2020 State of Our Watersheds Report Green-Duwamish River, White-Puyallup River and Lake Washington Basins

We are the salmon people. For generations, salmon have sustained our way of life. Now we must sustain the life of the salmon.

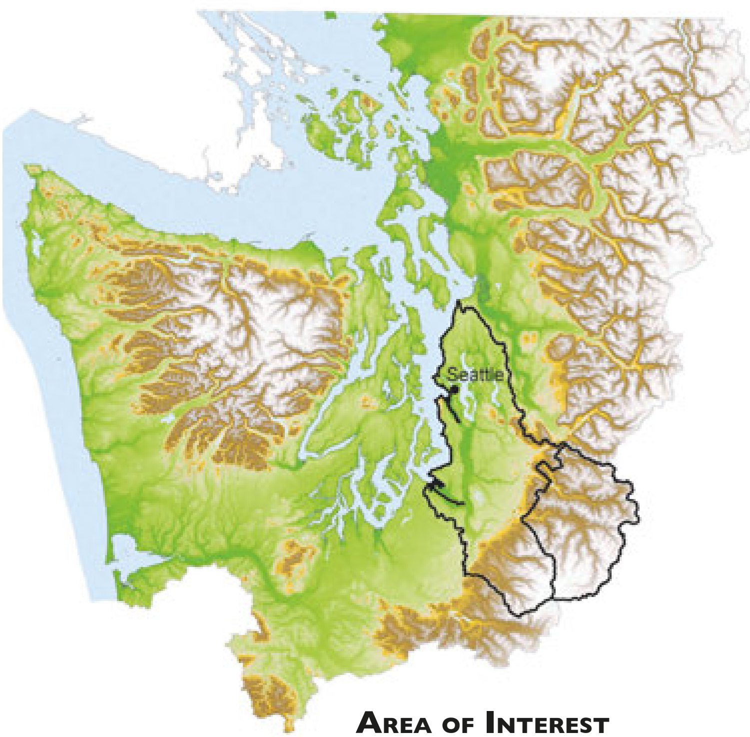
– Phil Hamilton
Muckleshoot Fish Commission

Muckleshoot Indian Tribe

The Muckleshoot Indian Tribe is a federally recognized Indian tribe whose membership is composed of descendants of the Duwamish and Upper Puyallup people who inhabited Central Puget Sound for thousands of years before non-Indian settlement.

The tribe's name is derived from the native name for the prairie on which the Muckleshoot Reservation was established. Following the reservation's establishment in 1857, the tribe and its members came to be known as Muckleshoot, rather than by the historic tribal names of their Duwamish and Upper Puyallup ancestors.

Today, the United States recognizes the Muckleshoot Tribe as a tribal successor to the Duwamish and Upper Puyallup bands from which the tribe's membership descends. Like all native people of western Washington, Muckleshoot ancestors depended on fish, animal and plant resources and traveled widely to harvest these resources. Village groups were linked by ties of marriage, joint feasting, ceremonies, commerce and use of common territory. Downriver people intermarried with other groups along the sound, while people on the upper reaches of the drainages also intermarried with groups east of the Cascade Mountains. This network of kinship tied together ancestral Muckleshoot villages within the Duwamish watershed, extended across watersheds and the Cascade crest, giving Muckleshoot ancestors access to fishing, hunting and gathering sites throughout a broad area extending from the west side of Puget Sound across the Cascade crest.



Area of Interest

Areas depicted do not necessarily correspond to Muckleshoot Usual & Accustomed fishing grounds and stations.

