
Public Access
Shoreline
Parcel
Transect Line

Figure 6-4.
Conceptual Restoration Plan at the Magnuson Park Mitigation Site

This page intentionally left blank.

6.3.3. Rationale for Site Selection

Magnuson Park was selected for shoreline and riparian restoration because of its documented use by North Lake Washington and Sammamish/Issaquah Chinook salmon juveniles for foraging, rearing, and migration toward the Ship Canal (Seiler et al. 2003). Some shoreline segments in and adjacent to the park have already been restored. The proposed restoration mitigation project will build on these past efforts and provide a more continuous natural shoreline. The Seattle Parks Department owns this property and will allow WSDOT to implement the mitigation projects. Magnuson Park will be owned by the City of Seattle into the foreseeable future.

6.3.4. Mitigation Site Design

Magnuson Park Project 1

There are four discrete mitigation opportunities on the Magnuson Park property. Magnuson Park Project 1 is located south of the boat launch (Figure 6-4). The length of this segment is approximately 200 feet and it has very little functional riparian vegetation (Figure A-5 in Appendix A). A 2-foot-high vertical bank is actively eroding and has concrete/asphalt rubble along the shore. Vertical profiles are provided in Appendix B. Mitigation actions at this site will include bank re-sloping, gravel augmentation, LWD installation, and revegetation. Proposed planting palettes for revegetation are included in Appendix C. Specific planting plans will be based on site-specific conditions and constraints.

Magnuson Park Project 2

Magnuson Park Project 2 is located north of the boat launch (Figure 6-4). The length of this segment is approximately 450 feet and the segment has a narrow band of functional riparian vegetation that provides fish cover (Figure A-6). However, a 2-foot-wide concrete bulkhead about 5 feet waterward of the shoreline is a barrier to fish accessing this functional shoreline (Figure A-6). Mitigation actions at this site will include removal of this bulkhead. The existing root structure of the bank vegetation will likely prevent shoreline erosion.

Magnuson Park Project 3

Magnuson Park Project 3 is located north of the designated swimming area (Figure 6-4). The length of this segment is approximately 450 feet and the segment has very little riparian vegetation. The average bank height is between 5 and 10 feet with pockets of gradually-sloped beach. The nearshore bathymetry along this reach is shallow and therefore has the potential to provide high-quality habitat for juvenile Chinook. Mitigation actions at this site will include revegetation of the shoreline and installation of LWD to increase fish cover. Proposed planting palettes for revegetation are included in Appendix C. Specific planting plans will be based on site-specific conditions and constraints.

Magnuson Park Project 4

Magnuson Park Project 4 is located at the northern end of the Magnuson Park shoreline (Figure 6-4). The length of this segment is approximately 600 feet and the segment has very little riparian vegetation. The average bank height is less than 5 feet along the southern 100 linear feet of the segment. The remainder of the shoreline has a bank height of around 10 feet. Mitigation actions at this site will include revegetation of the shoreline, and installation of LWD along the entire segment to increase fish cover. Proposed planting palettes for revegetation are included in Appendix C. Specific planting plans will be based on site-specific conditions and constraints.

6.3.5. Ecological Functions and Benefits

The mitigation actions at Magnuson Park will benefit a portion of the North Lake Washington and Sammamish/Issaquah Chinook juveniles that require shallow water rearing and foraging habitat, as well as lake-spawning sockeye salmon (Table 6-3). The juvenile Chinook will benefit from the conversion of the eroding shoreline and bulkheads to a gradually-sloping natural condition with functional riparian vegetation. These improved habitat features will provide an unobstructed migratory pathway, protection from piscivorous and avian predators, and enhanced food sources from the natural sediments and overhanging vegetation. The larger juveniles spend most of their time in deeper water, between 3 and 18 feet deep, but the gravel supplementation proposed within this depth range will match their preferred substrate. The Magnuson Park shoreline is located along the migratory corridor for Sammamish/ Issaquah Creek juvenile Chinook; these juveniles are using the entire littoral zone (shallow and deeper) during migration. Sockeye salmon could benefit from the gravel supplementation along the shoreline, which will improve potential spawning habitat (Table 6-3). Sockeye fry use the shoreline less than Chinook juveniles. However, since fry have been documented using the littoral zone during very early rearing (Martz et al. 1996), a functional littoral zone adjacent to suitable lake spawning habitat may be important.

The acreages of each mitigation type were weighted per the fish function and mitigation type modifiers (Table 6-1). The four Magnuson Park Projects were assigned a Fish Function Modifier of 0.8 because of known migration and rearing of juvenile Chinook and historical documentation of sockeye beach spawning along the shoreline. The mitigation value of Magnuson Park will be credited toward temporary impacts associated with the temporary work bridge (see Section 6.10.1). Temporary shading, fill, and predator habitat will disproportionately affect juvenile Chinook, relative to other species and stocks. The mitigation action benefits survival of juvenile Chinook by increasing habitat function along their migratory path toward the Ship Canal.

Table 6-3. Magnuson Park Mitigation Benefits

Mitigation Action	Acreage	Habitat Features Improved	Habitat Functions Improved	Species/ Life Stage Addressed
Shoreline Enhancement + Hard Structure Removal	0.34	Gradual, sloped bank Suitable sediment Prey input	Protection from predators Migratory corridor Suitable spawning habitat	Chinook (Juvenile Rearing/Feeding) Chinook (Juvenile Migration) Sockeye (Juvenile Rearing/Feeding) Sockeye (Spawning)
Riparian Restoration	4.41	Vegetative cover Prey input	Protection from predators Food sources	

6.4 Taylor Creek Site

6.4.1. Site Location

Taylor Creek is located in southeast Seattle (Figure 6-1). It is the fourth-largest creek in Seattle and drains a predominantly residential and park watershed. Its headwaters lie in King County and over two-thirds of the creek flows through relatively undisturbed wooded areas. Within the city limits, the creek flows through a large forested park before flowing into Lake Washington close to the southern city limits. The creek is unique in Seattle because of the length of contiguous forested buffers, low levels of development, and intact headwater wetlands. Taylor Creek enters the lake approximately 1.7 miles from the mouth of the Cedar River.

6.4.2. Mitigation Site Existing Conditions and Fish Use

Shoreline Conditions

The site's shoreline along Lake Washington consists of a delta that is armored with cobble in the prevailing flow paths, and gravel and sand in the remainder (Figure A-7 in Appendix A). The delta transitions into a sandy beach with small pockets of marsh vegetation (i.e., rushes). This very narrow marsh fringe transitions into a residential lawn (Figure A-8). Upstream from the delta, the creek flows through residential properties for 560 feet before reaching Rainier Avenue South (Figure A-9). The stream habitat in this reach is degraded because it has been confined by modifications including concrete walls, boulders, and pavers. The channel has been straightened to allow for historical industrial use and current residential use adjacent to the creek. The riparian/ floodplain area has been modified with fill, residential homes, asphalt driveways, and a patio/dock structure on the shoreline. The small amount of vegetation along the creek consists of a few mature trees and ornamental plants. The culvert under Rainier Avenue South is a total barrier to salmonids. No salmon have been found upstream of Rainier Avenue South for decades. The culvert was built in sections over time with different-sized pipes. Portions of the culvert are on private property.

Ecological Condition of Adjacent Parcels

Adjacent parcels along the shoreline and creek are high-density residential. The shoreline consists of bulkheads and docks.

Fish Use

Taylor Creek is used by sockeye, coho, and Chinook salmon, as indicated during surveys by Washington Trout (2000). These surveys are part of an annual program to document spawning salmon. Washington Trout inspects Seattle's major creeks weekly during the spawning season and documents the number of live and dead fish as well as the locations of redds (excavations dug by salmonids in gravel or other substrate for depositing eggs). Annual salmon spawning surveys have found coho and sockeye pooling just downstream of Rainier Avenue South. The results of these surveys are shown in Table 6-4. Juvenile Chinook use the Taylor Creek delta and convergence pool for feeding and rearing, but cannot access the upstream habitat because the gradient is too high (Tabor et al. 2004a). Tabor et al. (2010b) surveyed Taylor Creek in the summer and found juvenile Chinook and coho in Taylor Creek.

Table 6-4. Spawning Survey Results on Taylor Creek

Year	Coho	Sockeye
2000	0	28
2001	2	20
2002	4	29

Source: SPU and Washington Trout

A fish use and habitat evaluation of Taylor Creek concluded that the creek is capable of supporting coho and sockeye (Washington Trout 2000).

6.4.3. Rationale for Site Selection

The WRIA 8 Chinook Salmon Recovery Plan (King County 2005) prioritized the reduction of predation on juvenile migrants in Lake Washington by providing increased rearing and refuge opportunities. The Recovery Plan prescribes the restoration of shallow water habitats and creek mouths for juvenile rearing and migration. Chinook are known to make extensive use of tributary habitat in South Lake Washington (Tabor et al. 2006).

6.4.4. Mitigation Site Design

The stream, delta, and riparian restoration proposed by WSDOT will work in concert with restoration actions that will be implemented by SPU. SPU is currently developing plans to re-route Taylor Creek under Rainier Avenue South to the southeast at a new grade. This work will accomplish the following objectives:

- Provide full fish passage for all life stages and species of native salmonids.
- Pass flows beyond the 25-year flood event to meet drainage service levels.
- Minimize any flow constrictions that affect flooding conditions.

SPU has already acquired the properties in the WSDOT project area, below Rainier Avenue South to Lake Washington (Figure 6-5). SPU is currently developing alternative restoration designs for the WSDOT project area. WSDOT will implement restoration actions in the WSDOT project area to accomplish the following objectives:

- Ensure that stream flows, stream channel configurations, gradient, and woody debris allow for proper sediment transport and minimize maintenance needs in the stream and culvert.
- Increase floodplain and stream capacity and natural floodplain and stream functions.
- Improve spawning and rearing conditions for native salmonids, with an emphasis on juvenile Chinook rearing habitat along the lake shoreline and in the creek (Tabor et al. 2006).

All structures, impervious surfaces, non-essential utilities, underground storage tanks, and the existing patio and dock will be removed. In addition, the existing channel armoring and floodplain fill will be removed, providing a natural floodplain grade. The creek will be reconstructed with a natural meander pattern that will result in pool-riffle morphology. This will be accomplished using appropriate hydraulic and sediment modeling tools, and will likely involve the use of LWD and engineered logjams (ELJs) to reinforce the meander pattern and create the desired habitat features in the short-term. The mouth and delta of Taylor Creek will be configured to minimize constraints on the natural evolution of the stream delta. The cobble substrate that is currently armoring the delta will be removed. This will expose the smaller sand and gravel and will allow for a more complex delta that is passable by juvenile and adult salmon.

The entire project area up to the shoreline fringe will undergo riparian and floodplain restoration. Berms will be created along the parcel boundaries to allow natural flooding in the project area, but protect adjacent private property. Once the riparian vegetation has become established, it will provide cover, bank stability, water quality filtration, and (long-term) LWD recruitment.

The relatively flat topography of the shoreline adjacent to the delta will be planted with native marsh and riparian vegetation. Lake Washington water levels, as managed by USACE via the Ballard Locks, will seasonally inundate this area. Proposed planting palettes for revegetation are included in Appendix C. Specific planting plans will be based on site-specific conditions and constraints.

6.4.5. Ecological Functions and Benefits

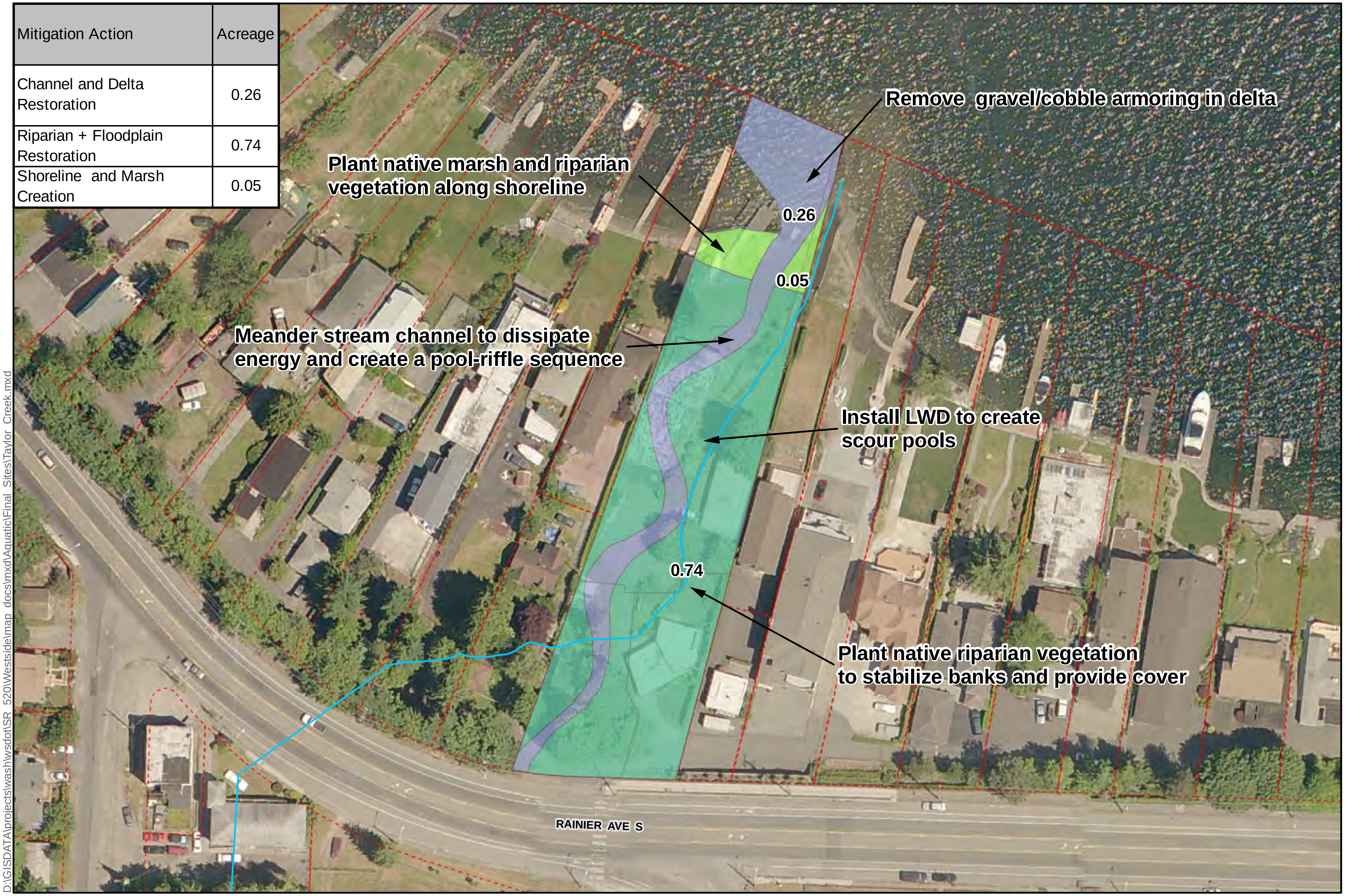
The proposed channel will be more complex and much less confined. This proposed condition will benefit multiple fish uses (Table 6-5). Coho and sockeye will have suitable spawning habitat in the riffle habitat and rearing habitat in the pools and margins. Pools associated with LWD will be particularly beneficial for coho and sockeye rearing. Chinook and sockeye fry will benefit from rearing and feeding in the delta, seasonal marsh, and the vegetated margins of the creek. Because the site is a migratory and rearing area of considerable importance for juvenile Chinook salmon, its mitigation areas have a Fish Function Modifier score of 0.8 (Table 6-1).

Table 6-5. Taylor Creek Mitigation Benefits

Mitigation Action	Acreage	Habitat Features Improved	Habitat Functions Improved	Species/Life Stage Addressed
Channel and Delta Restoration	0.26	Vegetative cover Suitable sediment Fish cover Pool LWD recruitment Off-channel	Protection from predators Food sources Suitable spawning habitat	Chinook (Rearing/Feeding) Sockeye (Spawning) Sockeye (Rearing/Feeding) Coho (Spawning) Coho (Rearing/Feeding)
Riparian + Floodplain Restoration	0.74	Vegetative cover Prey input	Protection from predators Food sources	
Shoreline and Marsh Creation	0.05	Gradual, sloped bank Suitable sediment Prey input	Protection from predators Food Sources Migratory corridor	Chinook (Rearing/Feeding) Sockeye (Rearing/Feeding)

This page intentionally left blank.

Mitigation Action	Acreage
Channel and Delta Restoration	0.26
Riparian + Floodplain Restoration	0.74
Shoreline and Marsh Creation	0.05



D:\GISDATA\projects\wash\wsdot\SR 520\Westside\map docs\mxd\Aquatic\Final Sites\Taylor Creek.mxd

Project details pending acquisition of concept design information from SPU.

N

0 75 150 Feet

Fringe Emergent Wetland Creation
Riparian Enhancement
Stream channel
Parcel
Existing Stream

Figure 6-5.
Conceptual Restoration Plan at the Taylor Creek Mitigation Site

This page intentionally left blank.

6.5 South Lake Washington Shoreline Restoration (DNR Parcel)

6.5.1. Site Location

The Washington State Department of Natural Resources (DNR) manages approximately 3 acres of filled shoreline area in South Lake Washington. The property is located adjacent to the Boeing plant, approximately 1,300 feet east of the mouth of the Cedar River and 600 feet west of Gene Coulon Park (Figure 6-1).

6.5.2. Mitigation Site Existing Conditions and Fish Use

Shoreline Conditions

This property was created in 1965 when Puget Sound Power and Light (PSPL) was permitted to place 150,000 cubic yards of fill into the lake (Figure A-10 in Appendix A). The fill was placed alongside a flume made of two sheet-pile walls that PSPL used to release cooling waters from its Shuffleton Steam Plant. The flume is still located along the shoreline of this property.

Approximately half of the hardened shoreline consists of the 650-foot-long flume on the northeastern half of the project area (Figure A-11). Portions of the adjacent upland and a private dock require sections of the flume for stability. The remaining shoreline in the project area (600 feet) has a natural grade, but is hardened with riprap. The entire shoreline and riparian zone is in a degraded condition, but with native vegetation cover (Figure A-12). Three dolphins are located east of the shoreline. Dolphins are man-made structures extending above the water level and not connected to the shore. Each dolphin at this site consists of seven creosote piles.

Ecological Condition of Adjacent Parcels

The shoreline to the west is a vertical bulkhead shoreline and paved commercial yard associated with the Boeing plant. However, this degraded shoreline is only 1,200 feet long, and the mouth of the Cedar River is at the other end of this bulkhead. The shoreline to the east consists of additional lengths of the flume, a bulkhead, and a floating dock. Gene Coulon Park is located on the other side of these adjacent features, and offers additional rearing habitat for salmonids.

Fish Use

The project area is most heavily used by Chinook fry that migrate through the site from the Cedar River toward the Ship Canal. The Chinook fry primarily use the portions of shoreline that contain naturally-sloped beach, though this shoreline is degraded from the presence of riprap and lack of native vegetation. High levels of Chinook fry/smolt use have been documented on the site (Tabor et al. 2004a; Tabor et al. 2006). Sockeye fry are known to use the shallow littoral zone in South Lake Washington, especially during the early stages of rearing. Since this site is located adjacent to the mouth of the Cedar River, it is likely that sockeye fry are present in the project area during early rearing.

6.5.3. Rationale for Site Selection

The WRIA 8 Chinook Salmon Recovery Plan (King County 2005) prioritized the reduction of predation on juvenile migrants in Lake Washington by providing increased rearing and refuge opportunities. The Recovery Plan prescribes the restoration of shallow water habitats and creek mouths for juvenile rearing and migration. The South Lake Washington DNR Shoreline Restoration Project is listed as project number C266 on the 3-year work plan under the WRIA 8 Chinook Salmon Conservation Plan. This project is a Tier 1 priority under the WRIA 8 Plan due to the project's capacity to provide high-quality shallow water habitat, and location in a migratory and rearing corridor of Chinook salmon. Shorelines that are free of over-water structures, bulkheads, and other shoreline hardening structures are rare in Lake Washington.

6.5.4. Mitigation Site Design

DNR is currently developing a restoration design for this project. The objective of restoration at this parcel is to restore approximately 1.68 acres of shoreline/ aquatic habitat and approximately 2 acres of upland habitat. This is intended to improve water quality and restore migratory habitat for juvenile Chinook salmon. This project will be funded by WSDOT, but is being permitted separately by DNR. The following project elements are proposed for this project.