Muckleshoot Indian Tribe

Lake Washington, Green-Duwamish & White-Puyallup River Basins

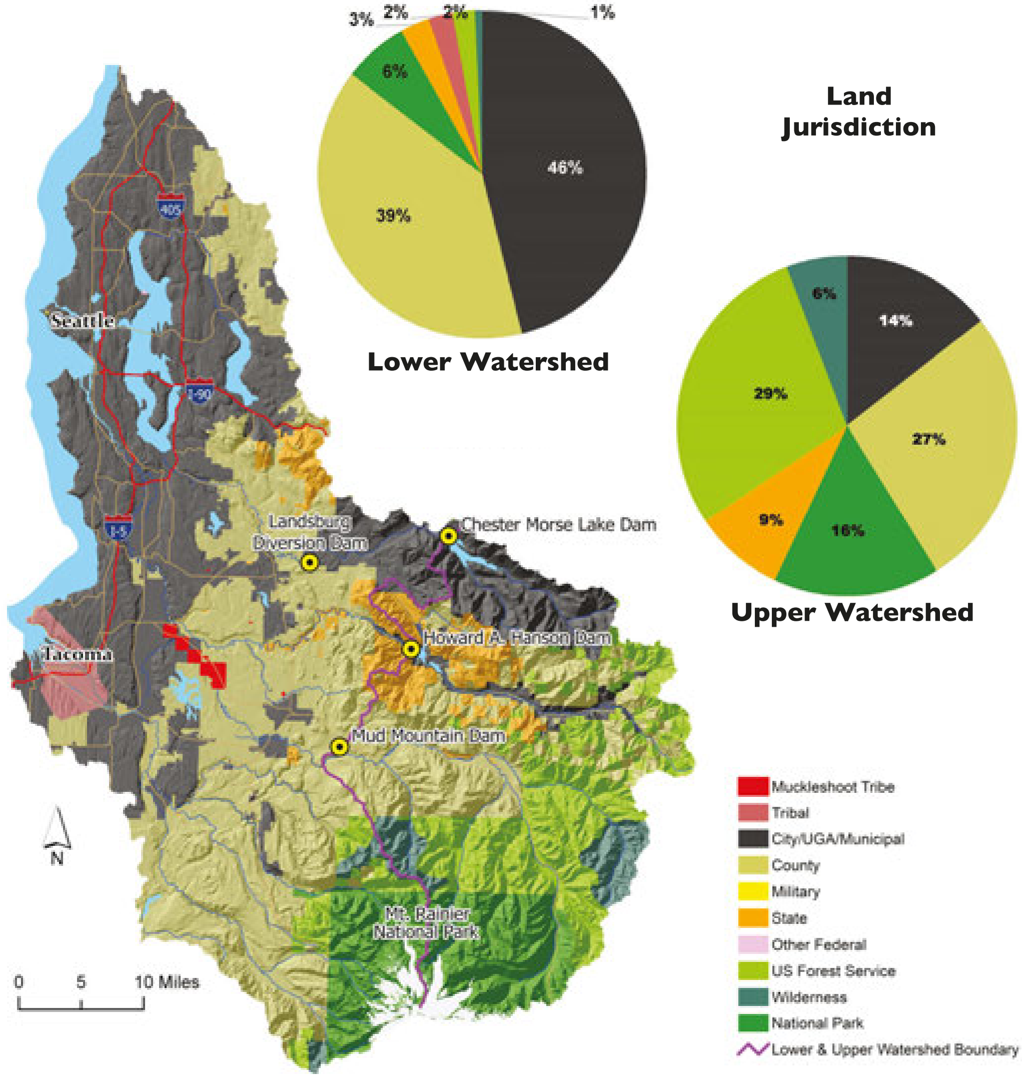
The Muckleshoot Indian Tribe's geographic Area of Interest includes all of WRIAs 8, 9 and 10. In this chapter, the tribe's focus is on Lake Washington (WRIA 8), the Green-Duwamish rivers (WRIA 9) and the White-Puyallup River basin (WRIA 10). Anadromous salmonids in this area include chinook, coho, sockeye, chum and pink salmon, and steelhead and bull trout.

The Green-Duwamish River basin was historically 1,736 square miles and included the White and Cedar rivers. The Cedar and White rivers were diverted in the early 1900s, reducing the basin area to 556 square miles. The Green River flow regime is altered by flood control and storage at Howard Hanson Dam and by water withdrawals. The U.S. Army Corps' dam was constructed in the 1960s without fish-passage facilities. Approximately 98% of historic intertidal marsh and flats have been replaced with commercial and industrial development. The basin supports an estimated 637,034 people (up 6.4% from 2014) and about 30% lies within Urban Growth Area boundaries.[1]

The 686-square-mile Lake Washington basin includes the Cedar and Sammamish rivers and the lakes of Sammamish, Union and Washington. Major alterations include channelization of the Sammamish River, and the construction of the Lake Washington Ship Canal and the Ballard Locks. The basin is heavily urbanized, leading to highly modified stream hydrology and shorelines. With 25 cities and an estimated 1.75 million people (up 13.8% from 2014), Lake Washington is the most populated basin in Puget Sound with 55% of its land area inside Urban Growth Area boundaries.[2]

The White River drains 494 square miles and originates on Mount Tacoma (Rainier) glaciers. The river flows 68 miles from its origin to its confluence with the Puyallup River at Sumner. Most of the upper White River is managed for timber production and has been intensively logged since 1945, leading to slope stability problems and increased sediment loads in non-glacial tributaries.[3] The U.S. Army Corps' Mud Mountain Dam blocks adult fish migration and the river's flow and sediment regime are heavily altered by flood control activities at the dam. From 1911 until 2004, Puget Sound Energy diverted up to 2,000 cfs from the White River into the Lake Tapps reservoir, depleting river flows on the Muckleshoot Indian Reservation and devastating salmon and steelhead populations. A 1986 settlement with the Muckleshoot Tribe required that the diversion meet a minimum instream flow. Hydropower diversion ceased in 2004, and in 2007 an agreement was reached with the Cascade Water Alliance that further limits water diversion to Lake Tapps. The basin includes Commencement Bay, which is highly altered and contaminated with industrial discharges and urban runoff. This basin saw an estimated 6.6% increase in population since 2014.[4]

Land development along with hydrologic and channel modification have severely diminished the potential for natural salmon production in these basins. Much of the habitat loss and degradation is not likely to be reversed, and new growth continues to add impacts. As a result, hatcheries continue to play a crucial role in providing salmon for tribal treaty and other harvest, and in maintaining the abundance of naturally spawning fish. Nonetheless, habitat protection and restoration remain essential in order to sustain future salmon populations regardless of hatchery or natural origin.



Areas depicted do not necessarily correspond to Muckleshoot Usual & Accustomed fishing grounds and stations.

Map Data Sources: SSHIAP 2004,[5] USFWS 2018,[6] USGS 2012,[7] WADNR 2016,[8] WADNR 2018,[9] WADOT 2018a,[10] WADOT 2018b,[11] WAECY 1994,[12] WAECY 2018a,[13] WAECY 2018b,[14]

Chapter Summary

The Muckleshoot Indian Tribe is a federally recognized Indian tribe whose membership is composed of descendants of the Duwamish and Upper Puyallup people who inhabited Central Puget Sound for thousands of years before non-Indian settlement. The tribe's name is derived from the native name for the prairie on which the Muckleshoot Reservation was established. Following the reservation's establishment in 1857, the tribe and its members came to be known as Muckleshoot. Like all native people of western Washington, Muckleshoot ancestors depended on fish, animal and plant resources and traveled widely to harvest these resources. The Muckleshoot Tribe are leaders in the region's salmon recovery effort. No other people know these watersheds as well as the tribes and none has a greater stake in their future. The tribes believe that if salmon are to survive, real gains in habitat protection and restoration must be achieved.

The primary limiting factors to salmon recovery are the quantity and quality of habitat in the watersheds where salmon begin and end their lives. The treaty tribes believe the salmon recovery effort should focus on improving the quality and quantity of habitat.

The State of Our Watersheds Report examines key indicators of habitat quality and quantity across the watersheds in the tribe's Usual and Accustomed fishing areas as defined by *U.S. v. Washington* (Boldt decision). The 1974 ruling upheld tribal treaty-reserved rights, including the right to half of the harvestable salmon returning to Washington waters every year, and established the tribes as co-managers of the salmon resource.

The goal of the State of Our Watersheds Report is to provide tribes with a basic assessment of the health of their watersheds and to gauge progress toward salmon recovery. This report is part of the Treaty Rights at Risk initiative begun by the tribes in 2011 as a call to action for the federal government to exercise its trust responsibility to the tribes and lead a more coordinated and effective salmon recovery effort. More information is available at *www.treatyrightsatrisk.org*.