Shoreline Enhancement and Hard Structure Removal

The outer, waterward edge of the flume does not appear to provide structural support to the adjacent uplands and will therefore be removed (Figure 6-6). The inner, landward edge of the flume will be removed where it is not required to maintain the structural integrity of the Boeing parcel. Where the inner flume needs to be retained, the lakebed grade will be restored to the extent possible to match this shoreline elevation. This may include raising the grade of the adjacent lakebed and excavating portions of the uplands to create a gradual shoreline grade. The grade of the lakebed will be raised such that a shallow bench waterward of the shoreline will be created. The remainder of the shoreline will undergo minor regrading and enhancement for juvenile Chinook foraging and rearing habitat. Approximately 600 linear feet of riprap will need to be removed.

Additional in-water debris will be removed from the entire site to the extent that it will provide ecological benefit to do so. The entire shoreline will undergo placement of appropriately-sized sediment and incorporation of small woody debris to provide cover for juvenile salmonids at or near the 16- to 18-foot elevation range.

Two engineered features will likely be constructed along the shoreline. First, an Engineered Log Jam (ELJ) will be installed at the western edge of the existing flume to maintain the existing cove beach. Second, an ELJ will be constructed at the eastern edge of the project area to guide juvenile fish to Gene Coulon Park and Bird Island instead of along the shoreline into a future marina development.

Riparian Restoration

Approximately 2 acres of shoreline and riparian zone will be restored by removing non-native invasive plants and planting native trees and understory vegetation. The upland vegetation palette is largely open with the exception of limited easement adjacent to the Boeing property for overhanging airplane wings. Large, native plants will be installed where practicable to quickly provide overhanging vegetation fish cover along the shoreline. Proposed planting palettes for revegetation are included in Appendix C. Specific planting plans will be based on site-specific conditions and constraints.

Dolphin Removal

Three derelict dolphins, consisting of approximately 21 creosote-treated piles, will be removed from the lake. The dolphins are located along the eastern portion of the project area (Figure 6-6).

6.5.5. Ecological Functions and Benefits

Once this shoreline is restored, it will provide functional habitat features such as naturally sloped shoreline, native vegetation, LWD, and appropriately-sized substrate (Table 6-6). All these functions help meet the goals set in the WRIA 8 Chinook Salmon Conservation Plan. The plan states that the restoration of Lake Washington is a high priority for regional restoration efforts, and the remaining areas with sandy shallow water habitat, overhanging vegetation, and large woody debris should be protected and maintained. Restoration of sites close to the mouth of the Cedar River will have a significant benefit for fisheries because juvenile Chinook and sockeye salmon are very abundant near the mouth of the Cedar River (Tabor 2006). The mouth of the Cedar River does not have a functioning delta with estuarine marsh or freshwater emergent wetlands that Chinook typically depend on during early rearing (King County 2005). Therefore, Cedar River Chinook fry are dependent on suitable Lake Washington shoreline immediately adjacent to the mouth of the Cedar River during early rearing for feeding opportunities and refugia from predators. Sockeye salmon fry only use the Lake Washington shoreline early in their life history. The proximity of this site to the mouth of the Cedar River (where most sockeye enter the lake as young fry) make it one of the few areas relevant for this life history function. Since this project is a migratory and rearing area of considerable importance for juvenile Chinook and sockeye salmon, this site’s mitigation areas have a Fish Function Modifier score of 0.8 for mitigation accounting purposes.

Table 6-6. South Lake Washington Shoreline Restoration (DNR Parcel) Mitigation Benefits

Mitigation Action	Acreage	Habitat Features Improved	Habitat Functions Improved	Species/ Life Stage Addressed
Shoreline Enhancement + Hard Structure Removal	1.68	Gradual, Sloped Bank; Suitable Sediment; Prey Input	Protection from Predators; Migratory Corridor	Chinook (Juvenile Rearing/ Feeding) Chinook (Juvenile Migration) Sockeye (Juvenile Rearing/Feeding)
Riparian Restoration	2.04	Vegetative Cover; Prey Input	Protection from Predators; Food Sources	
Remove Dolphins	0.01	Removal of predator habitat and toxic material	Protection from Predators; Water Quality	

Mitigation Action	Acreage
Shoreline Enhancement + Hard Structure Removal	1.68
Riparian Restoration	2.04
Remove 3 Dolphins (7 creosote piles per dolphin)	0.01
Debris Removal	0.24

D:\GISDATA\projects\wash\wsdot\SR 520\Westside\map docs\mxd\Aquatic\Final Sites\SouthLakeWa 101510.mxd

Project details pending acquisition of 30% design information from DNR.

N

0 75 150 Feet

Flume Removal
Hard Structure Removal
Shoreline Enhancement
Riparian Enhancement
Debris Removal
Parcel

Figure 6-6.
Conceptual Restoration Plan at the South Lake Washington Shoreline Restoration (DNR Parcel) Mitigation Site

This page intentionally left blank.

6.6 Cedar River/ Elliott Bridge Site

6.6.1. Site Location

The Cedar River/Elliott Bridge site is located on the main stem Cedar River. The project area is between the 154th Place SE Bridge and the City of Renton Ron Regis Park (Figure 6-1).

6.6.2. Mitigation Site Existing Conditions and Fish Use

Shoreline Conditions

The river channel throughout most of this reach is confined and stabilized by levees and revetments, all of which contribute to a loss of connectivity between the river and its floodplain and to poor riparian conditions (King County 2005). The aquatic habitat has very little complexity, fish cover, or pool habitat for adult holding and juvenile rearing.

On the upstream half of the left (south) bank, the floodplain is unconfined. An upper terrace on the left bank floodplain is likely formed from fill (3 to 5 feet above the active floodplain; see Figure A-13 in Appendix A). Several residences with associated structures are in the project area. King County acquired these properties, including the homes and related structures, as part of a floodplain property acquisition program. These structures are vacant and slated for demolition as part of the restoration project. A levee with large riprap extends into the river; it is located about midway through the project area below the OHWM (Figure A-14). The river is confined along this stretch, resulting in concentrated flow with the potential to erode unprotected riverbanks. The river has sufficient gradient and energy to produce a dynamic channel morphology if the artificial constraints confining the existing channel are removed. Just upstream of the levee and riprap, the river has been eroding the bank. Toward the downstream end of the levee and riprap and just upstream from the old 149th Street bridge abutment, a stormwater conveyance ditch passes through the levee in two culverts and extends through the project area to the south. King County actively maintains this ditch. The 149th Street bridge abutment is still there, with large boulders in the water around the abutment.

A King County restoration area is located on the right bank, the most upstream and northeast corner of the project area; it is vegetated with an off-channel habitat feature. Immediately downstream from the restoration area, a levee extends about 500 linear feet farther downstream. The levee has large boulder-size riprap below the OHWM that extends approximately 5 feet waterward and 3 to 5 feet below the waterline (Figure A-15). The levee has cobble-sized riprap. The elevation change from the waterline to the top of the levee is approximately 7 feet. Landward of the levee, there is an elevation drop of 2 to 3 feet. There are variable amounts of fill on each residential parcel. Downstream of the levee, the floodplain is at a natural grade and is equal to or around 2 feet higher than the base flow river stage.

Ecological Condition of Adjacent Parcels

The upstream parcels along the left bank belong to King County for several thousand feet upstream. The upstream parcels along the right bank also belong to King County, but only for approximately 1,000 feet. These parcels have mature vegetation with functioning riverine and off-channel habitat. Downstream parcels on both banks are owned by the City of Renton (Ron Regis Park) for about 1,500 feet. These parcels also have mature vegetation with functioning riverine and off-channel habitat.

Fish Use

This reach provides spawning habitat for all focal species: Chinook, sockeye, coho, and steelhead (WDFW and WWTIT 1994). Sockeye spawning is particularly heavy along the left (south) bank, upstream of the levee. This reach also functions as juvenile and adult migratory habitat for the four species listed above. Although side- and off-channel habitat does not currently exist in the project area because of past development, adjacent side- and off-channel habitat occurs naturally and is likely used by all four species.

6.6.3. Rationale for Site Selection

The WRIA 8 Chinook Salmon Recovery Plan (King County 2005) identified this portion of the Cedar River as lacking the habitat diversity needed for increased Chinook salmon productivity. The plan prescribes actions to increase Chinook salmon habitat diversity including protecting and restoring riparian habitat, removing or setting back levees and revetments to restore connections with off-channel habitat, and restoring sources of LWD and installing new LWD to restore pool habitat (King County 2005). The Cedar River/ Elliott Bridge project is listed as Project #C213 on the 3-year work plan under the WRIA 8 Chinook Salmon Conservation Plan. This project is a Tier 1 priority under the plan due to the project's capability to provide floodplain connectivity and riparian functions, and the heavy use of this reach by multiple salmonid species. This project will also increase floodplain capacity in the river, thereby attenuating downstream flooding and erosion problems in Ron Regis Park, directly downstream of the project area. The study of flooding and erosion in this downstream reach is also a Tier 1 priority C214 under the 3-year work plan.

6.6.4. Mitigation Site Design

The project area will include the properties acquired by King County as part of its floodplain property acquisition plan. On the right bank, the levee and riprap will be removed. The floodplain behind the levee will undergo significant excavation, reducing the overall elevation by 3 to 5 feet (Figure 6-7). Excavation to this elevation will make wetland and off-channel habitat creation feasible. A blind channel will be cut into the floodplain, with the entrance near the old 149th Street bridge abutment. Hyporheic connectivity (connection of shallow groundwater to surface water) and upland hydrologic sources will be utilized to maintain wetlands that will be connected to the blind channel. Similar channels exist in the

Lower Cedar River, including channels on the adjacent restoration projects associated with the 154th Place Bridge project. Buried LWD groins will be installed to (1) provide fish cover and pool habitat, and (2) protect the north bank of the channel in the event that the river avulses into the off-channel.

6.6.5. Ecological Functions and Benefits

The Cedar River will be reconnected to its historic floodplain on the right bank through levee setbacks and excavation of historic fill. Reconnection of the floodplain will attenuate flood intensity downstream, thereby reducing channel incision and erosion in the main stem (Table 6-7). Increased connectivity to the floodplain will also increase maintenance of freshwater emergent wetlands, will import materials (LWD, etc.) into the main stem, and will function as temporary fish habitat during high flows. Riparian restoration in the floodplain will provide fish cover, increase prey resources for fish, filter pollutants from nearby roads and development, provide bank stability, and contribute LWD to the river (Table 6-7). LWD recruitment is currently rated as poor along almost all of the Lower Cedar River, and land use practices generally preclude active recruitment. Also, large amounts of LWD are removed at Landsburg Dam due to liability concerns (King County 2005).

The installation of grade control and/or biotechnical bank protection (e.g., deflector ELJs) along the cutbank (locations of existing levee) will prevent the river from eroding into these banks and avulsing into the off-channel habitat. Biotechnical bank protection methods such as ELJs could provide scour pools and local depositional areas. This reach has very few pools and areas of fish cover. Scour pools will be used by adults of multiple salmonid species during upstream migration and for pre-spawn holding. Chinook salmon, in particular, will benefit from increased pools in the reach because they hold in pools prior to spawning, then spawn in riffle habitat adjacent to pools. Juvenile coho often rear in pools associated with LWD and fish cover.

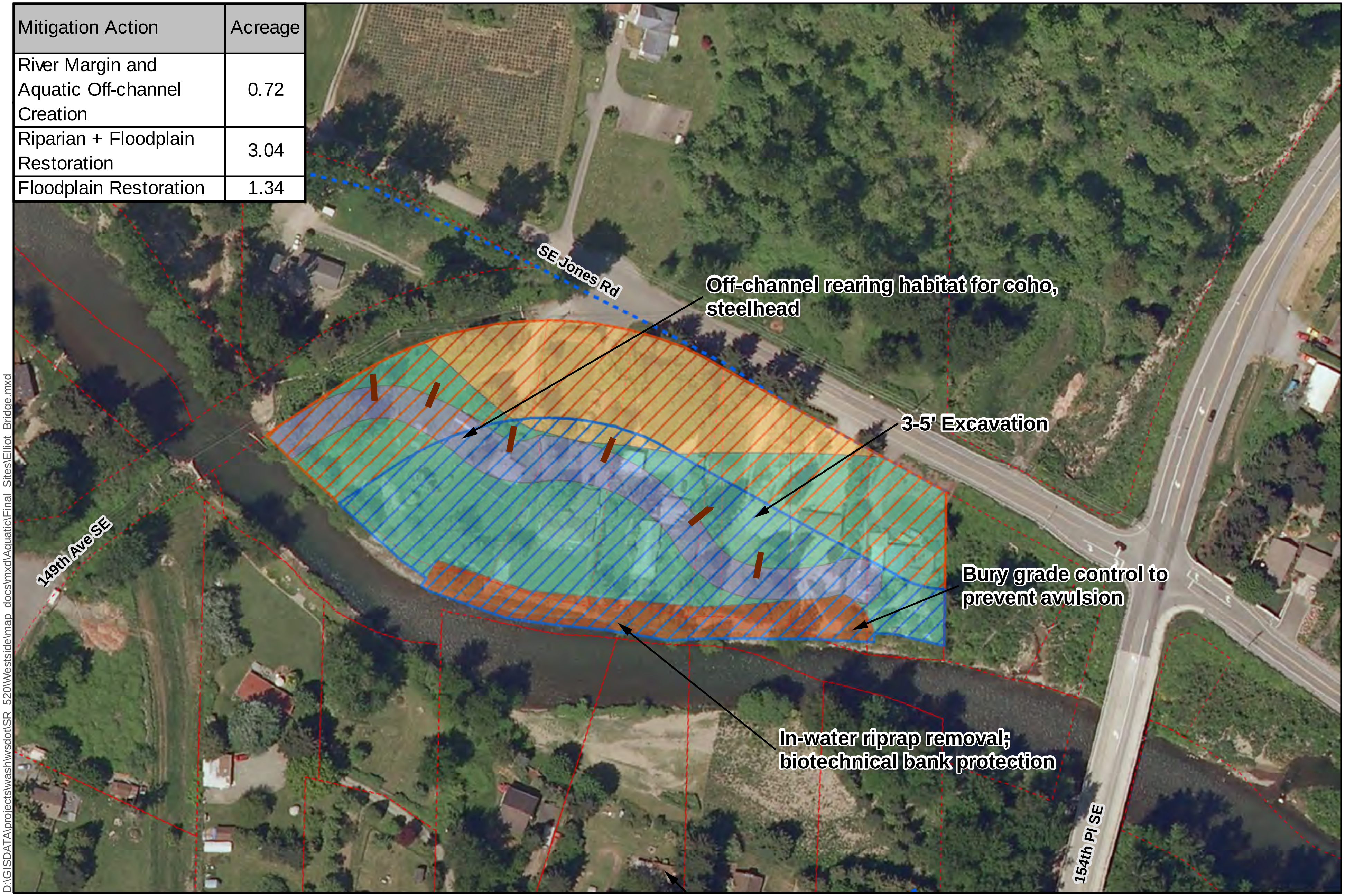
The creation of off-channel rearing habitat will benefit all salmonid species. In the Cedar River, this habitat was historically used by juvenile Chinook for rearing, which in turn likely resulted in a larger and later timing of outmigration from the Cedar River. The loss of habitat has forced juvenile Chinook to migrate into Lake Washington as very young fry, a life history trajectory that may have reduced their survival (King County 2005). Coho rely on off-channel habitat for rearing and overwintering (Bustard and Narver 1975; Brown and Hartman 1988; Swales and Levings 1989). Therefore, the off-channel rearing habitat will function as high-flow refugia.

Table 6-7. Cedar River/ Elliott Bridge Mitigation Benefits

<table>
<tr><th>Mitigation Action</th><th>Acreage</th><th>Habitat Features Improved</th><th>Habitat Functions Improved</th><th>Species/Life Stage Addressed</th></tr>
<tr><td>River Margin and Aquatic Off-channel Creation</td><td>0.72</td><td>Vegetative cover
Pools
Off-channel</td><td>Protection from predators
Food sources
High-flow refugia</td><td rowspan="3">Sockeye (Spawning)
Sockeye (Rearing/Feeding)

Chinook (Spawning
Chinook Rearing/Feeding)
Coho (Spawning)
Coho (Rearing/Feeding)

Steelhead (Spawning)
Steelhead (Rearing/Feeding)</td></tr>
<tr><td>Riparian + Floodplain Restoration</td><td>3.04</td><td>Vegetative cover
Prey input
LWD recruitment
Bank stability</td><td>Protection from predators
Food sources
Water quality</td></tr>
<tr><td>Floodplain Restoration</td><td>1.34</td><td>Floodplain connectivity
Channel complexity</td><td>Protection from predators
Food sources
Water quality</td></tr>
</table>



Mitigation Action	Acreage
River Margin and Aquatic Off-channel Creation	0.72
Riparian + Floodplain Restoration	3.04
Floodplain Restoration	1.34

Figure 6-7.
Conceptual Restoration Plan at the Cedar River / Elliott Bridge Mitigation Site

This page is intentionally left blank.

6.7 Bear Creek Site

6.7.1. Site Location

The project site is within the city of Redmond, in King County, adjacent to the Redmond Town Center. The site is located east of the Sammamish River, south of the Redmond Town Center, and north of SR 520 (Figure 6-1).

6.7.2. Mitigation Site Existing Conditions and Fish Use

Shoreline Conditions

The project site is primarily an open space area managed by the City of Redmond and Redmond Town Center. A 10-foot-wide asphalt trail connects to the Sammamish River trail in the project area. Although the trail is near the creek, it provides limited viewing of the creek. The trail accommodates pedestrian and bicycle use.

Structures on the property include the trail and stormwater treatment facilities for Bear Creek Parkway. Existing environmental conditions are degraded. The Bear Creek stream channel is an artificial, straight, riprap-lined channel created to convey flood flows (Figure A-16). From the mouth up to 2,600 feet upstream, Oregon ash (*Fraxinus latifolia*) and black cottonwood (*Populus trichocarpa*) grow adjacent to the stream banks in a narrow (one tree-width) riparian corridor. The stream buffer on either side of this narrow riparian zone is primarily vegetated with reed canarygrass (*Phalaris arundinacea*), thistle (*Circium* sp.), and blackberries (Figure A-17). From 2,600 to 3,000 feet upstream, a riverine wetland exists with a buffer of black cottonwood and Oregon ash.

Ecological Condition of Adjacent Parcels

The project area is bounded by developed parcels. Redmond Town Center is to the north, consisting of commercial properties. SR 520 lies to the south, and Marymoor Park is on the south side of SR 520. The park consists of ball fields, roads, parking lots, and some small buildings.

Fish Use

Although stream and buffer habitat is degraded in the area planned for mitigation, Bear Creek is a major producer of salmon in WRIA 8. Chinook, coho, and sockeye all spawn in Bear Creek upstream of the mitigation area. In the mitigation area, Bear Creek is used by salmonids as a migration and rearing corridor, but not for spawning.

6.7.3. Rationale for Site Selection

The WRIA 8 Chinook Salmon Recovery Plan (King County 2005) identified this portion of Bear Creek as lacking the habitat diversity needed for increased Chinook salmon productivity. Actions prescribed by the Recovery Plan to increase habitat diversity include the restoration of meanders, in-stream complexity, off-channel habitat, and riparian vegetation in the lower 3,000 feet of Bear Creek. Because of its role in upstream staging and downstream migration and rearing, and as a refuge for salmonids escaping the warmer waters of the Sammamish River, the Lower Bear Creek sub-basin has been recognized as a Locally Significant Resource Area by King County. The Lower Bear Creek project is listed as Project #N201 on the 3-year work plan under the WRIA 8 Chinook Salmon Conservation Plan, and is a Tier 1 priority under the plan. This project was funded by WSDOT, but was permitted separately by the City of Redmond.

6.7.4. Mitigation Site Design

Restoration will include increased meandering, LWD, bank stabilization, stream gravel, and native riparian plantings (Figure 6-8). Created wetlands will be hydraulically connected to the stream to provide high-flow refuge habitat and floodplain functions. Adjacent uplands will also be excavated to create more floodplain storage and habitat associated with the new channel. New riparian/floodplain plantings will enhance in-stream and riparian functions such as cover, shading, LWD recruitment, bank stabilization, terrestrial insect food production, and leaf-litter organic debris in support of in-stream food sources. By making the stream channel more sinuous, the channel’s length will be increased by 340 feet. The existing stream channel will be connected to the new channel in places to provide off-channel habitat. The remainder of the existing stream channel will be filled in with excavated gravels from the new channel. The new channel will include 1,300 linear feet of pool habitat with two different types of LWD bank stabilization methods. The outside of stream meanders will have a Type 3 configuration that will provide extra bank protection. A total of 3,000 pieces of LWD will be added to the stream channel within the bankfull width.

Three riparian planting zones will be located along elevational gradients across the site relative to flood stages of Bear Creek. The three riparian planting zones are listed in descending order of expected inundation:

1. Floodway Zone (1.71 acres): Tree layer consists of black cottonwood (12%) and Oregon ash (13%); shrub layer consists of Pacific ninebark (*Physocarpus capitatus*, 15%), Pacific willow *(Salix lucida*, 15%), red-osier dogwood (*Cornus sericea* 15%), salmonberry (*Rubus spectabilis*, 15%), and Sitka willow (*Salix sitchensis*, 15%).

2. Transition Slope Zone (4.35): Tree layer consists of black cottonwood (9%), Sitka spruce (*Picea sitchensis*, 8%), and western red cedar (*Thuja plicata*, 8%); shrub layer consists of black twinberry (*Lonicera involucrate*, 15%), Indian plum (*Oemleria cerasiformis*, 15%), peafruit rose (*Rosa pisocarpa*, 15%), salmonberry (15%), and Sitka willow (15%).

3. Upland Buffer Zone (5.22 acres): Tree layer consists of big leaf maple (*Acer macrophyllum*, 8%), Douglas fir (*Pseudotsuga menziesii*, 9%), and western hemlock (*Tsuga heterophylla*, 8%); shrub layer consists of bitter cherry (*Prunus emarginata*, 9%), cascara (*Rhamnus purshiana*, 9%), nootka rose (*Rosa nutkana*, 10%), oceanspray (*Holodiscus discolor,* 9%), red elderberry (*Sambucus racemosa*, 10%), tall Oregon grape (*Berberis aquifolium,* 10%), and vine maple (*Acer circinatum*, 9%).

Trees will be planted at an approximate spacing of 10 to 15 feet on center and shrubs at an approximate spacing of 5 feet on center, in randomly mixed groupings. In areas where the current vegetation will be retained, plant spacing will depend on the densities of the existing desirable native vegetation. Plants will be installed during specified planting windows. Native plants will be obtained from approved nurseries. A temporary irrigation system will be installed, if necessary, for watering during the plant establishment period. Emergent vegetation will not be planted for this project because of limiting factors such as depredation by waterfowl (e.g., Canadian geese) and reed canarygrass infestation. The intended vegetation types after restoration will be forested wetland and riparian plant communities, facultative or wetter, to withstand inundation. Scrub-shrub wetland plant communities may be included in final design. This will also lead to quicker establishment of woody vegetation close to the channel for habitat benefits, including in-stream cover and shading.

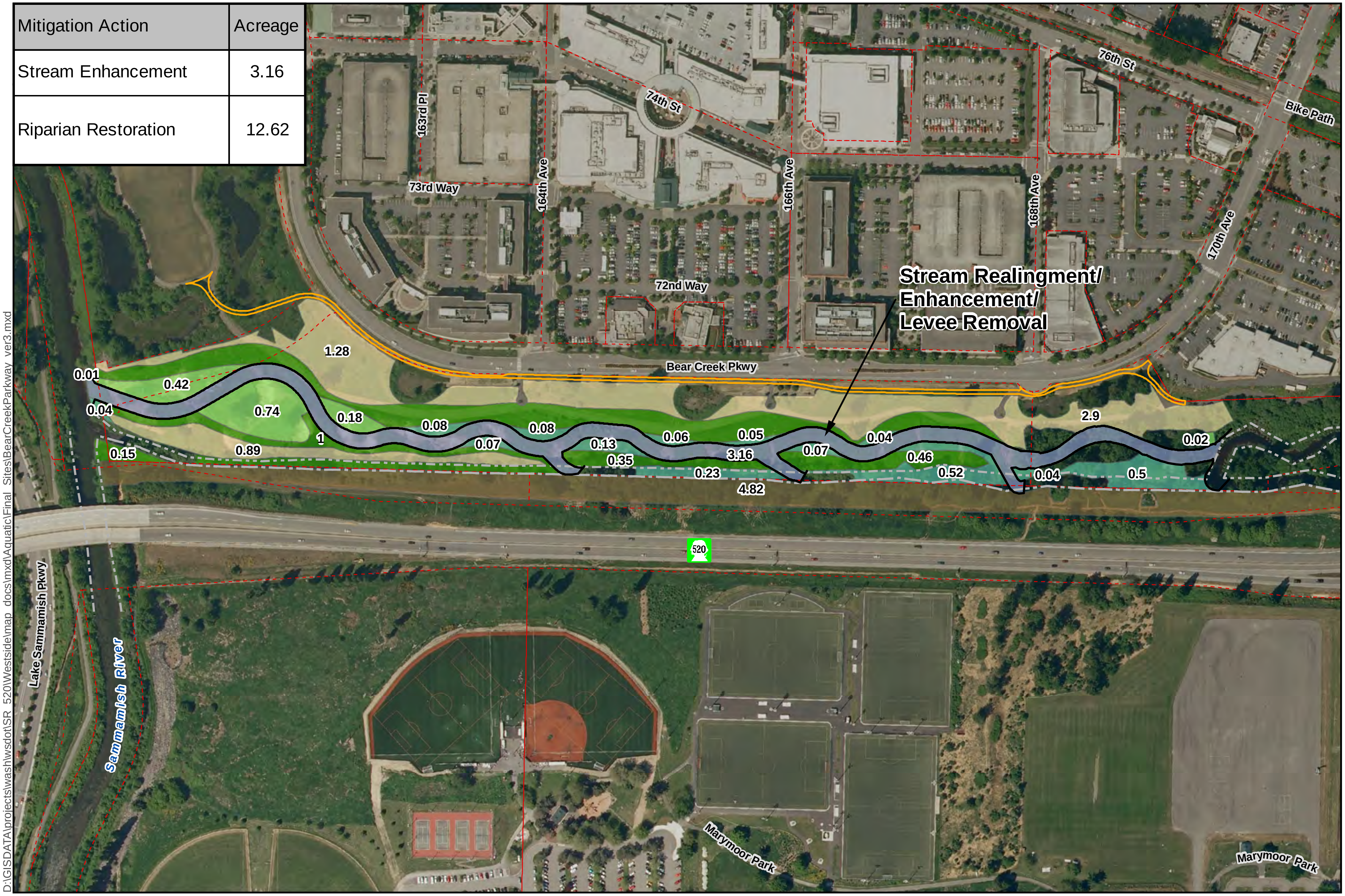
6.7.5. Ecological Functions and Benefits

The project will create significant habitat improvements to establish a compositionally and structurally complex ecosystem with attributes important for supporting fish and wildlife with an emphasis on anadromous fish such as Chinook, coho, and sockeye salmon (Table 6-8). As the riparian/floodplain vegetation matures, it will increase the continuous patch riparian corridor and contribute to channel and bank stabilization, riparian corridor habitat diversity, and cover and refuge for both juvenile and adult fish and wildlife.

Table 6-8. Bear Creek Mitigation Benefits

Mitigation Action	Acreage	Habitat Features Improved	Habitat Functions Improved	Species/Life Stage Addressed
Stream Enhancement	3.16	Off-Channel Pools LWD Fish Cover	Spawning Habitat Protection from Predators Food Sources	Sockeye (Spawning) Sockeye Rearing/Feeding) Chinook (Spawning) Chinook (Rearing/Feeding) Coho (Rearing/Feeding)
Riparian Restoration	12.62	Fish Cover, LWD recruitment	Spawning Habitat Water Quality Protection from Predators Food Sources	

Mitigation Action	Acreage
Stream Enhancement	3.16
Riparian Restoration	12.62



N

0 150 300 Feet

- Forested Wetland
- Riparian - Floodway
- Riparian - Transition Slope
- Riparian - Upland Buffer
- Stream Buffer - Planting by Others
- Proposed Stream Channel
- Parcel
- Proposed OHW
- Existing OHW
- Proposed Trail

Figure 6-8.
Conceptual Restoration Plan at the Bear Creek Mitigation Site

SR520, I-5 to Medina: Bridge Replacement and HOV Project

D:\GISDATA\projects\wash\wsdot\SR 520\Westside\map docs\mxd\Aquatic\Final Sites\BearCreekParkway ver3.mxd

This page intentionally left blank.

6.8 East Approach

6.8.1. Site Location

Shoreline and nearshore enhancement is proposed near the existing and proposed SR 520 east approach (Figure 6-1 and Figure 6-9).

6.8.2. Mitigation Site Existing Conditions and Fish Use

Shoreline Conditions

Portions of the shoreline in the project area are highly modified with bulkheads, docks, and landscaped riparian zones (WSDOT 2009d). Natural, undisturbed shoreline in the project area is limited to a stretch directly below the Evergreen Point Bridge. In addition, boat traffic here is concentrated relatively close to the shoreline, leading to considerable wave action. As a result, vegetation densities tend to be relatively low close to shore, and substrate material relatively large. In general, the lake bottom substrate is cobble and gravel near the shoreline and transitions to sand and finer material moving away from the shoreline.

The shoreline consists of a failing wood bulkhead, some large boulder-sized riprap, and two piers (Figure A-18). Much of the shoreline is modified with bulkheads and boat docks, although the shoreline immediately under the existing bridge is relatively unmodified, with a natural slope. The two piers will be removed and replaced with one pier that will be used for WSDOT maintenance activities (see Section 4.3.1). The non-native species Eurasian watermilfoil (*Myriophyllum spicatum*) and native species of pondweed (*Potamogeton* sp.) and American wild celery (*Vallisneria americana*) are the most abundant aquatic plants (WSDOT 2009d). Lake bottom substrate in the project area is dominated by cobble and sand. In general, substrate near the shore consists of cobble and transitions through gravel to sand and silt moving offshore (Figure A-19); patches of bare clay are also present (WSDOT 2009d).

Ecological Condition of Adjacent Parcels

Parcels in the project vicinity consist of the SR 520 approach, bridge, and residential properties with piers, ramps, and floats.

Fish Use

The site has been identified in the past as a sockeye spawning area based on historical WDFW map records (Kurt Buchanan, Biologist, WDFW, Olympia, WA, July 26, 2004, pers. comm.). However, no recent surveys have been conducted to determine if spawning sockeye currently use this location. This sockeye spawning area is one of more than 85 shoreline spawning areas identified in Lake Washington on maps provided by WDFW (Kurt Buchanan, Biologist, WDFW, Olympia, WA, July 26, 2004, pers. comm.).

Sockeye typically spawn in areas of clean gravel substrate and groundwater upwelling. The site has some areas of clean cobble and gravel that have the potential to support sockeye spawning (WSDOT 2009d). However, most of the nearshore substrate consists of cobble material and the offshore areas are dominated by sandy substrate. The site is generally less than 50 feet deep. This depth stratum is associated with the Colluvium/ Recessional geologic stratum (WSDOT 2011b). A confined and pressurized aquifer underneath the Colluvium/ Recessional stratum provides localized groundwater upwelling into the project area.

Estimated annual escapement of Lake Washington beach spawning sockeye varied from 54 to 1,032 fish from 1976 through 1991 (WDFW 2004). These sockeye spawn wherever suitable gravel beaches and groundwater upwelling occur around the lake, particularly along the north shore of Mercer Island and the east shore of Lake Washington. These spawning areas occur over a wide range of water depths. The estimated total beach spawning population ranged between 200 and 1,500 fish between 1986 and 2003 (WDFW 2004).

6.8.3. Rationale for Site Selection

This site was selected for sockeye spawning enhancement because of documented sockeye spawning and known groundwater upwelling. The colluviums/weathered till geologic strata probably result in a patchy distribution of upwelling areas from the underlying pressurized aquifer. In much of this area, the existing sediments do not currently appear suitable for sockeye spawning (WSDOT 2009d). Therefore, gravel supplementation is expected to maximize spawning habitat suitability where groundwater upwelling does occur.

Shoreline restoration is proposed because of the paucity of natural shoreline in this area of the lake and because of likely Chinook and sockeye use during early rearing. Chinook juveniles migrating along from the shoreline from the south lake and local beach spawning sockeye are the most likely to benefit from a natural shoreline feature.

6.8.4. Mitigation Site Design

In general, sockeye dig redds in gravel and small cobbles between 13 and 102 mm (Reiser and Bjornn 1979). Olsen (1968) indicated that sockeye may use either sand or gravel, depending upon which is available. If small amounts of silt, detritus, or fine sand are mixed with the coarser gravel, they are removed by the fish in the process of excavating the redd (Foerster 1968). Mathisen (1955) observed sockeye salmon egg concentrations 6 to 9 inches below the gravel surface.

These observations on suitable habitat will govern the design requirements for Lake Washington spawning supplementation. Approximately 0.75 acre of lake nearshore will be supplemented with gravel and cobbles between 13 and 102 mm to a depth of 1 foot. The gravel and cobble mix will be screened, washed, and placed on a barge. The barge will transport the gravel to the project location. The gravel will be dumped so that it distributes equally throughout the project area, yielding an average depth of approximately 1 foot. The gravel enhancement will take place during the fish work window, when sockeye juveniles and adults are unlikely to be in the area.

The wood bulkhead and adjacent boulder-sized riprap will be removed. The shoreline behind the bulkhead will be re-graded to a gradually sloped shoreline (see Appendix B) and supplemented with appropriately-sized gravel. The grass upland immediately landward of the bulkhead will be revegetated using the planting palettes shown in Appendix C. Revegetation will include a mixed willow/emergent community near high lake level elevation and transition to a riparian upland community. Specific planting plans will be based on site-specific conditions and constraints. Immediately south of the shoreline restoration area, WSDOT is installing spawning gravel along about 60 linear feet of shoreline, extending out from the OHWM about 20 feet. This 1,200-square-foot area of gravel installation, which also includes the removal of some existing rubble and boulders, is a mitigation action for the SR 520, Medina to SR 202: Eastside Transit and HOV Project, and will not serve as mitigation credit for the SR 520, I-5 to Medina Project. This action will likely be completed prior to the initiation of the shoreline restoration and gravel supplementation projects discussed above.

6.8.5. Ecological Functions and Benefits

This mitigation action will primarily benefit sockeye salmon spawning habitat (Table 6-9). Shoreline areas with upwelling and suitable sockeye spawning substrate are an important habitat feature in Lake Washington. Therefore, a Fish Function Modifier of 0.8 is proposed.

Table 6-9. East Approach Mitigation Benefits

<table>
<tr><th>Mitigation Action</th><th>Acreage</th><th>Habitat Features Improved</th><th>Habitat Functions Improved</th><th>Species/Life Stage Addressed</th></tr>
<tr><td>Spawning Gravel Supplementation</td><td>0.75</td><td>Suitable sediment</td><td>Suitable spawning habitat</td><td>Sockeye (Spawning)</td></tr>
<tr><td>Riparian Enhancement</td><td>0.05</td><td>Vegetative cover

Prey input</td><td>Protection from predators

Food sources</td><td rowspan="2">Chinook
(Juvenile Rearing/Feeding)

Chinook
(Juvenile Migration)

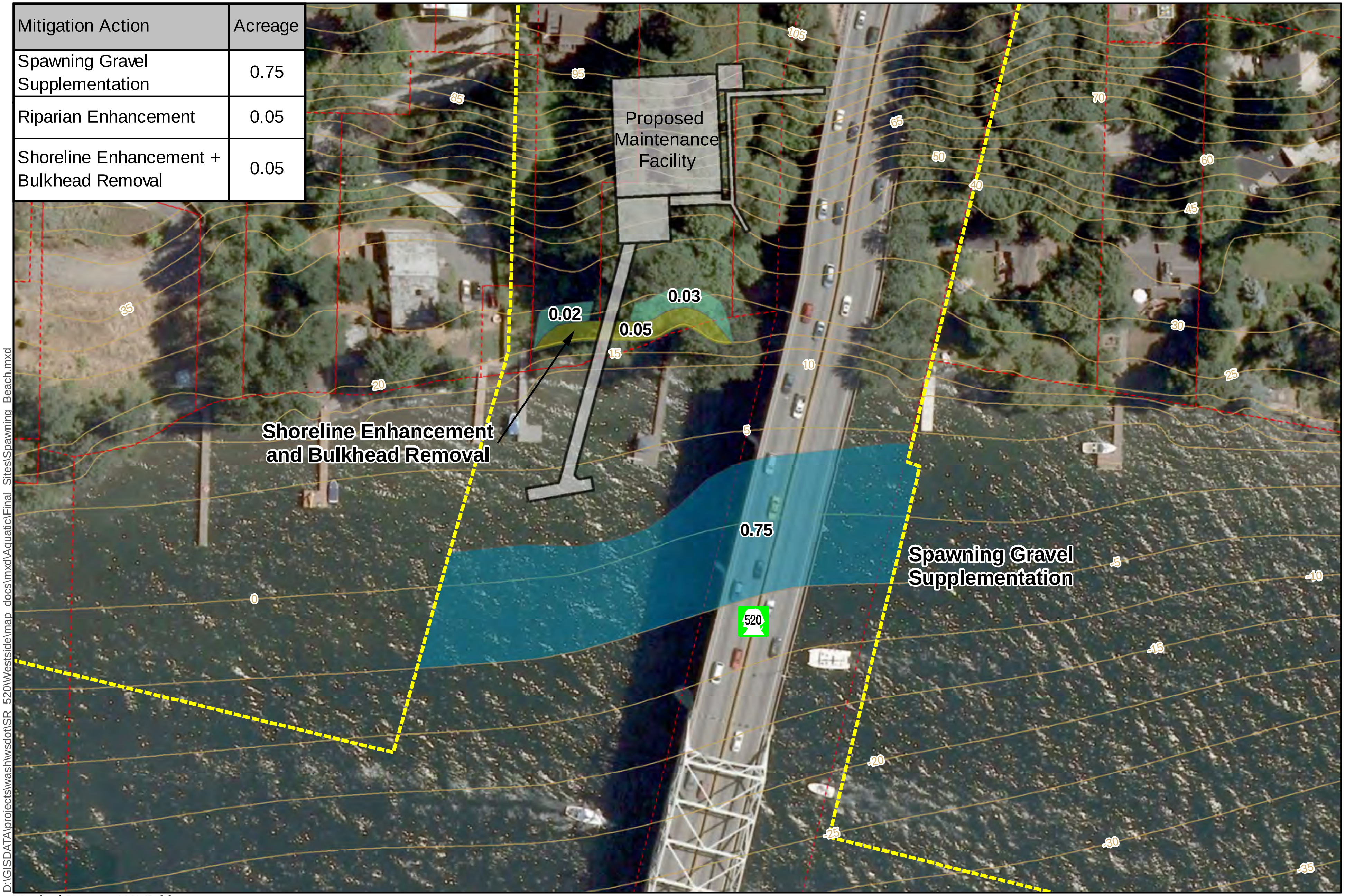
Sockeye
(Juvenile Rearing/Feeding)</td></tr>
<tr><td>Shoreline Enhancement + Bulkhead Removal</td><td>0.05</td><td>Gradual, sloped bank

Suitable sediment

Prey input</td><td>Protection from predators

Migratory corridor</td></tr>
</table>

Mitigation Action	Acreage
Spawning Gravel Supplementation	0.75
Riparian Enhancement	0.05
Shoreline Enhancement + Bulkhead Removal	0.05



D:\GISDATA\projects\wash\wsdot\SR 520\Westside\map docs\mxd\Aquatic\Final Sites\Spawning Beach.mxd

Vertical Datum: NAVD88

N

0 25 50 100 Feet

Spawning Gravel Supplementation
Riparian Enhancement Area
Shoreline Enhancement and Bulkhead Removal
Proposed Maintenance Facility
Parcel
Proposed Right-of-Way
Bathymetry

Figure 6-9.
Conceptual Restoration Plan at the East Approach Mitigation Site

This page intentionally left blank.

6.9 Implementation Schedule

Implementation schedules for these mitigation sites have not yet been developed. However, the following studies will be implemented for each project, as appropriate, as part of the design process:

- Shallow groundwater monitoring
- Identification of historic elevations, fill elevations, etc.
- Hydrologic and hydraulic modeling
- Topographic survey
- Geotechnical survey
- Hazardous materials site assessment (Phase I)
- Cultural and archeological investigation
- Permit applications
- Permit approval

A more comprehensive implementation schedule will be developed as each project design advances.

6.10 Summary of Ecological Functions and Benefits

Under the proposed mitigation approach, these temporary impacts could be offset by applying temporary mitigation value from variety of project combinations (Table 6-10). The specific application of mitigation towards temporary or permanent impacts should match the species, stock, life stage, and habitat function, respectively.

Table 6-10. Proposed Mitigation Sites and Their Compensatory Value

Mitigation Site	Mitigation Type (mitigation acreage applied to one or the other category, not both)		
	Permanent Mitigation Credits (acres)		Temporary Mitigation Credits (acre-years)
Seward	0.95	OR	15.53
Magnuson	0.98		12.60
Taylor Creek	0.48		7.02
S. Lake WA	1.68		27.66
Cedar	1.76		23.31
Bear	4.55		67.21
East Approach	0.60		11.48

6.10.1. Mitigation for Temporary Impacts

Temporary project impacts that require compensatory mitigation include partial shading, fill, and increased predator fish habitat from the construction work bridges and falsework. These temporary impacts will bear the largest effect on juvenile Chinook as they migrate towards the Ship Canal in the shallow nearshore, where these work bridges are proposed to occur (see Section 4.3).