For this report, the Muckleshoot Tribe has focused on portions of their watersheds that are of greatest concern because of habitat loss and degradation. It is important to note that the State of Our Watersheds Report is a living document that will be updated as new data become available, providing both a metric for assessing changes in salmon habitat and a method for monitoring those changes. The report also will be used to quantify the progress made with the region's salmon recovery plans.

Principal Findings

Impervious Surface Continues to Increase

From 2011-2016, the Lake Washington, Green-Duwamish and Puyallup-White lower basins continued to gain impervious surface area. Though the gain in this time was small, (.5%) of combined lower basin area, the trend is for further development and additional impervious land cover.

Narrowing Down Stormwater Runoff Mortality Factors Connected with Coho Pre-Spawning Mortality (PSM)

Based on NOAA's latest 2017 model, 471 stream miles of known coho distribution in the Green-Duwamish and Lake Washington basins are predicted to have a PSM rate of 5% or more, with 147 miles predicted to have 35-100% PSM. Researchers are still trying to determine which chemicals in stormwater are contributing to the deaths of large numbers of coho salmon in Puget Sound.

Water Quality Continues to Require Corrective Actions

The Washington State Department of Ecology 2014 Water Quality Assessment lists approximately 190 miles of stream in WRIAs 8, 9 and 10 as "impaired waters." An additional 42 miles in WRIAs 8 and 9 are assumed to exceed water temperature standards for fish based on adjacent impairments or other data.

Summer-Fall Flows Decreasing as Water Resource Development Continues

From 2015-2019, 398 new water wells (7% increase) were added to the Lake Washington and Green-Duwamish basins, while the Puyallup-White basin saw an increase of 462 new water wells (18% increase). 482 miles of streams in the Lake Washington and Green-Duwamish basins are identified as having low streamflow problems, while in the Puyallup-White basin there are 122 miles of low flow concerns. In the future, the rate of declining stream flow levels will likely increase, as population growth and reduced snowpack continue to put more stress on this finite resource.

Overwater Structures Impact Lakeshore Habitat in Lake Washington

Along Lake Washington alone, there are about 3,000 residential piers and marinas. The number of new docks since 2016 is minimal as most homes already have docks and there is no more room for further development. An estimated 82% of Lake Washington's shoreline remains heavily modified with bulkhead and riprap.

Streams Still Lack Large Wood and Natural Habitat Features

Wood counts in the lower Cedar and Green rivers continue to have less than 5% of the expected key piece quantities. There is an urgent need for controlled field experiments and long-term studies that focus on the protection of existing large woody debris in stream channels and the recruitment of new debris from the surrounding forest.

Riverbank and Shoreline Modifications Limit Fish Habitat in Fresh and Marine Waters

From 2015-2018, marine shoreline conditions in King County have continued to change very little. During this time, 750 feet of armoring was removed, while 235 feet of new armoring was constructed. Almost 1 mile of armoring was replaced. A total of 125 miles of artificial shoreline negatively affect nearshore and fresh water habitat for salmon.

Conclusion

The Muckleshoot Tribe's watersheds have seen very few successes to the recovery of habitat over the past decade while other habitat indicators have stayed the same or worsened. The Green-Duwamish, Puyallup-White and Lake Washington basins in Central Puget Sound continue to support important salmon and steelhead runs despite dramatic habitat alteration and ecosystem decline. These watersheds are the most developed in all of Washington state. Their populations are continuing to grow rapidly which will undoubtedly continue to affect salmon populations in a negative way.

From 2011-2016, the Lake Washington, Green-Duwamish and Puyallup-White lower basins continued to gain impervious surface area. Though the gain in this time was small, (.5%) of combined lower basin area, the trend is for further development and additional impervious land cover. Based on NOAA's latest 2017 model, 471 stream miles of known coho distribution in the Green-Duwamish and Lake Washington basins are predicted to have a PSM rate of 5% or more, with 147 miles predicted to have 35-100% PSM. The Washington State Department of Ecology 2014 Water Quality Assessment lists approximately 190 miles of stream in WRIAs 8, 9 and 10 as impaired waters. An additional 42 miles in WRIAs 8 and 9 are assumed to exceed water temperature standards for fish based on adjacent impairments or other data. From 2015-2019, 398 new water wells (7% increase) were added to the Lake Washington and Green-Duwamish basins, while the Puyallup-White basin saw an increase of 462 new water wells (18% increase). A total of 482 miles of streams in the Lake Washington and Green-Duwamish basins are identified as having low streamflow problems, while in the Puyallup-White basin there are 122 miles of low flow concerns.