Based on a review of project impacts and available mitigation types, WSDOT is currently proposing using the restoration projects at Seward Park, Magnuson Park, Taylor Creek, and the South Lake Washington Shoreline Restoration (DNR Parcel) to offset temporary impacts (Table 6-11) The mitigation actions will benefit survival of juvenile Chinook by increasing habitat function along their migratory path towards the Ship Canal. Most of the habitat restoration will benefit the juvenile Chinook originating from the Cedar River (i.e., Seward Park, Taylor Creek. Magnuson Park will benefit the North Lake Washington and Issaquah/ Sammamish stocks. This allocation of compensatory mitigation is proportional to the higher exposure of the Cedar River stocks to the temporary work bridge impacts. While some of the North Lake Washington and Issaquah/ Sammamish stocks may encounter the temporary work bridges during outmigration, most will outmigrate through the Ship Canal without straying south into the work zone.

However, the assignment of mitigation sites to specific impact categories (permanent or temporary) has not been finalized, and could change pending finalization of the suite of mitigation sites and/or input from regulatory agencies. A summary of the compensatory mitigation value of these projects is presented in Appendix D, Table D1. Per Section 5.4, the mitigation value is based on plan view acreages of mitigation actions. The plan view acreages are weighted by (1) relative fish use, (2) project type, and (3) discounts for the temporal lag of project function.

6.10.2. Mitigation for Permanent Impacts

A wide range of habitat restoration projects are proposed to address potential impacts to different salmonid species at various life stages during operation of the proposed SR 520, I-5 to Medina Project. Under the proposed mitigation approach, these permanent impacts could be offset by applying permanent mitigation value in a variety of project combinations Table 6-10). Based on a review of project impacts and available mitigation types, WSDOT is currently proposing using the South Lake Washington Shoreline, Cedar River/ Elliott Bridge, Bear Creek, and east approach restoration projects to offset permanent (operational) impacts because the benefits include a wide range of species and life stages (Table 6-11). However, the assignment of mitigation sites to specific impact categories (permanent or temporary) has not been finalized, and could change pending finalization of the suite of mitigation sites and/or input from regulatory agencies. The mitigation accounting for each project is detailed in Appendix B, Table B-2.

This page intentionally left blank.

1 **Table 6-11. Proposed Mitigation Sites and Their Allocation to Permanent and Temporary Impacts**

Mitigation Site	Mitigation Actions	Species/Life Stage Addressed	Permanent Mitigation Credit (acres)	Temporary Mitigation Credit (acre-years)
Seward Park	Shoreline Enhancement + Hard Structure Removal, Riparian Restoration	Chinook (Juvenile Rearing/ Feeding, Juvenile Migration), Sockeye (Spawning, Juvenile Rearing/ Feeding)	0	15.53
Magnuson Park	Shoreline Enhancement + Hard Structure Removal, Riparian Restoration	Chinook (Juvenile Rearing/ Feeding, Juvenile Migration) Sockeye (Spawning, Juvenile Rearing/Feeding)	0	12.60
Taylor Creek	Channel and Delta Restoration, Riparian + Floodplain Restoration, Shoreline and Marsh Creation	Chinook (Rearing/Feeding) Sockeye (Spawning, Rearing/Feeding) Coho (Spawning, Rearing/Feeding)	0	7.02
South Lake Washington Shoreline Restoration (DNR) site	Shoreline Enhancement + Hard Structure Removal, Riparian Restoration, Dolphin Removal	Chinook (Juvenile Rearing/Feeding, Juvenile Migration) Sockeye (Juvenile Rearing/Feeding)	1.68	0
Bear Creek	Stream Enhancement, Riparian Restoration	Chinook (Spawning, Rearing/Feeding) Sockeye (Spawning, Rearing/Feeding) Coho (Rearing/Feeding)	4.55	0
Cedar River/ Elliott Bridge	River Margin and Aquatic Off-channel Creation, Riparian + Floodplain Restoration,	Chinook (Spawning, Rearing/Feeding) Sockeye (Spawning, Rearing/Feeding) Coho (Spawning, Rearing/Feeding) Steelhead (Spawning, Rearing/Feeding)	1.76	0
East Approach	Spawning Gravel Supplementation	Sockeye (Spawning)	0.60	0

2

This page intentionally left blank.

6.10.3. Comparison of Impacts and Mitigation

According to the impact and mitigation–assessment framework, the SR 520, I-5 to Medina Project's proposed mitigation actions compensates for both permanent and temporary impacts (Table 6-11 and 6-12). Although the final dispensation of permanent and temporary mitigation credit assignment to individual sites has not been finalized, the current site assignment, as discussed above, the variety and quantity of proposed mitigation is adequate to compensate for both temporary and permanent project impacts.

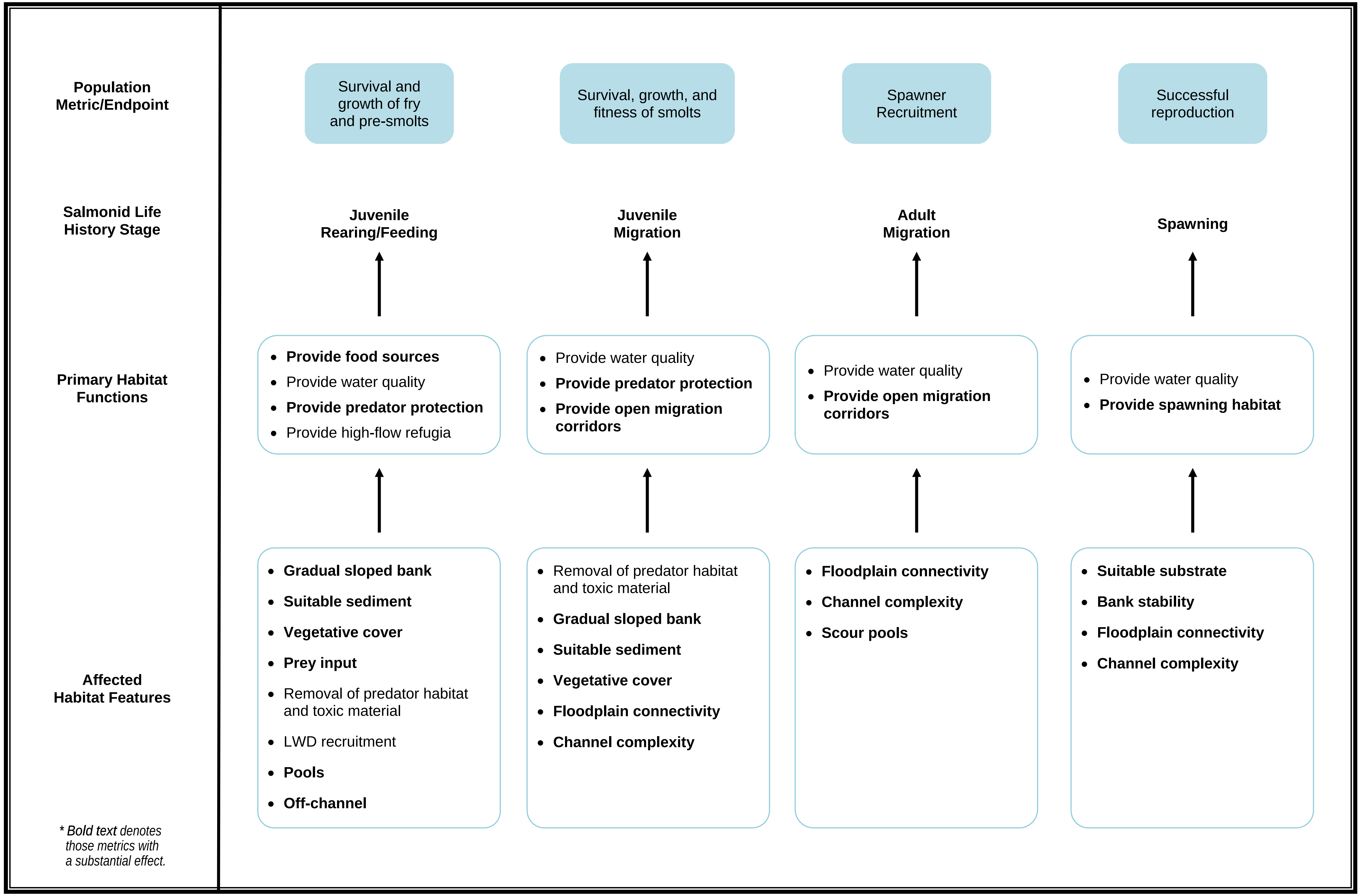
The mitigation value to the focal fish and their survival at various life stages are commensurate with potential impacts to the same species and life stages, as modeled in Figure 6-10. Although the impacted habitat features (see model in Figure 4-1) and mitigation habitat features (see model in Figure 6-13) differed in type and spatial location, the project's mitigation targeted the same species, stocks, and life stages that were impacted (Section 4.1; Table 6-1). Because the temporary and permanent impacts are likely to affect juveniles migrating toward the Ship Canal, most compensatory mitigation actions are designed to benefit juvenile survival. In addition, these restoration projects are intended to enhance spawning success of all focal species in order to address the concern of unanticipated project effects on adults migrating from the Ship Canal into the lake.

Any unknown project impacts that are identified in the future will be mitigated, as appropriate. WSDOT has commissioned a study to evaluate potential effects to Lake Washington arising from the floating bridge modifying lake circulation and currents. If these effects are found to be significant, WSDOT will first pursue minimization measures and then evaluate mitigation needs for those effects, which will be in addition to those characterized within this framework.

Table 6-12. Total Impact and Mitigation Metrics after Application of the Mitigation Framework

	Temporary (Acre-Years)	Permanent (Acres)
Impacts	24.92	7.30
Mitigation	35.15	8.59

Figure 6-10. Conceptual Model of Mitigation Benefits



This page intentionally left blank.

7. Mitigation Goals, Objectives, and Performance Criteria

WSDOT uses goals and objectives to guide mitigation design and construction. Goals and objectives typically are based on area or function. Goals describe the overall intent of mitigation efforts; objectives describe individual components of the mitigation site in detail. Performance standards are the benchmarks that define success for each objective and direct adaptive management. These standards describe specific on-site characteristics that indicate whether the mitigation site meets an objective. They also guide the management of the mitigation site. Performance standards are also used to evaluate compliance with regulatory permits during the monitoring period. Contingency plans describe what actions can be taken to correct site deficiencies.

WSDOT uses the adaptive management process to improve mitigation success. Adaptive management is a process through which changes to mitigation activities, maintenance procedures, or monitoring protocols are developed based on the successes or failures in other mitigation projects. These changes are then incorporated into the current mitigation projects. Information from ongoing monitoring further directs subsequent site management activities. WSDOT will monitor the site for up to 10 years and perform maintenance, as necessary, to achieve the mitigation performance standards. As part of the adaptive management process, mid-course corrections may be necessary if the site develops in ways that were not anticipated during design and permitting of the project. These mid-course corrections require coordination with regulators, and may, in some cases, require negotiation of revised performance standards.

7.1 Goals

The SR 520, I-5 to Medina Project will use a comprehensive mitigation plan to compensate for permanent aquatic impacts by restoring 2.49 acres of shoreline, 19.09 acres of riparian/ floodplain habitat, and 3.88 acres of stream and off-channel habitat. This mitigation plan will compensate for temporary aquatic impacts by restoring 1.59 acres of lacustrine shoreline/ stream habitat, 6.56 acres of riparian/ floodplain habitat, and 0.74 acre of floodplain habitat. This mitigation plan will be sufficient to meet federal, state, and local regulatory requirements.

7.2 Objectives

7.2.1. Seward Park

Off-site mitigation will take place at four locations at Seward Park. The off-site compensatory mitigation will provide the following:

SEW1: *Enhance 0.94 acre of shoreline habitat by removing bulkheads and riprap, excavating the shoreline to a gradual grade, and installing appropriate-sized gravel and LWD.*

SEW2: *Enhance 1.42 acres of riparian habitat through removal of invasive vegetation and installation of native tree and shrub vegetation.*

7.2.2. Magnuson Park

Off-site mitigation will take place at four locations at Magnuson Park. The off-site compensatory mitigation will provide the following:

MAG1: *Enhance 0.34 acre of shoreline habitat by removing bulkheads and riprap, excavating the shoreline to a gradual grade, and installing appropriate-sized gravel and LWD.*

MAG2: *Enhance 4.41 acres of riparian habitat through removal of invasive vegetation and installation of native tree and shrub vegetation.*

7.2.3. Taylor Creek

Off-site mitigation will take place at four locations at Taylor Creek, between the Lake Washington shoreline and Rainier Avenue SW. The off-site compensatory mitigation will provide the following:

TAY1*: Restore 0.26 acre of stream habitat by relocating the existing stream channel, stabilizing stream banks, and installing appropriate-sized gravel and LWD.*

TAY2: *Enhance 0.05 acre of shoreline habitat; install appropriate-sized gravel and LWD.*

TAY3: *Enhance 0.74 acre of riparian habitat through removal of invasive vegetation and installation of native tree and shrub vegetation.*

TAY4: *Restore 0.74 acre of floodplain habitat by removing historical fill, structures, asphalt, concrete, utilities, underground storage tanks, etc.*

7.2.4. South Lake Washington Shoreline Restoration (DNR Parcel)

Off-site mitigation will take place at four locations at the South Lake Washington Shoreline Restoration (DNR Parcel). The off-site compensatory mitigation will provide the following:

DNR1: *Enhance 1.69 acres of shoreline habitat through removal of a corrugated sheet metal flume, shoreline excavation to attain a gradual grade, and installation of appropriate-sized gravel.*

DNR2: *Enhance 2.04 acres of riparian habitat, where invasive weeds will be removed and native vegetation will be installed.*

7.2.5. Cedar River/ Elliott Bridge Reach

Off-site mitigation will take place at the Elliott Bridge reach mitigation site. The off-site compensatory mitigation will provide the following:

CED1*:* *Restore 4.38 acres of floodplain habitat (includes 3.04 acres in CED2), where existing levees will be removed, areas behind the levees excavated to appropriate grades, and the natural hydrologic processes restored along the Cedar River.*

CED2: *Enhance 3.04 acres of riparian habitat through removal of invasive vegetation and installation of native tree and shrub vegetation.*

CED3: *Enhance 0.72 acre of off-channel rearing habitat and riverine marginal habitat and install deflector ELJs.*

7.2.6. Bear Creek

Off-site mitigation will take place at the Bear Creek mitigation site. The off-site compensatory mitigation will provide the following:

BEAR1: *Restore 12.62 acres of floodplain habitat through removal of existing levees, excavation within areas behind the levees to appropriate grades, and restoration of natural hydrologic processes along Bear Creek.*

BEAR2: *Enhance 12.62 acres of riparian habitat through removal of invasive vegetation and installation of native tree and shrub vegetation.*

BEAR3: *Restore 3.16 acres of stream habitat by relocating existing stream channel, stabilizing stream banks, and installing appropriate-sized gravel and LWD.*

7.2.7. East Approach

Off-site mitigation will take place at the east approach site. The off-site compensatory mitigation will provide the following:

SOCK1: *Enhance 0.75 acre of sockeye salmon beach-spawning habitat through installation of spawning gravel offshore.*

SOCK2: *Enhance 0.05 acre of shoreline habitat through removal of bulkheads and riprap, excavation of the shoreline to a gradual grade, and installation of appropriate-sized gravel and LWD.*

***SOCK3:** Enhance 0.05 acre of riparian habitat through removal of invasive vegetation and installation of native tree and shrub vegetation.*

7.3 Performance Criteria

The performance standards described below provide benchmarks for measuring the progress of the mitigation sites' goals and objectives. Mitigation activities are intended to meet these performance standards within 10 years. Methods to monitor each performance standard are described in general terms.

Performance criteria describe measurable attributes that can be used to evaluate success in meeting the goals and objectives of a compensatory mitigation project. Performance measures are used to guide site management activities during the monitoring period. Success standards are benchmarks measured during the final year of monitoring (Year 5 or 10) that are used to help evaluate compliance with regulatory requirements. Performance measures will be used to verify that the mitigation is on track to achieve the success standards.

Performance criteria and contingency plans will be organized by objectives that re-occur in the array of mitigation sites proposed in this plan. The mitigation projects and their objectives are summarized in Table 7-1.

Table 7-1. Generalized Project Objectives

Mitigation Site	Objective			
	Shoreline Enhancement (Lacustrine)	Stream Restoration	Riparian Restoration	Floodplain Restoration
Seward Park	X		X	
Magnuson Park	X		X	
Taylor Creek	X	X	X	X
South Lake Washington Shoreline Restoration (DNR Parcel)	X		X	
Cedar River		X	X	X
Bear Creek		X	X	X
East Approach	X			

7.3.1. Shoreline Enhancement (Lacustrine) Performance

The shoreline enhancement performance standards document and verify that the shoreline features are established according to the criteria specified during the design. The shoreline restoration performance standards also ensure that the shoreline features are functioning as intended. These shoreline performance standards directly relate to Objectives SEW1, MAG1, TAY1, DNR1, and SOCK1.

Interim Performance Standards

Year 1

- As-built condition is consistent with the project design elements, including hard structure removal, site grading plan, gravel supplementation specifications, and installed habitat features.

Year 3

- The slope of the enhanced shoreline habitat is at or below 15% grade, as measured from low lake level to high lake level.
- The LWD structures are hydraulically engaged within the wetted portion of the lakes (at high lake level).
- At least 80% of placed LWD pieces is retained within the project limits.
- The areas between created shoreline habitat and adjacent upland does not show signs of obvious and significant bank failures, including sloughing, slumping, or bank fractures, as determined from visual inspection.
- At the shoreline substrate enhancement sites (not including the deep water gravel installation at the east approach site), substrate composition is maintained within 80% of the D_{50} (the size at which 50% of the pebbles are finer) compared with as-built gravel installation.

Success Standard

Year 5

- The slope of the enhanced shoreline habitat is equal to or less than 15%, as measured from low lake level to high lake level.
- The LWD structures are engaged within the wetted portion of the lakes (at high lake level).
- At the shoreline substrate enhancement sites (not including the deep water gravel installation at the east approach site), substrate composition is maintained within 60% of the D_{50} compared with as-built gravel installation.
- At least 50% of placed LWD is retained within the project limits.

7.3.2. Stream Restoration Performance

The performance standards for stream restoration document and verify that the stream features are established according to the criteria specified during the design. The stream restoration performance standards also assure that the stream features are functioning as intended. These stream restoration performance standards directly relate to Objectives TAY1, CED3, and BEAR3.

Interim Performance Standards

Year 1

- As-built condition is consistent with the project design elements, including hard structure removal, site grading plan, and installed habitat features.

Year 3

- Stream habitat is accessible to adult and juvenile fish, specifically at the Cedar River side channel, the lower reach of Taylor Creek, and the off-channel habitat at Bear Creek. Methods presented in the Stream Habitat Restoration Guidelines (Saldi-Caromile et al. 2004) will be used to determine if the water depths and velocities within these features support use by juvenile and adult salmonids.
- The channel does not show signs of significant headcutting, avulsion, or subsurface seepage as determined from visual inspection.
- The LWD and ELJ structures are hydraulically engaged within the wetted portion of the lakes (at high lake level).
- The in-stream structures (LWD and ELJ) remain intact and properly functioning as determined from visual inspection. The inspection should look for evidence of structure movement, cover creation, sediment trapping, and development of pools.
- At least 80% of placed LWD is retained within the project limits.

Success Standard

Year 5

- Stream habitat is accessible to adult and juvenile fish, specifically at the Cedar River side channel, the lower reach of Taylor Creek, and the off-channel habitat at Bear Creek. Methods presented in the Stream Habitat Restoration Guidelines (Saldi-Caromile et al. 2004) will be used to determine if the water depths and velocities within these features support use by juvenile and adult salmonids.
- The channel does not show signs of significant headcutting, avulsion, or subsurface seepage as determined from visual inspection.
- The LWD and ELJ structures are engaged within the wetted portion of the lakes (at high lake level).

- The in-stream structures (LWD and ELJ) remain intact and properly functioning as determined from visual inspection. The inspection should look for evidence of structure movement, cover creation, sediment trapping, and development of pools.
- At least 60% of placed LWD is retained within the project limits.

7.3.3. Riparian Restoration Performance

The riparian performance criteria document the establishment of a plant community that (1) stabilizes shoreline or stream banks, and (2) provides fish cover. The riparian performance criteria directly relate to Objectives SEW2, MAG2, TAY3, DNR2, CED2, and BEAR2.

Interim Performance Standards

Year 0

- As-built condition is consistent with the planting plan.

Year 1

- Native woody species (planted and volunteer) achieve an average density of at least four plants per 100 square feet in the overall riparian zone and a density of 6 plants per 100 square feet within 10 feet of the shoreline.

Year 3

- Native woody species (planted and volunteer) achieve an average density of at least four plants per 100 square feet in the overall riparian zone and a density of 6 plants per 100 square feet within 10 feet of the shoreline.
-

Year 5

- Cover of native woody species (planted and volunteer) is at least 30% in the riparian zone.

Year 7

- Cover of native woody species (planted and volunteer) is at least 40% in the riparian zone.

All years

- Washington State and King County listed Class A Noxious Weeds indentified on the site are eradicated.
- King County listed Class B and C Weeds identified on the site are controlled. Control of noxious weeds means to prevent all seed production and to prevent the dispersal of

all propagative parts capable of forming new plants. If Japanese knotweed is found at the mitigation site during monitoring, WSDOT (or its designated representatives) will promptly remove the stems above ground and chemically treat it to facilitate elimination of roots and rhizomes below ground.

- Noxious weeds listed by King County as Non-Designate including reed canarygrass, non-native blackberries, and Scot's broom do not exceed 25% aerial cover in riparian zones.

Success Standard

Year 10

Cover of native woody species (planted and volunteer) is at least 50% in the riparian zone.

7.3.4. Floodplain Restoration Performance

The floodplain restoration performance criteria document the establishment of a plant community that (1) provides habitat for native wildlife, (2) allows for regular inundation above the OHWM, and (3) provides vegetative roughness to slow floodwaters and allow the deposition of sediment and associated pollutants. The buffer woody vegetation performance criteria directly relate to Objectives TAY4, CED1, and BEAR1.

Interim Performance Standards

Year 0

- As-built condition is consistent with the grading, planting, and habitat structure elements of the project design.

Year 1 and Year 3

- Native woody species (planted and volunteer) achieve an average density of at least four plants per 100 square feet in the floodplain.

Year 5

Cover of native woody species (planted and volunteer) is at least 30% in the floodplain.

Year 7

- Cover of native woody species (planted and volunteer) is at least 40% in the floodplain.

All years

- Washington State and King County listed Class A Noxious Weeds identified on the site are eradicated.
- King County listed Class B and C Weeds identified on the site are controlled. Control of noxious weeds means to prevent all seed production and to prevent the dispersal of all propagative parts capable of forming new plants. If Japanese knotweed is found at

the mitigation site during monitoring, WSDOT (or its designated representatives) will promptly remove the stems above ground and chemically treat it to facilitate elimination of roots and rhizomes below ground.

- Noxious weeds listed by King County as Non-Designate including reed canarygrass, non-native blackberries, and Scot's broom do not exceed 25% aerial cover in floodplain.

Success Standard

Year 10

Cover of native woody species (planted and volunteer) is at least 50% in the floodplain

7.4 Monitoring

WSDOT staff (or its designated representatives) will monitor the mitigation site for 10 years after installation. If all the performance standards are achieved in less than 10 years, WSDOT may terminate monitoring with approval of the review agencies.

Quantitative monitoring will be completed and documented 1, 3, 5, 7, and 10 years after initial acceptance of the mitigation construction. The site should be evaluated during the summer following plant installation to assess survival rates and document the presence of non-native invasive species. Engineered stream channels and structures will be monitored during years 1, 3, 5, and 7 to verify that their habitat and hydraulic elements are functioning as intended. The WSDOT HQ Monitoring Program (or its designated representatives) will also complete informal (qualitative) assessments of the mitigation sites in years 2, 4, 6, 8, and 9 for adaptive management purposes only.

Quantitative monitoring will be designed to determine if the performance standards have been met. Monitoring reports will be submitted to the recipients listed in Table 7-2 by the month of April following the formal monitoring activities conducted the previous year.

Table 7-2. Monitoring Report Recipients

Permitting Agency or Organization	Contact Name and Address
U.S. Army Corps of Engineers	TBD
Washington State Department of Ecology	TBD
WDFW	TBD
City of Seattle	TBD

WSDOT has established a comprehensive set of monitoring methods used to monitor mitigation sites. The actual methods used to monitor each site are documented in annual monitoring reports prepared by WSDOT's Monitoring Program based in the Environmental Services Office in Olympia, Washington, or its designated representatives.

Contingency Plans

WSDOT anticipates that the mitigation goals will be accomplished with the construction and installation of the mitigation design shown on the grading and planting plans. Contingency actions, however, may be needed to correct unforeseen problems. Contingency revisions typically require coordination with the permitting agencies.

As necessary, contingency measures (site management or revisions to performance criteria with permitting agency agreement) will be implemented to meet performance measures and standards.

7.5 Site Management

WSDOT (or its designated representatives) will manage the sites annually for the first 10 years. Site management activities shall include noxious weed control and may include mulching, fertilizing, supplemental watering, maintaining access, repairing damage from vandals, correcting erosion or sedimentation problems, or picking up litter. During the first year, supplemental watering of installed vegetation will occur during July, August, and September to ensure, at a minimum, the equivalent of normal rainfall levels and no periods of drought (no rainfall or watering) longer than 3 weeks.

Reed canarygrass dominates the watershed and suppression/control of this invasive plant will require careful site preparation and active site management. While complete elimination of reed canarygrass from the mitigation site may not be possible, it should be managed sufficiently to ensure survival of the native planted species until they can effectively compete.

8. References

Ames, J. 2006. *A retrospective on Lake Washington sockeye salmon: origins, stock assessment and spawner capacities*. Washington State Department of Fish and Wildlife.

Armbrust, E., J. Toft, and J. Cordell. 2009. *Evaluation of selected Corps of Engineers ecological restoration projects in the Central Puget Sound, 2009; Review of past monitoring and current status*. Wetland Ecosystem Team, University of Washington, School of Aquatic and Fishery Sciences. Seattle, WA.

Berg, L. and T.G. Northcote. 1985. Changes in territorial, gill-flaring, and feeding behavior in juvenile coho salmon (*Onchorhynchus kisutch*) following short-term pulses of suspended sediment. *Can. J. Fish. Aquat. Sci.* 42: 1410-1417.

Bisson, P.A. and R.E. Bilby. 1982. Avoidance of suspended sediment by juvenile coho salmon. *North American Journal of Fisheries Management*. 2 (4):371-374.

Bradbury, A. and B. Pfeifer. 1992. Lake Sammamish creel survey – 1982-1983. Part IV. Fisheries investigation of Lake Washington and Sammamish – 1980-1990. Washington Department of Fish and Wildlife. Unpublished draft report.

Brocksmith, R. 1999. *Abundance, feeding ecology and behavior of a native piscivore northern pikeminnow (Ptychocheilus oregonensis) in Lake Washington*. M.S. Thesis, University of Washington, Seattle, Washington.

Brown, T.G. and G.F. Hartman. 1988. Contribution of seasonally flooded lands and minnow tributaries to the production of coho salmon in Carnation Creek, British Columbia. *Transactions of the American Fisheries Society* 117:546-551.

Buchanan, Kurt. 2004. Personal Communication. Phone communication between K. Buchanan, Habitat Biologist, Washington Department of Fish and Wildlife, Olympia, Washington with Don Weitkamp, Senior fish biologist, Parametrix, on July 26, 2004.

Burton, K.B., and R.M. Little. 1997. Instream Flow Regulation and Steelhead (*Oncorhynchus mykiss*) Redd Protection: A Case Study in Adaptive Management. *Proceedings of AWWA Water Resources Conference*, Seattle, Washington. 1:409–423.

Bustard, D.R. and D.W. Narver. 1975. Aspects of the winter ecology of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead (*Salmo gairneri*). *Journal of Fisheries Research Board of Canada* 32:667-680.

Celedonia, M.T., R.A. Tabor, S. Sanders, D.W. Lantz, and J. Grettenberger. 2008a. *Movement and Habitat Use of Chinook Salmon Smolts and Two Predatory Fishes in Lake Washington and the Lake Washington Ship Canal: 2004-2005 Acoustic Tracking Studies*. U.S. Fish and Wildlife Service, Lacey, Washington. http://www.fws.gov/westwafwo/fisheries/Publications/2004_2005%20Acoustic%20 Final%20Report.pdf.

Celedonia, M.T., R.A. Tabor, S. Sanders, S. Damm, D.W. Lantz, T.M. Lee, Z. Li, J. Pratt, B.E. Price, and L. Seyda. 2008b. *Movement and Habitat use of Chinook Salmon Smolts, Northern Pikeminnow and Smallmouth Bass near the SR 520 Bridge: 2007 Acoustic Tracking Study*. U.S. Fish and Wildlife Service Office, Lacey, Washington.

Celedonia, M.T., R.A. Tabor, S. Sanders, S. Damm, D.W. Lantz, T.M. Lee, Z. Li, B.E. Price, W. Gale, and K. Ostrand. 2009. *Movement and Habitat Use of Chinook Salmon Smolts, Northern Pikeminnow and Smallmouth Bass Near the SR 520 Bridge, 2008 Acoustic Tracking Study*. Unpublished review draft report to the Washington State Department of Transportation by U.S. Fish and Wildlife Service, Washington Fish and Wildlife Office, Fisheries Division, Lacey, Washington.

Chrzastowski, M. 1983. Historical changes to Lake Washington and route of the Lake Washington Ship Canal, King County, Washington. *Dept. of the Interior, U. S. Geological Survey Water Resources Investigations*. WRI 81-1182.

City of Seattle. 1999. *City of Seattle Built Environment Shoreline Surveys*. Prepared by Parametrix and Natural Resources Consultants for the Seattle Public Utilities. Seattle, Washington.

City of Seattle. 2000. *Final Cedar River Watershed Habitat Conservation Plan for the Issuance of a Permit to Allow Incidental Take of Threatened and Endangered Species*. Seattle, Washington.

City of Seattle. 2001. *Seattle's Urban Blueprint for Habitat Protection and Restoration*. Prepared for the City of Seattle by the City of Seattle Salmon Team.

City of Seattle and USACE (U.S. Army Corps of Engineers). 2008. *Synthesis of Salmon Research and Monitoring, Investigations Conducted in the Western Lake Washington Basin*. December 31, 2008. Seattle, Washington.

Dillon, J.F., F. Goetz, and C. Ebel. 2000. Lake Washington tributary mouth survey. Lake Washington GI Program, U.S. Army Corps of Engineers, Seattle District, Seattle, Washington.

DNR (Washington State Department of Natural Resources). 1999. *Lake Union water quality*. Olympia Washington.

DNR (Washington State Department of Natural Resources). 2010. Overwater Structures in Navigable Lakes of Washington State. Data available online at: http://fortress.wa.gov/dnr/app1/dataweb/metadata/OWS_Lakes_metadata.htm.

Ecology (Washington State Department of Ecology). 2008. Washington State's Water Quality Assessment [303(d)]. Accessed April 2, 2009.

Edmondson, W.T. 1994. Sixty years of Lake Washington: A curriculum vitae. *Lake and Reservoir Management* 10: 75-84.

Eggers, D.M., N.W. Bartoo, N.A. Rickard, R.E. Nelson, R.C. Wissmar, R.L. Burgner, and A.H.Devol. 1978. The Lake Washington ecosystem: the perspective from the fish community production and for age base. *Journal of the Fisheries Research Board of Canada* 35(5):1553-1571.

Fayram, A.H. and T.H. Sibley. 2000. Impact of predation by smallmouth bass on sockeye salmon in Lake Washington, Washington. *North American Journal of Fisheries Management* 20:81-89.

Foerster, R.E. 1968. The sockeye salmon, *Oncorhynchus nerka*. *Bull. Fish. Res. Board, Canada*. 162, 422 pp.

Fresh, K.L. 2000. Use of Lake Washington by Juvenile Chinook Salmon, 1999 and 2000. *Proceedings of the Chinook Salmon in the Greater Lake Washington Watershed Workshop*. Shoreline, Washington, November 8–9, 2000. King County, Seattle, Washington.

Fresh, K.L. and G. Lucchetti. 2000. Protecting and restoring the habitats of anadromous salmonids in the Lake Washington Watershed, and urbanizing ecosystem. Pages 525-544 *in* E. E. Knudsen, C. R. Steward, D. E. MacDonald, J. E. Williams, editors. *Sustainable Fisheries Management: Pacific Salmon*. Lewis Publishers, Boca Raton, FL.

Fresh, K.L., E. Warner, R. Tabor, and D. Houck. 1999. *Migratory behavior of adult Chinook salmon spawning in the Lake Washington watershed in 1998 as determined with ultrasonic telemetry*. Draft progress report, October 1999.

Fresh, K., E. Warner, R. Tabor, D. Houck. 2000. *Migratory Behavior of Adult Chinook Salmon Spawning in the Lake Washington Watershed in 1998 and 1999 as Determined with Ultrasonic Telemetry*. King County, Wastewater Treatment Division, November 2000.

Fresh, K.L., D. Rothaus, K.W. Mueller, and C. Waldbillig. 2001. *Habitat Utilization by Predators, with Emphasis on Smallmouth Bass, in the Littoral Zone of Lake Washington*. Draft report, Washington State Department of Fish and Wildlife, Olympia, Washington.

Garland, R.D., K.F. Tiffan, D.W. Rondorf, and L.O. Clark. 2002. Comparison of Subyearling Fall Chinook Salmon's Use of Riprap Revetments and Unaltered Habitats in Lake Wallula of the Columbia River. *N. Am. J. Fish. Mgmt*. 22:1283-1289.

Gayaldo, P.F. and K. Nelson. 2006. Preliminary results of light transmission under residential piers in Lake Washington, King County, Washington: A comparison between prisms and grating. *Lake and Reserv. Manage*. 22(3):245-249.

Goetz, F.A., E. Jeanes, D. Seiler, and P. Topping. 2006. *Chinook salmon thermal habitat use of estuary and lake environments within the Lake Washington basin: Progress Report 1*. U.S. Army Corps of Engineers, Seattle District, Seattle, WA. Internal Technical Report.

Hendry, A.P., T.P. Quinn, and F.M. Utter. 1996. Genetic evidence for the persistence and divergence of native and introduced sockeye salmon (*Oncorhynchus nerka*) within Lake Washington, Washington. *Can. J.Fish. Aquat. Sci.* 53:823–832.

Hendry, A.P. and T.P. Quinn. 1997. Variation in adult life history and morphology among Lake Washington sockeye salmon (*Oncorhynchus nerka*) populations in relation to habitat features and ancestral affinities. *Canadian Journal of Fisheries and Aquatic Sciences* 54: 75-84.

Horner, R.R., and C.W. May. 1998. Watershed urbanization and the decline of salmon in Puget Sound streams. Pages 16-19 *in* Salmon in the City, Conference Proceedings. American Public Works Association, Washington Chapter. Washington State University. Pullman, Washington; Mount Vernon, Washington.

Howick, G. L. and W. J. O'Brien. 1983. Piscivorous feeding behavior of largemouth bass: an experimental analysis. *Transactions of the American Fisheries Society*. 12:508-516.

Hynes, H.B.N. 1970. *The ecology of running waters*. Liverpool: Liverpool University Press.

Illingworth and Rodkin, Inc. 2010. *Underwater sound levels associated with driving steel piles for the State Route 520 Floating Bridge Test Pile Project*. Prepared for WSDOT, Office of Air Quality and Noise, Seattle, Washington.

Jones, G.R., and E. Jones. 1975. *East Campus Research Arboretum*. Jones & Jones, Seattle, Washington.

Jones & Stokes. 2005. *Biological Assessment Mercer Island Sewer Line Replacement Project*. August 3. (Jones & Stokes 3522.02.) Bellevue, Washington.

Kahler, T., M. Grassley, and D. Beauchamp. 2000. *A Summary of the Effects of Bulkheads, Piers and other Artificial Structures and Shorezone Development on ESA-listed Salmonids in Lakes.* City of Bellevue, Bellevue, Washington.

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

King County. 1995. *Combined sewer overflow plan: 1995 updates*. Department of Metropolitan Services, Seattle, Washington.

King County. 2003. *Lake Washington existing conditions report*. Sammamish/Washington Analysis and Modeling Program (SWAMP). Prepared by Tetra Tech ISG, Inc. and Parametrix, Inc. for King County Department of Natural Resources and Parks, Water and Land Resources Division, Seattle, Washington.

King County. 2005. *Final Lake Washington/Cedar/Sammamish Watershed (WRIA 8) Chinook Salmon Conservation Plan – WRIA 8*. July 2005.

King County. 2007. *Major lakes continuous temperature study*. Prepared by Curtis DeGasperi, Water and Land Resources Division. Seattle, Washington.

King County. 2008. Ravenna Creek, sewer spill response – King County Natural Resources and Parks, Wastewater Treatment Division. King County website accessed April 29, 2009. http://dnr.metrokc.gov/wtd/community/sewer-spill-response/0805-RavennaCreek.htm.

King County. 2009. Major Lakes Monitoring. http://green.kingcounty.gov/lakes/LakeUnion.aspx.

Koehler, M.E. 2002. *Diet and Prey Resources of Juvenile Chinook Salmon (Oncorhynchus tshawytscha) Rearing in the Littoral Zone of Lake Washington*. M.S. Thesis, Univ. Washington, Seattle, Washington.

Koehler, M.E., K.L. Fresh, D.A. Beauchamp, J.R. Cordell, C.A. Simenstad, and D.E. Seiler. 2006. Diet and bioenergetics of lake-rearing juvenile Chinook salmon in Lake Washington. *Trans. Amer. Fish. Soc.* 135:1580-1591.

Machesan, M., M. Spoto, L. Verginella, and E.A. Ferrero. 2005. Behavioral effects of artificial light on fish species of commercial interest. *Fisheries Research* 73:171–185.

Martz, M., F. Goetz, J. Dillon, and T. Shaw. 1996. *Study element II: early lake life history of sockeye salmon (Oncorhynchus nerka) in Lake Washington, year 1: 1994*. Final report. U.S. Army Corps of Engineers, Seattle District, Seattle, Washington.

Mathisen, O.A. 1955. *Studies on the spawning biology of the red salmon, Oncorhynchus nerka Walbaum, in Bristol Bay, Alaska, with special reference to the effect of altered sex ratios*. Ph.D. Thesis. University of Washington, Seattle.

Mazur, M.M., and D.A. Beauchamp. 2003. A comparison of visual prey detection among species of piscivorous salmonids: Effects of light and low turbidities. *Environmental Biology of Fishes* 4:397–405.

McPherson, S. and J.C. Woodey. 2009. *Cedar River and Lake Washington Sockeye Salmon-Biological Reference Point Estimates*. Prepared for Washington Department of Fisheries and Wildlife. June 15, 2009.

Moscrip, A.L., and D.R. Montgomery. 1997. Urbanization, flood frequency, and salmon abundance in Puget lowland streams. *J. Am. Water Res. Assoc*. 33(6):1289-1297.

Newell, J.C. 2005. *Migration and Movement Patterns of Adult Sockeye Salmon (Oncorhynchus nerka) in Lake Washington*. Masters Thesis, University of Washington, School of Aquatic and Fishery Sciences.

Newell, J.C., and Quinn, T.P. 2005. Behavioral thermoregulation by maturing adult sockeye salmon (*Onorhynchus nerka*) in a stratified lake prior to spawning. *Canadian Journal of Zoology* 83: 1232-1239.

Nightingale, B.J., and C.A. Simenstad. 2001. *Overwater Structures: Marine Issues*. White paper prepared for the Washington Department of Fish and Wildlife, Washington Department of Ecology, and Washington Department of Transportation, Olympia, Washington.

NMFS (National Marine Fisheries Service). 2008a. Endangered Species Act Section 7 Formal Consultation and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for the Operation and Maintenance of the Lake Washington Ship Canal located in the City of Seattle, King County, Washington. 6th Field HUC 171100120301 – Lower Sammamish River, 171100120302 – Cedar River, and 171100190401 – Shell Creek.

NMFS (National Marine Fisheries Service). 2008b. Endangered Species Act Section 7 Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation – Barbee Maintenance Dredging and Boathouse Renovation. King County Washington. August 2008.

Nowak, G.M. 2000. *Movement patterns and feeding ecology of cutthroat trout (Oncorhynchus clarki clarki) in Lake Washington*. M.S. Thesis, University of Washington, Seattle, Washington.

Olsen, J.C. 1968. Physical environment and egg development in a mainland beach area and an island beach area of Iliamna Lake. *Univ. Wash. Publ. Fish.* New Ser. 3:169–198.

Quinn, T.P., J.A. Peterson, V.F. Galluci, W.K. Hershberger, and E.L. Brannon. 2002. Artificial selection and environmental change: countervail timing affecting the timing of spawning by coho and Chinook salmon. *Transactions of the American Fisheries Society* 131:591–598.

Reiser, D.W., and T.C. Bjornn. 1979. Habitat requirements of anadromous salmonids. *U.S. For. Serv., Pac. Northwest For. Range Exp. Stn. Gen. Tech. Rep*. PNW-96.