Along Lake Washington alone, there are about 3,000 residential piers and marinas. The number of new docks since 2016 is minimal as most homes already have docks and there is no more room for further development. An estimated 82% of Lake Washington's shoreline remains heavily modified with bulkhead and riprap. Wood counts in the lower Cedar and Green rivers continue to have less than 5% of the expected key piece quantities.

From 2015-2018, marine shoreline conditions in King County have continued to change very little. During this time, 750 feet of armoring was removed, while 235 feet of new armoring was constructed. Almost 1 mile of armoring was replaced. A total of 125 miles of artificial shoreline negatively affect nearshore and fresh water habitat for salmon. Even though restoration is occurring, it is not enough to keep up with the impacts of a growing population and their land-use decisions. Land use and water laws that are in place and meant to protect critical areas and fish habitat need to be implemented. Implementation includes education and voluntary actions, but it also needs to include enforcement when those laws are broken. The future of the Muckleshoot Tribe's exercising its treaty rights depends on it.

Recovery Efforts Show Improvement But Still Lagging in Key Indicators

At the 15-year mark of the Puget Sound Salmon Recovery Plan, a review of key environmental indicators reveals negative results in progress toward the recovery plan's goals and objectives. Priority issues continue to be the degradation of water quantity and quality and the floodplain and riparian processes. There has been progress in the reduction of shoreline armoring, but concerns still exist with the large amount of shoreline armor replacement. In general, there is a shortage of staff at all levels (e.g., federal, state, tribal, county) needed to address the issues and implement actions to restore and protect habitat, and to monitor and enforce compliance of existing regulations. In addition, funding shortfalls for large-scale projects contribute to the slow pace of progress.

Review of the trend for these key environmental indicators since the 2016 State of Our Watersheds Report shows a steady loss, except improvements in the reduction of shoreline armoring in habitat status:

Tribal Indicator	Status	Trend Since SOW 2016 Report
Impervious Surface	From 2011-2016, the Lake Washington, Green-Duwamish and Puyallup-White lower basins continued to gain impervious surface area. Though the gain was small, (.5 percent) of lower basin area, the trend is for further development and additional impervious land cover.	Declining
Coho Pre-Spawn Mortality	Based on NOAA's latest 2017 model, 471 stream miles of known coho distribution in the Green-Duwamish and Lake Washington basins are predicted to have a PSM rate of 5% or more, with 147 miles predicted to have 35-100% PSM. In the 2016 State of Our Watersheds Report, these estimates were 269 miles and 141 miles respectively.	Declining
Water Quality	The Washington State Department of Ecology 2014 Water Quality Assessment lists approximately 190 miles of stream in WRIA's 8, 9 and 10 as "impaired waters". An additional 42 miles in WRIA's 8 and 9 are assumed to exceed water temperature standards for fish based on adjacent impairments or other data.	Declining
Water Wells	From 2015-2019, 398 new water wells (7% increase) were added to the Lake Washington and Green-Duwamish basins, while the Puyallup-White basin saw an increase of 462 new water wells (18% increase). A total of 482 miles of streams in the Lake Washington and Green-Duwamish basins are identified as having low streamflow problems, while in the Puyallup-White basin there are 122 miles of low flow concerns.	Declining
Overwater Structures	Along Lake Washington alone, there are about 3,000 residential piers and marinas.1 The number of new docks since 2016 is minimal as most homes already have docks and there is no more room for further development. An estimated 82% of Lake Washington's shoreline remains heavily modified with bulkhead and riprap.	Declining
Large Woody Debris	Wood counts in the lower Cedar and Green Rivers continue to have less than 5% of the expected key piece quantities.	Concerns
Shoreline Modifications/Forage Fish Impacts	From 2015-2018, marine shoreline conditions in King County have continued to change very little. During this time, 750 feet of armoring was removed, while 235 feet of new armoring was constructed. Almost one mile of armoring was replaced. A total of 125 miles of artificial shoreline negatively affect nearshore and fresh water habitat for salmon.	Marginally Improving

The tribe continues to work toward the protection and restoration of water quality, streamflows, nearshore, estuarine and river habitat, and to conduct research to understand the organisms and the habitats they occupy.