Saldi-Caromile, K., K. Bates, P. Skidmore, J. Barenti, D. Pineo. 2004. *Stream Habitat Restoration Guidelines: Final Draft*. Co-published by the Washington Departments of Fish and Wildlife and Ecology and the U.S. Fish and Wildlife Service. Olympia, Washington.

Savino, J. F. and R. A. Stein. 1989. Behavior of fish predators and their prey: habitat choice between open water and dense vegetation. *Environmental Biology of Fishes*, Vol. 24, No. 4 , pp. 287-293.

Schindler, D. 2000. Predation and temperature. Preliminary data presented at the workshop Chinook salmon in the Greater Lake Washington Watershed. University of Washington, Seattle, Washington.

Seattle Parks and Recreation. 2003. *Seattle Shoreline Park Inventory and Habitat Assessment*. Seattle, Washington.

Seiler, D., G. Volkhardt, and L. Kishimoto. 2003. *Evaluation of Downstream Migrant Salmon Production in 1999 and 2000 from Three Lake Washington Tributaries: Cedar River, Bear Creek, and Issaquah Creek*. Wild Salmon Production Evaluation Unit Science Division, Fish Program. Washington Department of Fish and Wildlife, Olympia, Washington.

Seiler, D., G. Volkhardt, and L. Fleischer. 2004. *Evaluation of Downstream Migrant Salmon Production in 2002 from the Cedar River and Bear Creek*. Washington Department of Fish and Wildlife, Olympia, Washington.

Shared Strategy. 2007. *Puget Sound salmon recovery plan*. Shared Strategy for Puget Sound. Seattle, Washington.

Sigler, J.W., T.C. Bjornn and F.H. Everst. 1984. Effects of Chronic Turbidity on Density and Growth of Steelhead and Coho Salmon. *Transactions of the American Fisheries Society*. 113:142–150.

Simenstad, C.A., and J.R. Cordell. 2000. Ecological Assessment Criteria for Restoring Anadromous Salmonid Habitat in Pacific Northwest Estuaries. *Ecol. Engin.* 15:283–302.

Swales, S. and C.D. Levings. 1989. Role of off-channel ponds in the life cycle of coho salmon (*Oncorhynchus kisutch*) and other juvenile salmonids in the Coldwater River, British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences* 46:232-242.

Sweka, J.A. and K.J. Hartman. 2003. Reduction of reactive distance and foraging success in smallmouth bass, *Micropterus dolomieu*, exposed to elevated turbidity levels. *Environmental Biology of Fishes*. Vol.67:341-347.

Tabor, R., F. Mejia, D. Low, B. Footen, and L. Park. 2000. Predation of juvenile salmon by littoral fishes in the Lake Washington-Lake Union Ship Canal: Powerpoint presentation. Lake Washington Chinook Workshop, Shoreline, Washington.

Tabor, R. A. and R.M. Piaskowski. 2002. *Nearshore Habitat Use by Juvenile Chinook Salmon in Lentic Systems of the Lake Washington Basin*. U.S. Fish and Wildlife Service, Western Washington Fish and Wildlife Office, Lacey, Washington. Funded and published by Seattle Public Utilities.

Tabor, R.A., M.T. Celedonia, F. Mejia, R.M. Piaskowski, D.L. Low, B. Footen, and L. Park. 2004a. *Predation of Juvenile Chinook Salmon by Predatory Fishes in Three Areas of the Lake Washington Basin*. Miscellaneous report. U.S. Fish and Wildlife Service, Western Washington Fish and Wildlife Office, Lacey, Washington.

Tabor, R.A., G. Brown, and V. Luiting. 2004b. The effect of light intensity on sockeye salmon fry migratory behavior and predation by cottids in the Cedar River, Washington. *North American Journal of Fish Management* 24:129–145.

Tabor, R.A., H.A. Gearns, C.M. McCoy III, and S. Camacho. 2006. *Nearshore Habitat Use by Juvenile Chinook Salmon in Lentic Systems of the Lake Washington Basin, Annual Report, 2003 and 2004*. U.S. Fish and Wildlife Service, Western Washington Fish and Wildlife Office, Lacey, Washington.

Tabor, R.A., S. Sanders, M. Celedonia, D. Lantz, S. Damm, T. Lee, Z. Li, and B. Price. 2010a. *Spring/ Summer Habitat Use and Seasonal Movement Patterns of Predatory Fishes in the Lake Washington Ship Canal; Final Report, 2006–2009*. U.S. Fish and Wildlife Service, Western Washington Fish and Wildlife Office, Lacey, Washington.

Tabor, R.A., D. Lantz, and S. Sanders. 2010b. *Distribution and Habitat Use of Fish in Seattle's Streams Final Report, 2005 and 2006*. U.S. Fish and Wildlife Service, Western Washington Fish and Wildlife Office, Lacey, Washington.

Timko, M.A., P.A. Nealson, and S.V. Johnston. 2002. *Using acoustic tags for monitoring adult Chinook salmon behavior at the Hiram M. Chittenden Locks, Summer 2000*. Prepared for U.S. Army Corps of Engineers, Seattle District, by Hydroacoustic Technology, Seattle, Washington.

Toft, J. 2001. *Shoreline and Dock Modifications on Lake Washington*. SoFs-UW Rept. No. 0106.

Toft, J.J., C. Simenstad, C. Young, and L. Stamatiou. 2003. *Inventory and mapping of City of Seattle Shorelines along Lake Washington, the Ship Canal, and Shilshole Bay*. SoFs-UW Rept. No. 0302. Prepared by the School of Aquatic and Fishery Sciences, University of Washington for Seattle Public Utilities, City of Seattle.

USFWS (U.S. Fish and Wildlife Service). 1998. *Candidate and listing priority assignment form for the coastal/Puget Sound population segment*. February 12, 1998.

USFWS (U.S. Fish and Wildlife Service). 2008. Endangered Species Act – Section 7 Consultation Biological Opinion Operation and Maintenance of the Lake Washington Ship Canal, Lower Sammamish River 171100120301, Cedar River 171100120302, and Shell Creek 171100190401 King County, Washington. U.S. Fish and Wildlife Service, Western Washington Fish and Wildlife Office. Report # 1-3-02-F-0393.

Warner, E.J., and K.L. Fresh.1998. *Technical review draft: Lake Washington Chinook salmon recovery plan*. Muckleshoot Indian Tribe and Washington Department of Fish and Wildlife.

Washington Trout. 2000. *Water typing and fish distribution within the City of Seattle*. Draft report. May 18, 2000.

WDFW (Washington Department of Fisheries), Washington Department of Wildlife, and Western Washington Treaty Indian Tribes. 1993. *1992 Washington State Salmon and Steelhead Stock Inventory (SASSI): Summary Report*. Olympia, Washington.

WDFW (Washington State Department of Fish and Wildlife). 1998. *1998 Washington State Salmonid Stock Inventory*. *Appendix: Bull Trout and Dolly Varden*. Olympia, Washington.

WDFW (Washington State Department of Fish and Wildlife). 2004. *Salmonid Stock Inventory (SaSI).* Olympia, Washington. http://wdfw.wa.gov/fish/sasi/.

WDFW (Washington State Department of Fish and Wildlife). 2006. *Lake Washington Winter Steelhead Stock Status Report*. http://wdfw.wa.gov/webmaps/salmonscape/sasi/full_stock_rpts/6154.pdf.

WDFW (Washington State Department of Fish and Wildlife) and WWTIT (Western Washington Treaty Indian Tribes).1994. *1992 Washington State salmon and steelhead stock inventory*. Appendix One. Puget Sound Stocks. Hood Canal and Strait of Juan de Fuca volume. Olympia, Washington.

Weitkamp, D., G. Ruggerone, L. Sacha, J. Howell, and B. Bachen. 2000. *Factors Affecting Chinook Populations, Background Report*. Prepared for the City of Seattle by Parametrix, Inc. Natural Resources Consultants, and Cedar River Associates, June 2000.

Williams, D.B. 2000. Building the Ship Canal: A saga of dreamers, schemers and one tough government engineer. *Pacific Northwest Magazine*, Seattle Times, Seattle, Washington.

WSDOT (Washington State Department of Transportation). 2005. WSDOT Floating Bridge Stormwater Monitoring Project. http://your.kingcounty.gov/kcdot/roads/wcms/environment/stormwater/stormwatercharacterization/HerreraWSDOTFloatingBridgeStormwaterMonitoringReport_June2005.pdf. Accessed August 2009.

WSDOT (Washington State Department of Transportation). 2008. *Highway Runoff Manual*. Publication No. M 31-16. http://www.wsdot.wa.gov/Environment/WaterQuality/Runoff/HighwayRunoffManual.htm#2008revision.

WSDOT (Washington State Department of Transportation). 2009a. *Assessment of Nighttime Roadway Lighting Effect on Lake Washington Fish Habitat*. Technical Memorandum prepared for Washington State Department of Transportation by the SR 520 Traffic/Illumination Design Team, I-5 to Medina: Bridge Replacement and HOV Project. Seattle, Washington.

WSDOT (Washington State Department of Transportation). 2009b. *Supplemental Draft EIS Ecosystems Discipline Report*. SR 520, I-5 to Medina: Bridge Replacement and HOV Project. Seattle, Washington.

WSDOT (Washington State Department of Transportation). 2009c. *Initial Aquatic Mitigation Report: SR 520, I-5 to Medina: Bridge Replacement and HOV Project*. Seattle, Washington.

WSDOT (Washington State Department of Transportation). 2009d. *Shoreline Habitat Report, Technical Memorandum: SR 520, SR 520 Eastside Transit and HOV Project*. Seattle, Washington.

WSDOT (Washington State Department of Transportation). 2010a. *Biological Assessment: SR 520, I-5 to Medina: Bridge Replacement and HOV Project*. Seattle, Washington.

WSDOT (Washington State Department of Transportation). 2010b. *Supplemental Draft Environmental Impact Statement: SR 520, I-5 to Medina: Bridge Replacement and HOV Project*. Seattle, Washington.

WSDOT (Washington State Department of Transportation). 2010c. *AKART and Water Quality Studies for SR 520 Replacement Floating Bridge*. SR 520 Bridge Replacement and HOV Program, I-5 to Medina: Bridge Replacement and HOV Project. Prepared by CH2M HILL. April 2010.

WSDOT (Washington State Department of Transportation). 2010d. *Work Bridge, Falsework and Piling Technical Memorandum*. Prepared for SR 520 Environmental Discipline – ESA White Papers 1 and 8 Development: SR 520, I-5 to Medina: Bridge Replacement and HOV Project. Seattle, Washington.

WSDOT (Washington State Department of Transportation). 2010e. *Underwater Sound Levels Associated with Driving Steel Piles for the State Route 520 Bridge Replacement and HOV Project Pile Installation Test Program: SR 520, I-5 to Medina: Bridge Replacement and HOV Project*. Seattle, Washington.

WSDOT (Washington State Department of Transportation). 2010f. *Hydraulics Manual*. Publication No. M 23-03. http://www.wsdot.wa.gov/Publications/Manuals/M23-03.htm.

WSDOT (Washington State Department of Transportation). 2011a. In preparation. *SR 520, I-5 to Medina: Bridge Replacement and HOV Project Conceptual Wetland Mitigation Report*.

WSDOT (Washington State Department of Transportation). 2011b. *Final Geotechnical Assessment of the East Approach Maintenance Building, SR 520, I-5 to Medina: Bridge Replacement and HOV Project*. Prepared by Shannon and Wilson: Seattle, Washington.

Wydoski, R.S. and R.L. Whitney. 2003. *Inland fishes of Washington*. University of Washington Press. Seattle, Washington.

Appendix A

Compensatory Mitigation Site Photos

Figure A-1. Seward Project 1, existing bulkhead. View is to the east.

Figure A-2. Seward Park Project 2, southern portion where re-vegetation is proposed. View is to the NNE.

Figure A-3. Seward Park Project 2, northern portion where riprap removal and bank re-sloping is proposed. View is to the SSE.

Figure A-5. Magnuson Park Project 1 shoreline has very little riparian vegetation and an actively eroding vertical bank.

Figure A-6. Magnuson Park Project 2 existing shoreline.

Figure A-7. Taylor Creek delta.

Figure A-8. Taylor Creek existing shoreline.

Figure A-9. Taylor Creek, just upstream of the delta. Note the channel confinement with placement of boulders, the adjacent asphalt parking area, and upstream culvert. Also note the abundant gravel bedload.

Figure A-10. DNR Parcel, looking east towards the undeveloped shoreline. The end of the flume is located on the left side of the photo.

Figure A-11. DNR Parcel, looking east at the opening of the flume.

Figure A-12. DNR Parcel looking south towards Boeing plant.

Figure A-13. Cedar River, left bank floodplain and terrace.

Figure A-14. Cedar River, levee and riprap on left (south) bank.

Figure A-15. Cedar River, levee and riprap on right (north) bank.

Figure A-16. Bear Creek low gradient riffle and armored streambanks near mouth.

Figure A-17. Southern riparian buffer of Bear Creek. SR 520 in background.

Figure A-18. WSDOT shoreline at the East Approach Gravel Supplementation project area.

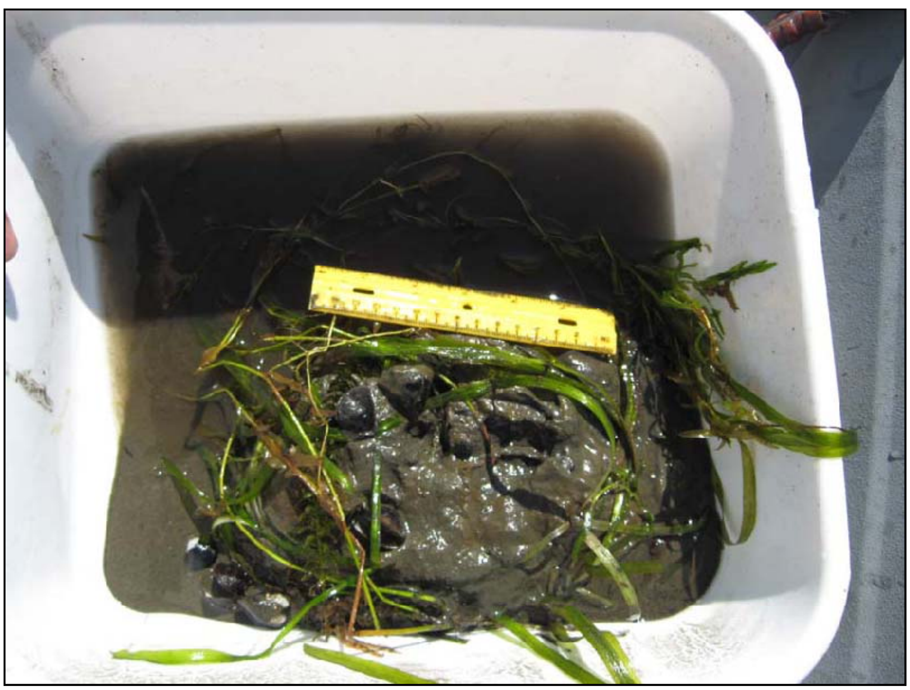


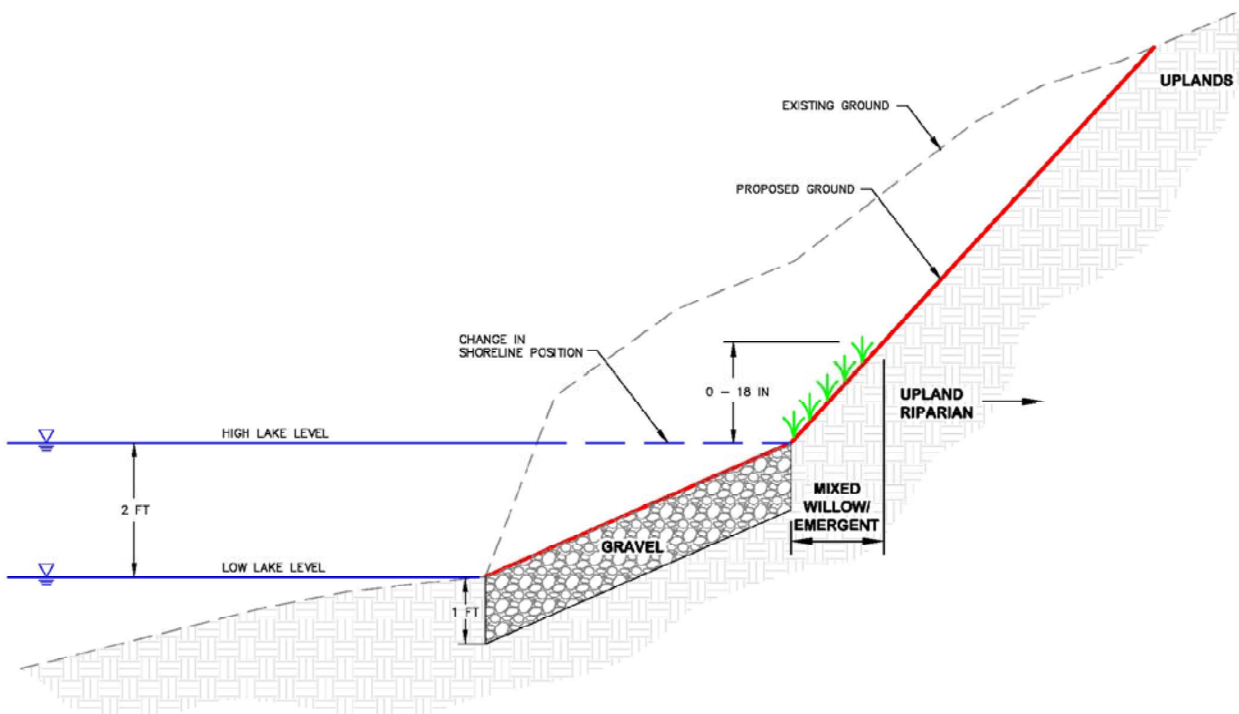
Figure A-19. Existing substrate in the East Approach project area targeted for gravel supplementation.

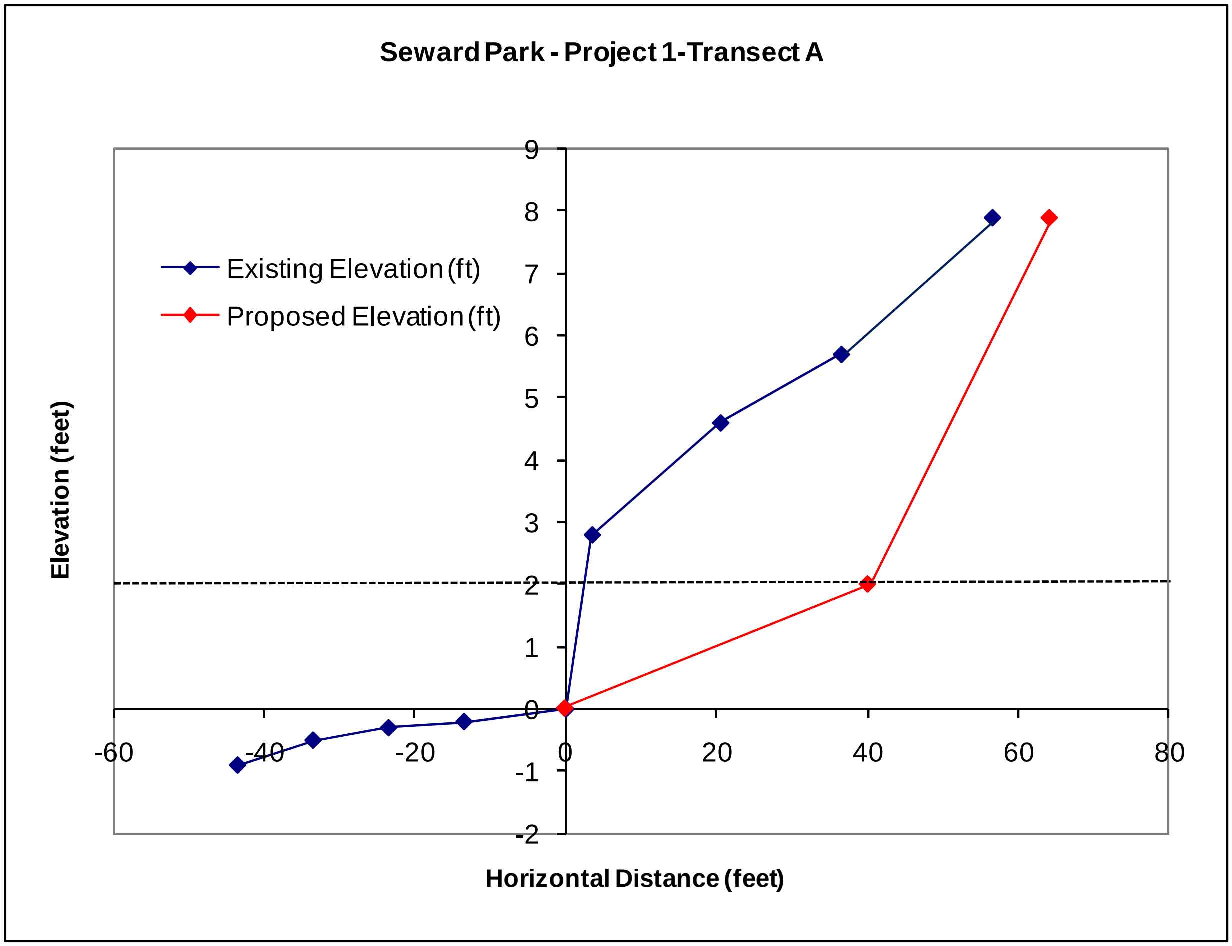
This page intentionally left blank

Appendix B

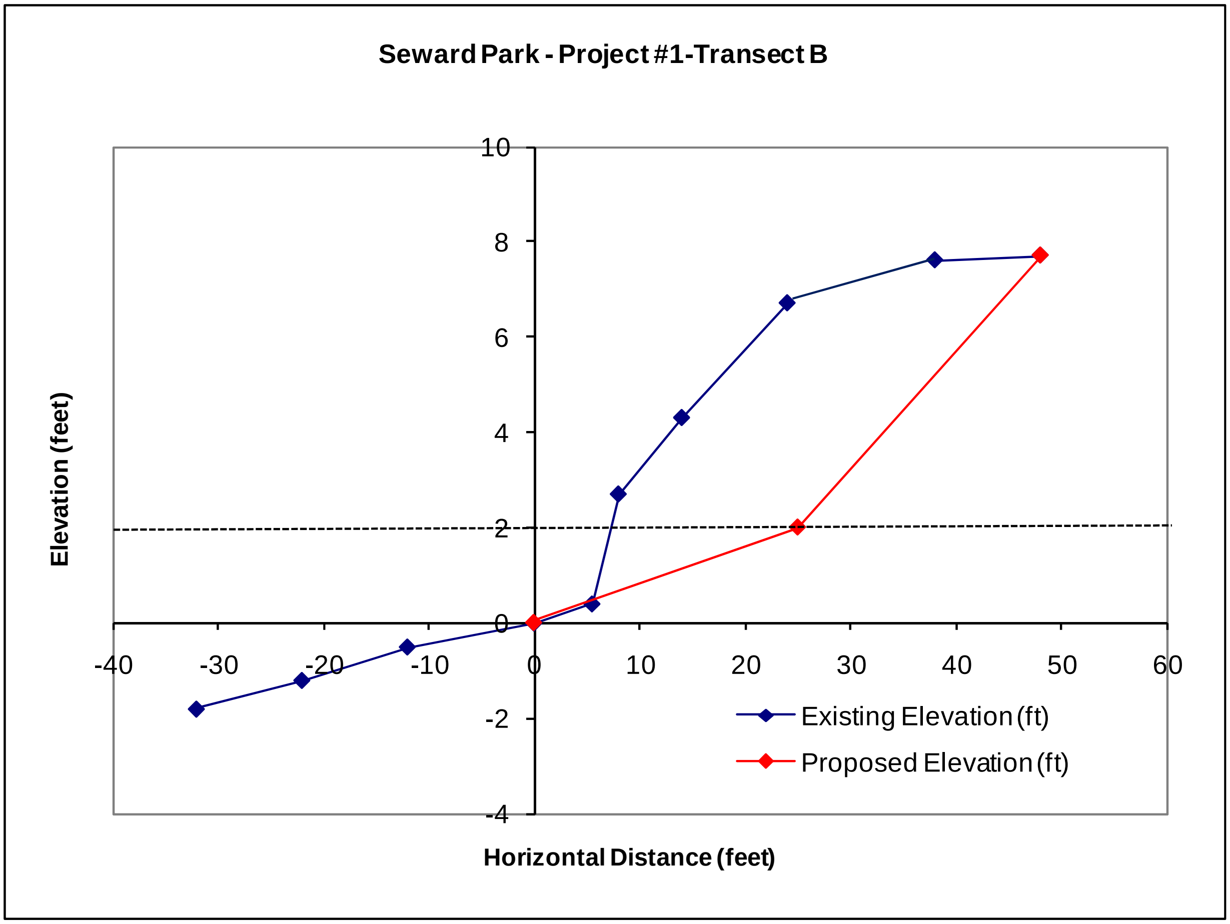
Beach Grading Profiles

Grading Typical

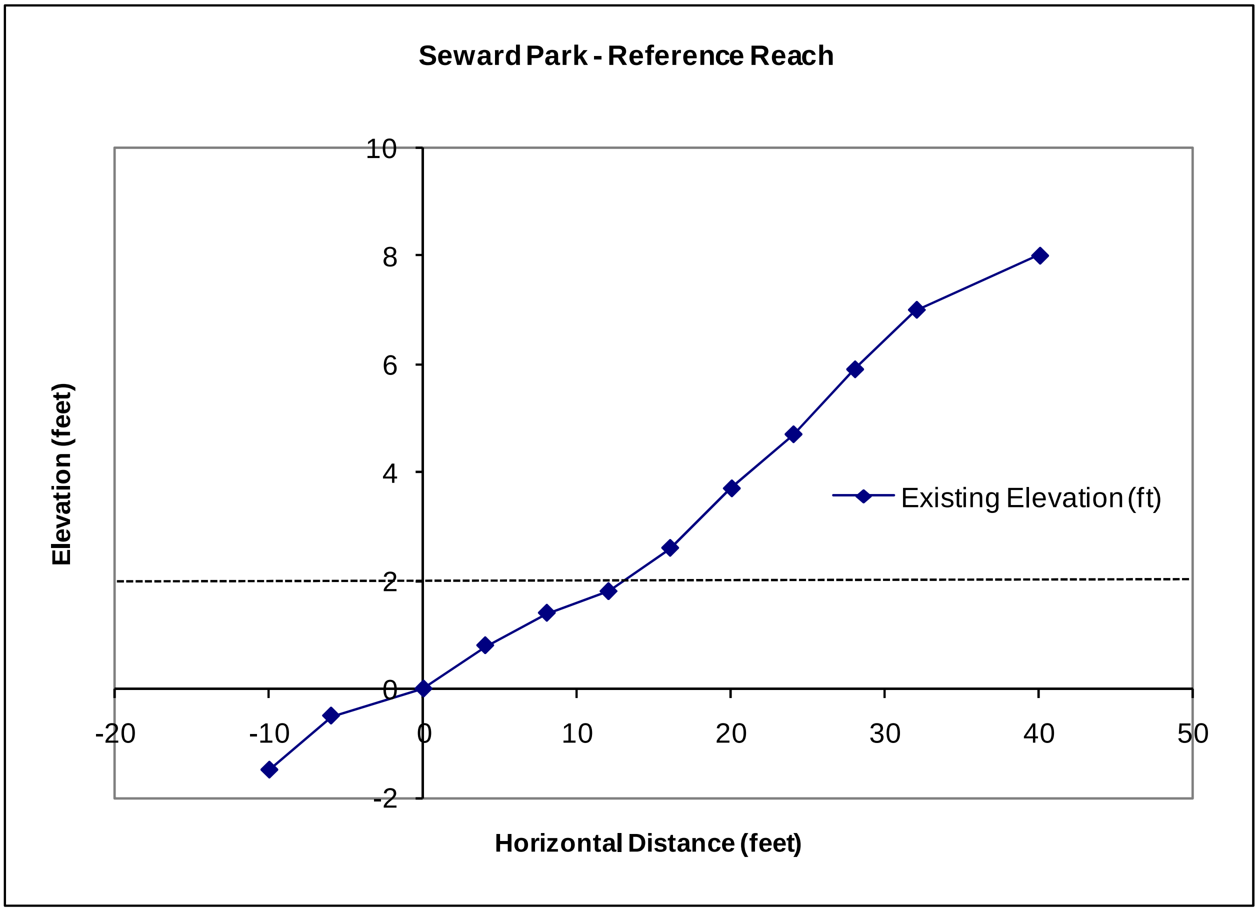




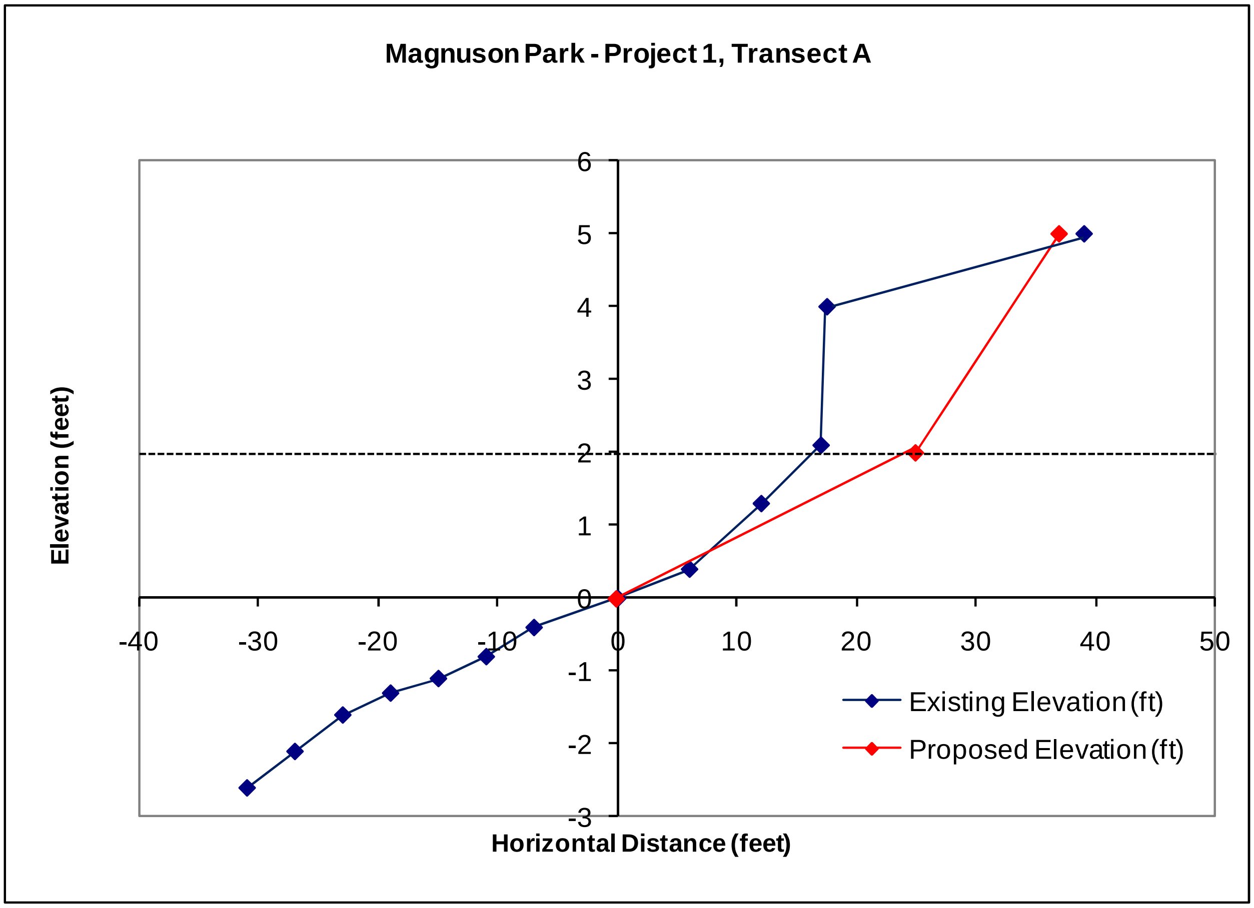
EXISTING	
Slope of in-water reach (%)	2
PROPOSED	
From Low to High Lake Level (%)	5
From High Lake Level to Upland (%)	25
Change in Shoreline Position (ft)	37



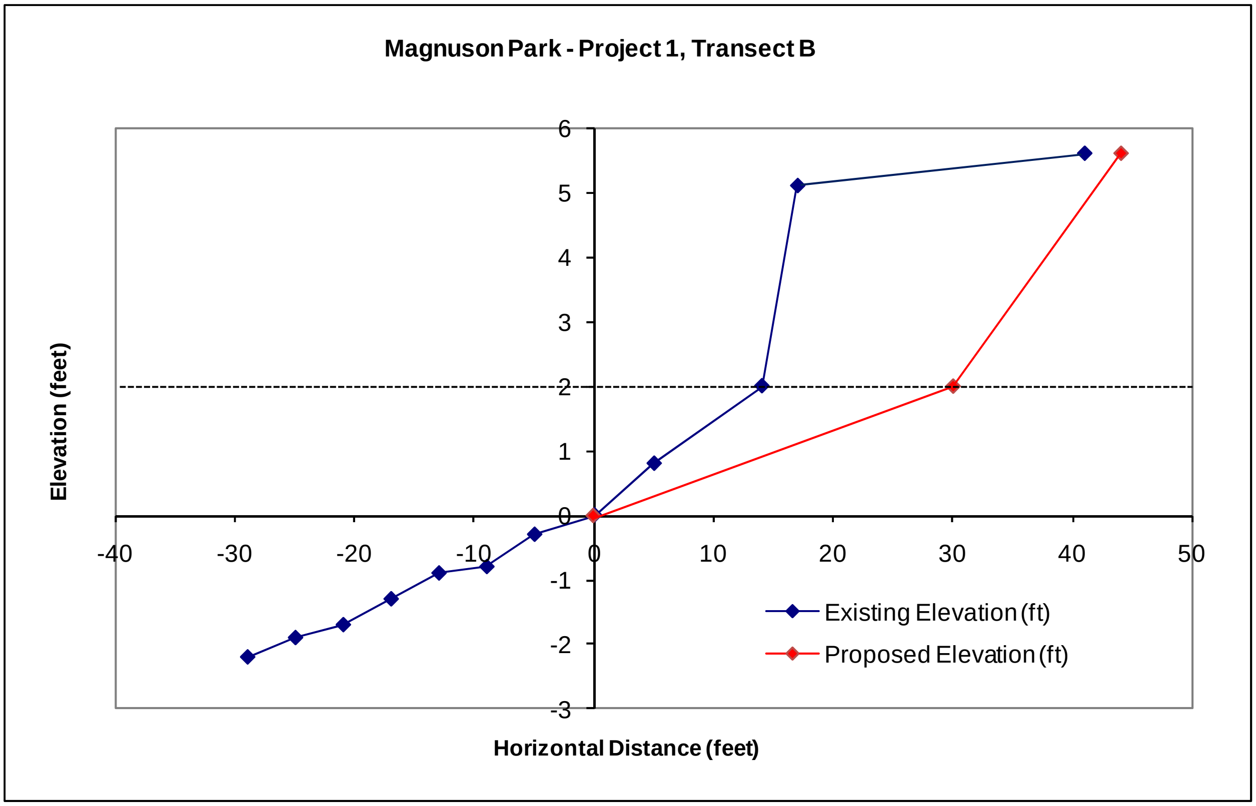
EXISTING	
Slope of in-water reach (%)	6
PROPOSED	
From Low to High Lake Level (%)	8
From High Lake Level to Upland (%)	25
Change in Shoreline Position (ft)	18



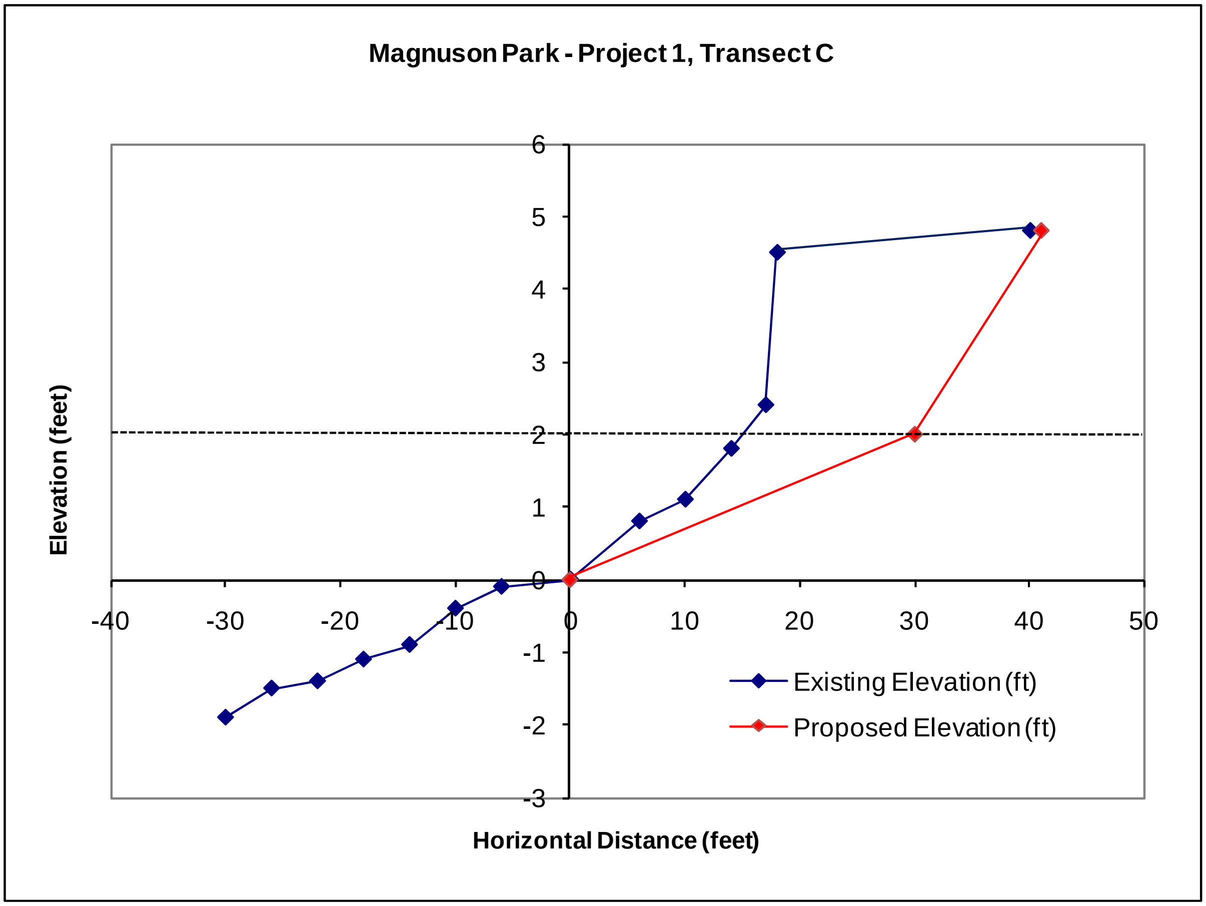
EXISTING	
Slope of in-water reach (%)	15.0
Slope of non-wetted reach (%)	20.0