Looking Ahead

Salmon returns and treaty harvest opportunities continue to deteriorate in Central and South Puget Sound. The long-term outlook for the Muckleshoot Indian Tribe is challenging given degraded habitat functions and degraded water quality, rising human population, unstable marine conditions and other effects associated with climate change. Dramatic improvements are required, along with a flexible approach to rebuilding salmon and steelhead populations to harvestable levels.

Over the next five years, the Muckleshoot Indian Tribe will continue to work with WDFW to implement the Co-Managers' Urban Salmon Strategy. This strategy is designed to optimize hatchery production and bypass bottlenecks affecting survival in the urban environment. The Lake Washington basin will be a priority as salmonids entering and exiting this basin encounter passage problems, marine mammal predation and thermal blockages at the Ballard Locks and Ship Canal, miles of docks, bulkheads, riprap and light pollution outlining the basin, warm water, and the many native and exotic fish predators favored by those degraded conditions. The co-managers will also continue working to restore Lake Washington sockeye to harvestable levels by implementing and evaluating delayed release strategies designed to increase survival and will also continue working to secure that Seattle's mitigation obligations for the Landsburg Dam blockage are achieved.

Habitat priorities for the next five years include establishing a riparian shade corridor along the Green River (including 20 miles through Kent and Tukwila) to address unhealthy water temperatures and comply with Washington water quality standards. To accomplish this, a new level of support from local, state and federal agencies will be demanded regarding permit approvals and mitigation for levee construction and repairs. Reducing lethal temperatures in the Lake Washington Ship Canal and the Sammamish River is another priority. The quality and quantity of instream wood in the Green and Cedar rivers continue to be extremely low compared to natural conditions, due to land use and river management. The amount of existing instream wood in the Green and Cedar Rivers was estimated to be 89% to 95% less than NMFS criteria required for properly functioning conditions for salmon habitat.[1] Long-awaited fish passage improvements at the U.S. Army Corps' Mud Mountain Dam are scheduled for completion at the end of 2020 followed by several years of monitoring the expected increased survival. Also, renewal of ESA consultation for the U.S. Army Corps operation of the Ballard Locks is overdue and must address marine mammal predation on listed salmonids passing through the facility. Finally, state and tribal hatchery water supplies need to be secured against the degradation of water quality and quantity caused by the impacts of upstream development and groundwater withdrawals.

Population growth and development will continue to challenge salmon rebuilding efforts in the urban environment. Trends indicate that we'll lose habitat even as restoration projects are implemented. Increasing implementation of priority restoration efforts and enforcing or revising regulations that are supposed to protect salmon habitat must occur if salmon populations are to be sustained into the future. Natural salmon production alone will not support fisheries; more hatchery supplementation is essential to restore fishing opportunity for tribal members and to fulfill treaty fishing rights. For the past century, the tribe has relied on hatcheries for harvest and will continue to depend on hatchery production for years to come.