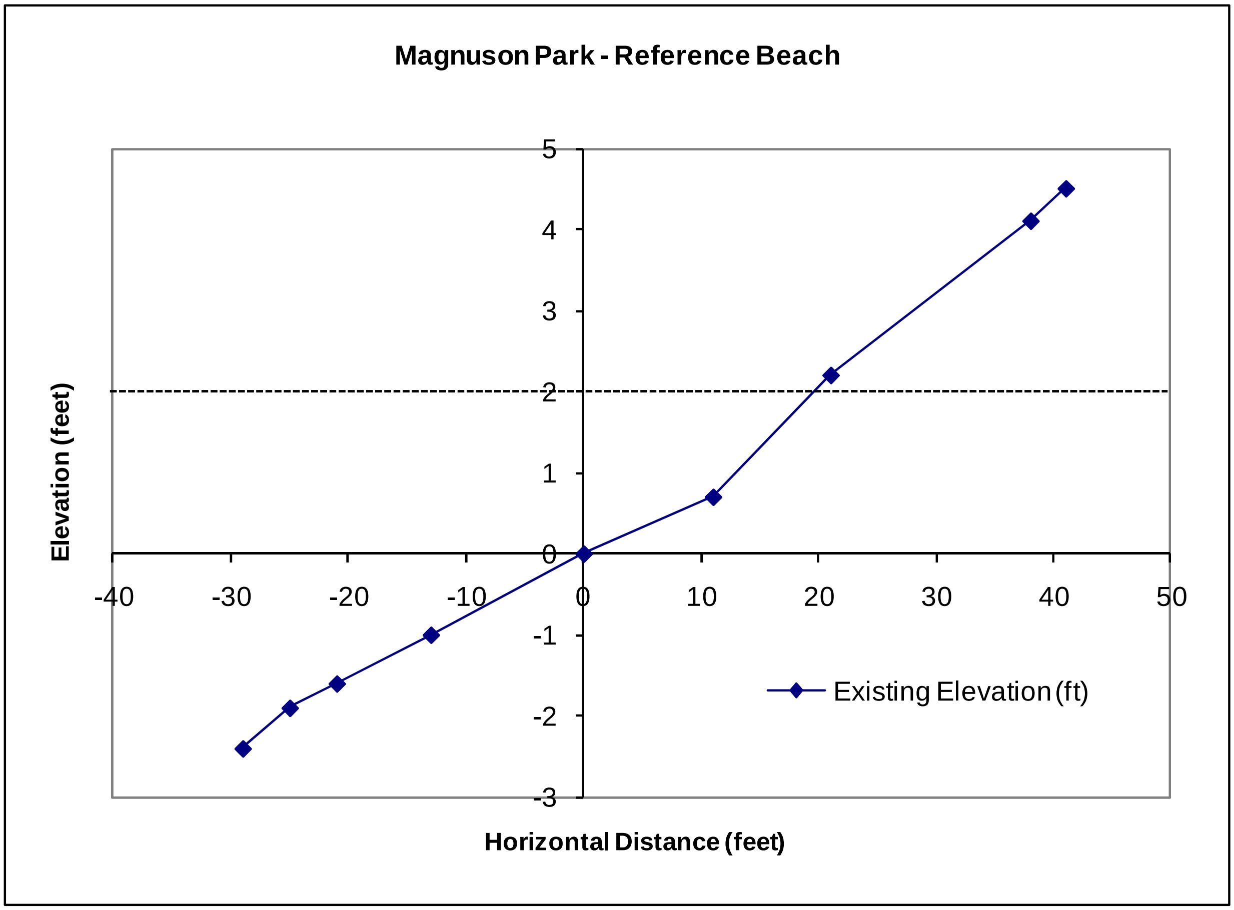
EXISTING	
Slope of in-water reach (%)	8
Slope of non-wetted reach (%)	13
PROPOSED	
From Low to High Lake Level (%)	8
From High Lake Level to Upland (%)	21
Change in Shoreline Position (ft)	8



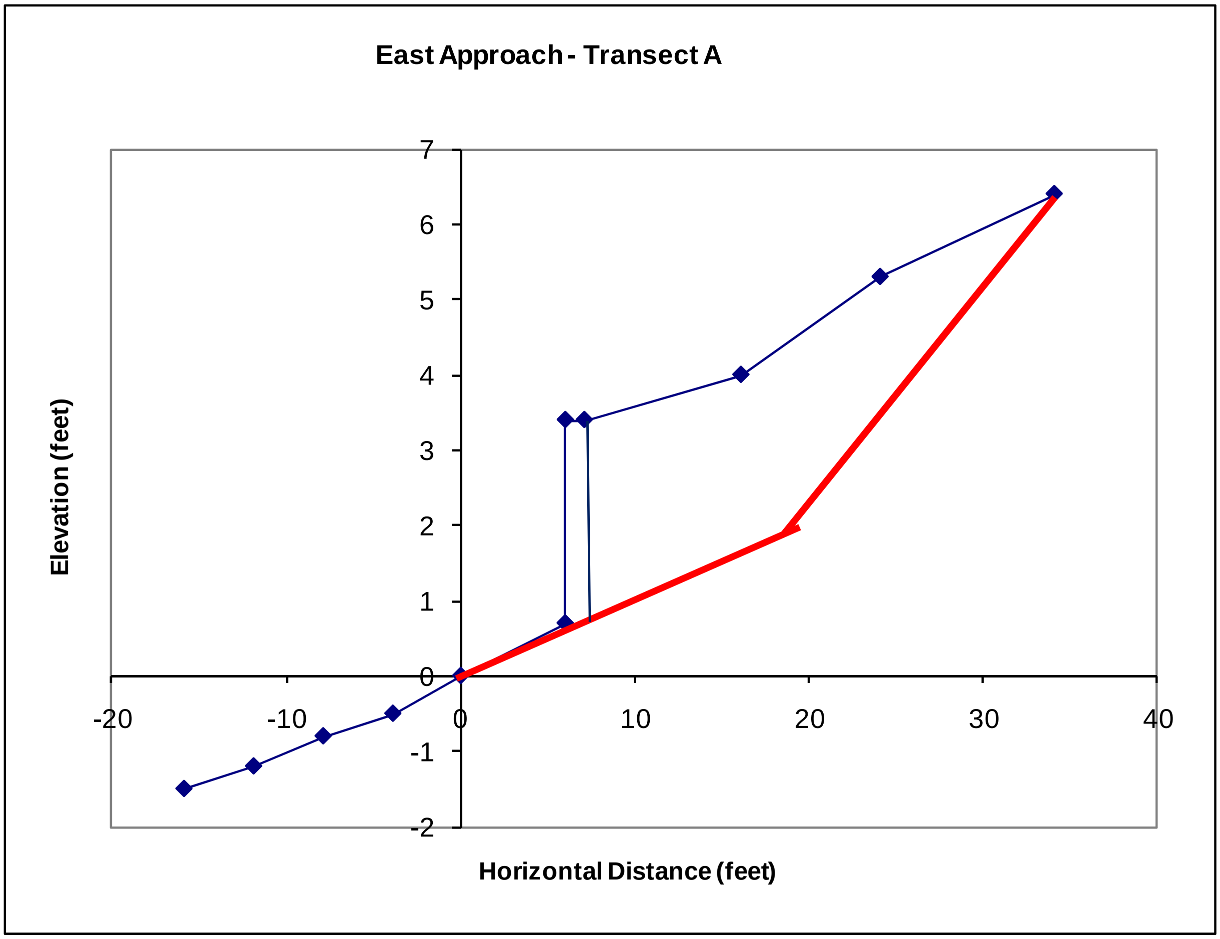
EXISTING	
Slope of in-water reach (%)	8
Slope of non-wetted reach (%)	14
PROPOSED	
From Low to High Lake Level (%)	7
From High Lake Level to Upland (%)	25
Change in Shoreline Position (ft)	16



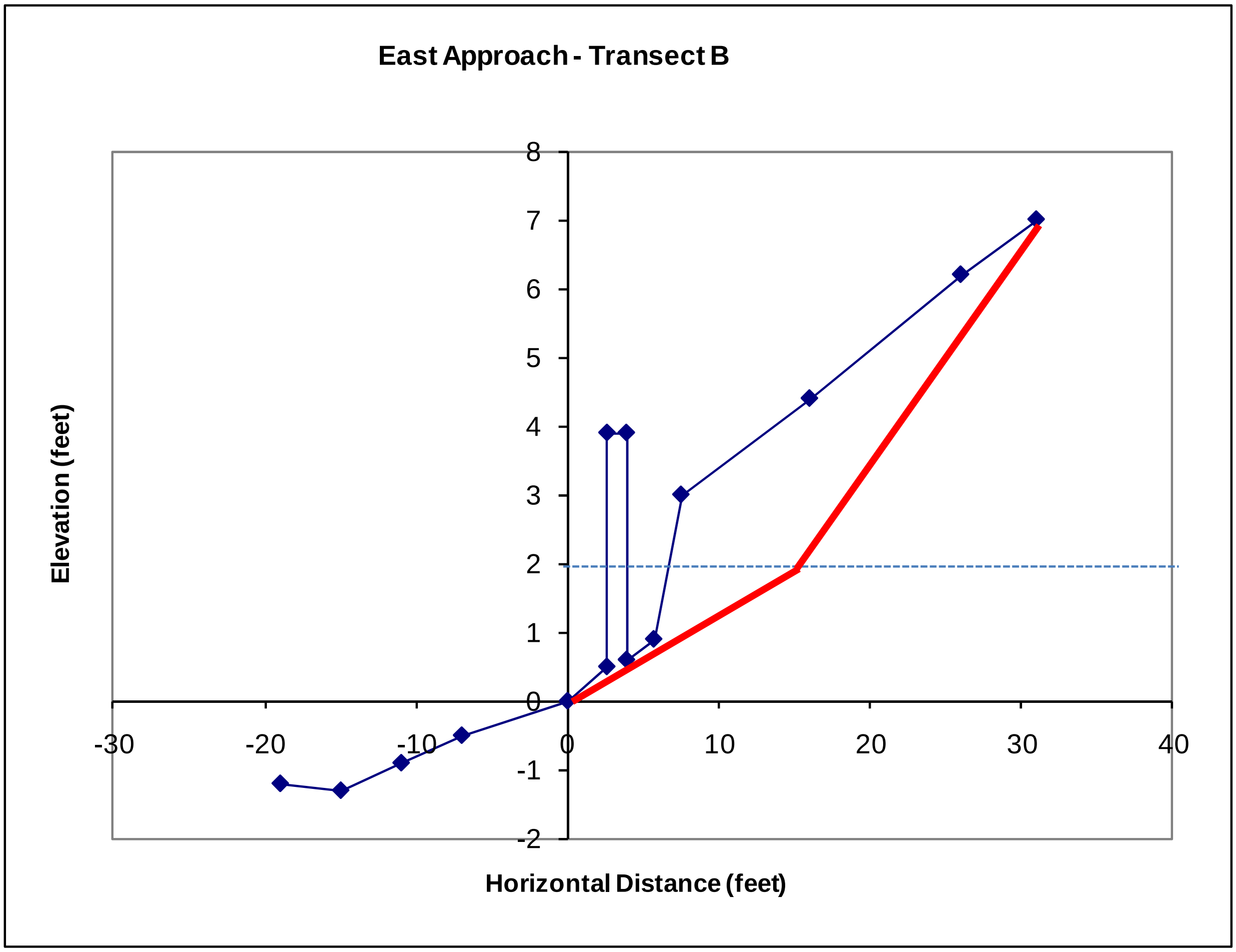
EXISTING	
Slope of in-water reach (%)	6
Slope of non-wetted reach (%)	12
PROPOSED	
From Low to High Lake Level (%)	7
From High Lake Level to Upland (%)	25
Change in Shoreline Position (ft)	15



EXISTING	
Slope of in-water reach (%)	8.3
Slope of non-wetted reach (%)	11.0



EXISTING	
Slope of in-water reach (%)	9.4
Slope of non-wetted reach (%)	18.8
PROPOSED	
From Low to High Lake Level (%)	10.0
From High Lake Level to Upland (%)	31.4
Change in Shoreline Position (ft)	12.9



EXISTING	
Slope of in-water reach (%)	6.3
Slope of non-wetted reach (%)	22.6
PROPOSED	
From Low to High Lake Level (%)	13.3
From High Lake Level to Upland (%)	31.3
Change in Shoreline Position (ft)	8.4

Appendix C

Riparian Planting Palette

Riparian plantings at the aquatic mitigation sites will be largely composed of mixed upland forest species. A typical upland species list is shown in Table C-1. The list includes canopy communities (consisting of both deciduous and coniferous tree species) and sub-canopy communities (consisting of deciduous species tolerant to a broad variety of light availability). Planting densities will be higher than in similar wetland areas to reduce intrusion and provide additional screening for the resources. Wetland species will be incorporated, as appropriate, depending on site conditions. A typical wetland species list is shown in Table C-2. Definitions of indicator status codes are in Table C-3

Table C-1. Proposed Typical Planting List for Upland Riparian Areas

Common Name	Scientific Name	Indicator Status
Upland Forested		
Trees		
Big leaf maple	*Acer macrophyllum*	FACU
Black cottonwood	*Populus balsamifera ssp. trichocarpa*	FAC
Bitter cherry	*Prunus emarginata*	FACU
Douglas-fir	*Pseudotsuga menziesii*	FACU
Red alder	*Alnus rubra*	FAC
Western red cedar	*Thuja plicata*	FAC
Cascara	*Rhamnus purshiana*	FAC
Shrubs		
Baldhip rose	*Rosa gymnocarpa*	FACU
Beaked hazelnut	*Corylus cornuta*	FACU
Common snowberry	*Symphoricarpos albus*	FACU
Red elderberry	*Sambucus racemosa*	FACU
Redflower currant	*Ribes sanguineum*	FACU
Serviceberry	*Amelanchier alnifolia*	FACU
Thimbleberry	*Rubus parviflorus*	FAC
Vine maple	*Acer circinatum*	FAC

Table C-2. Proposed Typical Planting List for Wetland Areas

Common Name	Scientific Name	Indicator Status
Emergent Planting		
Common spikerush	*Eleocharis palustris*	OBL
Ovoid spikerush	*Eleocharis obtusa*	OBL
Hardstem bulrush	*Schoenoplectus acutus*	OBL
Sawbeak sedge	*Carex stipata*	OBL
Small fruited bulrush	*Scirpus microcarpus*	OBL
Wool-grass	*Scirpus cyperinus*	OBL
Slough sedge	*Carex obnupta*	OBL
Tapertip rush	*Juncus acuminatus*	OBL
Rice cutgrass	*Leersia oryzoides*	OBL
Scrub-shrub Wetland Planting		
Black hawthorn	*Crataegus douglasii*	FAC
Black twinberry	*Lonicera involucrata*	FAC
Nootka rose	*Rosa nutkana*	FAC
Pacific ninebark	*Physocarpus capitatus*	FACW
Peafruit rose	*Rosa pisocarpa*	FAC
Red-osier dogwood	*Cornus sericea*	FACW
Salmonberry	*Rubus spectabilis*	FAC
Scouler's willow	*Salix scouleriana*	FAC
Sitka willow	*Salix sitchensis*	FACW
Forested Wetland Planting		
Trees		
Black cottonwood	*Populus balsamifera ssp.*	FAC
Oregon ash	*Fraxinus latifolia*	FACW
Pacific willow	*Salix lucida var. lasiandra*	FACW
Red alder	*Alnus rubra*	FAC
Sitka spruce	*Picea sitchensis*	FAC
Western red cedar	*Thuja plicata*	FAC
Shrubs		
Black twinberry	*Lonicera involucrata*	FAC
Nootka rose	*Rosa nutkana*	FAC
Red-osier dogwood	*Cornus sericea*	FACW
Salmonberry	*Rubus spectabilis*	FAC

Table C-3. Definitions of Wetland Plant Indicator Categories.

Wetland Indicator Category	Code	Definition
Obligate Wetland Plants	OBL	Plants that almost always (> 99% of the time) occur in wetlands, but which may rarely (< 1% of the time) occur in non-wetlands.
Facultative Wetland Plants	FACW	Plants that often (67 to 99% of the time) occur in wetlands, but sometimes (1 to 33% of the time) occur in non-wetlands.
Facultative Plants	FAC	Plants with a similar likelihood (34 to 66% of the time) of occurring in both wetlands and non-wetlands.
Facultative Upland Plants	FACU	Plants that sometimes (1 to 33% of the time) occur in wetlands, but occur more often (67 to 99% of the time) in non-wetlands.

Appendix D

Mitigation Accounting

Table D-1. Potential Value of Compensatory Mitigation Sites to Offset Temporary Impacts

	Mitigation Action	Acreage	Fish Function Modifier	Fish Function Modified Acreage	Mitigation Type Modifier	Mitigation Type Modified Acreage	Duration (Years)	Proportion of Full Function	Mitigation Credit (Acre-Year)
Seward Park	Shoreline Enhancement + Hard Structure Removal (Potential Spawning)	0.94	0.80	0.75	1.0	0.75	1	0.8	0.60
						0.75	17	1.0	12.78
	Riparian Restoration (Potential Spawning Shoreline)	0.61	0.80	0.49	0.2	0.10	5	0.1	0.05
						0.10	5	0.5	0.24
						0.10	8	1.0	0.78
	Riparian Restoration (non-spawning shoreline)	0.81	0.60	0.49	0.2	0.10	5	0.1	0.05
						0.10	5	0.5	0.24
						0.10	8	1.0	0.78
								Subtotal	**15.53**
Magnuson Park	Shoreline Enhancement + Hard Structure Removal	0.34	0.8	0.27	1.0	0.27	1	0.8	0.22
						0.27	17	1.0	4.62
	Riparian Restoration	4.41	0.8	3.53	0.2	0.71	5	0.1	0.35
						0.71	5	0.5	1.76
						0.71	8	1.0	5.64
								Subtotal	**12.60**
Taylor Creek	Channel, Delta, Shoreline, and Marsh Restoration	0.31	0.8	0.25	1.0	0.25	1	0.8	0.20
						0.25	17	1.0	4.22
	Riparian + Floodplain Restoration	0.74	0.8	0.59	0.4	0.24	5	0.1	0.12
						0.24	5	0.5	0.59
						0.24	8	1.0	1.89
								Subtotal	**7.02**
South Lake Washington Shoreline Restoration (DNR Parcel)	Shoreline Enhancement + Hard Structure Removal	1.69	0.8	1.35	1	1.35	1	0.8	1.08
						1.35	17	1.0	22.98
	Riparian Restoration	2.04	0.8	1.63	0.2	0.33	5	0.1	0.16
						0.33	5	0.5	0.82
						0.33	8	1.0	2.61
								Subtotal	**27.66**
Cedar River/ Elliot Bridge	River Margin and Aquatic Off-channel Creation	0.72	0.8	0.58	1	0.58	1	0.8	0.46
						0.58	17	1.0	9.79
	Riparian + Floodplain Restoration	3.04	0.8	2.43	0.4	1.0	5	0.1	0.49
						1.0	5	0.5	2.43
						1.0	8	1.0	7.78
	Floodplain Restoration	1.34	0.8	1.07	0.2	0.2	5	0.1	0.11
						0.2	5	0.5	0.54
						0.2	8	1.0	1.72
								Subtotal	**23.31**

	Mitigation Action	Acreage	Fish Function Modifier	Fish Function Modified Acreage	Mitigation Type Modifier	Mitigation Type Modified Acreage	Duration (Years)	Proportion of Full Function	Mitigation Credit (Acre-Year)
Bear Creek	Stream Enhancement	3.16	0.8	2.53	1	2.53	1	0.8	2.02
						2.53	17	1.0	42.98
	Riparian Restoration	12.62	0.8	10.10	0.2	2.02	5	0.1	1.01
						2.02	5	0.5	5.05
						2.02	8	1.0	16.15
								Subtotal	**67.21**
East Approach Gravel Supplementation	Spawning Gravel Supplementation + Shoreline Enhancement + hard Structure Removal	0.8	0.8	0.64	1	0.64	1	0.8	0.51
						0.64	17	1.0	10.88
	Riparian Restoration	0.05	0.8	0.04	0.2	0.01	5	0.1	0.00
						0.01	5	0.5	0.02
						0.01	8	1.0	0.06
								Subtotal	**11.48**
					Total Potential Permanent Mitigation				**164.81**

Table D-2. Potential Value of Compensatory Mitigation Sites to Offset Permanent Impacts

	Mitigation Action	Acreage	Fish Function Modifier	Fish Function Modified Acreage	Mitigation Type Modifier	Mitigation Credit (acres)
Seward	Shoreline Enhancement + Hard Structure Removal (potential spawning)	0.94	0.8	0.8	1.00	0.75
	Riparian Restoration (potential spawning shoreline)	0.61	0.8	0.5	0.20	0.10
	Riparian Restoration (non-spawning shoreline)	0.81	0.6	0.5	0.20	0.10
					Subtotal	**0.95**
Magnuson	Shoreline Enhancement + Hard Structure Removal	0.34	0.8	0.27	1.00	0.27
	Riparian Restoration	4.41	0.8	3.53	0.20	0.71
					Subtotal	**0.98**
Taylor Creek	Channel and Delta Restoration	0.26	0.8	0.21	1.0	0.21
	Shoreline and Marsh Restoration	0.05	0.8	0.04	1.0	0.04
	Riparian + Floodplain Restoration	0.74	0.8	0.59	0.40	0.24
					Total	**0.48**
South Lake Washington Shoreline Restoration (DNR Parcel)	Shoreline Enhancement + Hard Structure Removal	1.69	0.8	1.35	1.00	1.35
	Riparian Restoration	2.04	0.8	1.63	0.20	0.33
					Total	**1.68**
Cedar River/ Elliot Bridge	River Margin and Aquatic Off-channel Creation	0.72	0.8	0.58	1.0	0.6
	Riparian + Floodplain Restoration	3.04	0.8	2.43	0.40	1.0
	Floodplain Restoration	1.34	0.8	1.07	0.2	0.2
					Subtotal	**1.76**
Bear Creek	Stream Enhancement	3.16	0.8	2.53	1.00	2.5
	Riparian Restoration	12.62	0.8	10.10	0.20	2.0
					Subtotal	**4.55**
East Approach Gravel Supplementation	Spawning Gravel Supplementation	0.75	0.8	0.60	1	0.60
	Shoreline Enhancement + Hard Structure Removal	0.05	0.8	0.04	0.2	0.01
	Riparian Restoration	0.05	0.8	0.04	0.2	0.01
					Subtotal	**0.60**
					Total Potential Permanent Mitigation	**11.00**

This page intentionally left blank.