Muckleshoot Indian Tribe

Impervious Surface Continues to Increase

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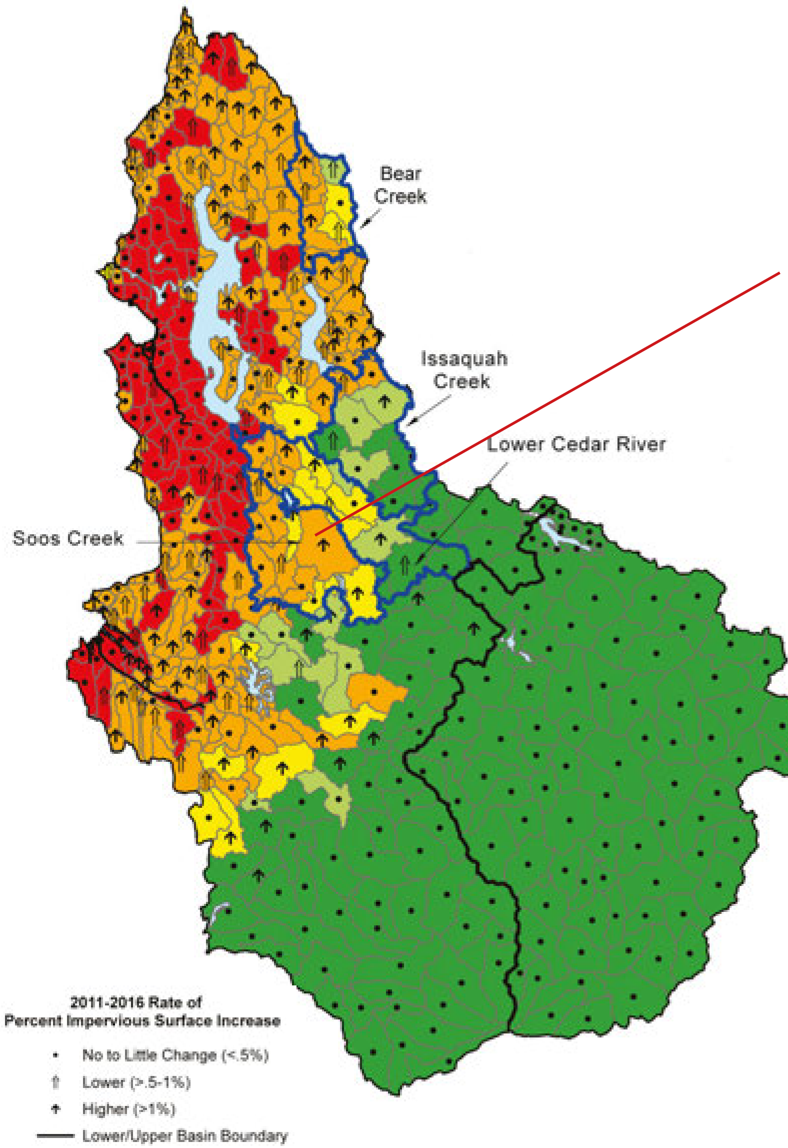


NAIP 2017

An example of impervious surface near a salmon-bearing stream in Soos Creek, Green-Diamond River basin.

The Green/Duwamish and Central Puget Sound watersheds are among the most densely populated and developed in the state, resulting in many sub-watershed areas having high amounts of impervious surface areas. The detrimental effect of stormwater runoff from impervious surfaces on salmon habitat is well documented; this nonpoint source pollution is among the least regulated. Salmonid populations are adversely affected by increased peak flows that scour out salmon redds and displace fry; increased low flows resulting from reduced infiltration and groundwater recharge; by the contaminants carried by water running across impervious surfaces; and by sedimentation and habitat simplification caused by excessive runoff. Salmon survival is critically linked to landscape cover and the management of surface water and stormwater runoff. Stormwater discharges from impervious surfaces also are the primary way in which pollutants are conveyed to the marine waters of Puget Sound.[3]

The growing northwest population will continue to impact the quality and quantity of surface water in local streams and lakes as well as the quantity of groundwater available. Pollutants such as oil, metals, pesticides and herbicides are washed off developed surfaces and enter our waterways. Impervious surfaces, like roads and buildings, prevent water from being filtered by the soil and cause a greater volume of runoff than natural conditions, causing flooding and erosion.[4] Though the increase in impervious surface from 2011-2016 was minimal, according to the Washington State Office of Financial Management, WRIA 8 saw an 8.8% increase in population from 2011-2016, while WRIA 9 saw a 5.8% increase and WRIA 10 increased by 5.7%. This continuing growth in population will bring about a continued increase in impervious surface, a trend that needs to stop if salmon populations stand any chance of recovering.

Map Data Sources: NLCD 2011,[5] NLCD 2016,[6] WAECY 2008b,[7] WADNR 2006[8]

Stormwater Runoff Increases Coho Pre-Spawning Mortality

Based on NOAA's latest 2017 model, 471 stream miles of known coho distribution in the Green-Duwamish and Lake Washington basins are predicted to have a PSM rate of 5% or more, with 147 miles predicted to have 35-100% PSM.[1] In the 2016 State of Our Watersheds Report, these estimates were 269 miles and 141 miles respectively.[2]

Puget Soundkeeper

A coho salmon in Longfellow creek exhibits signs of stress.

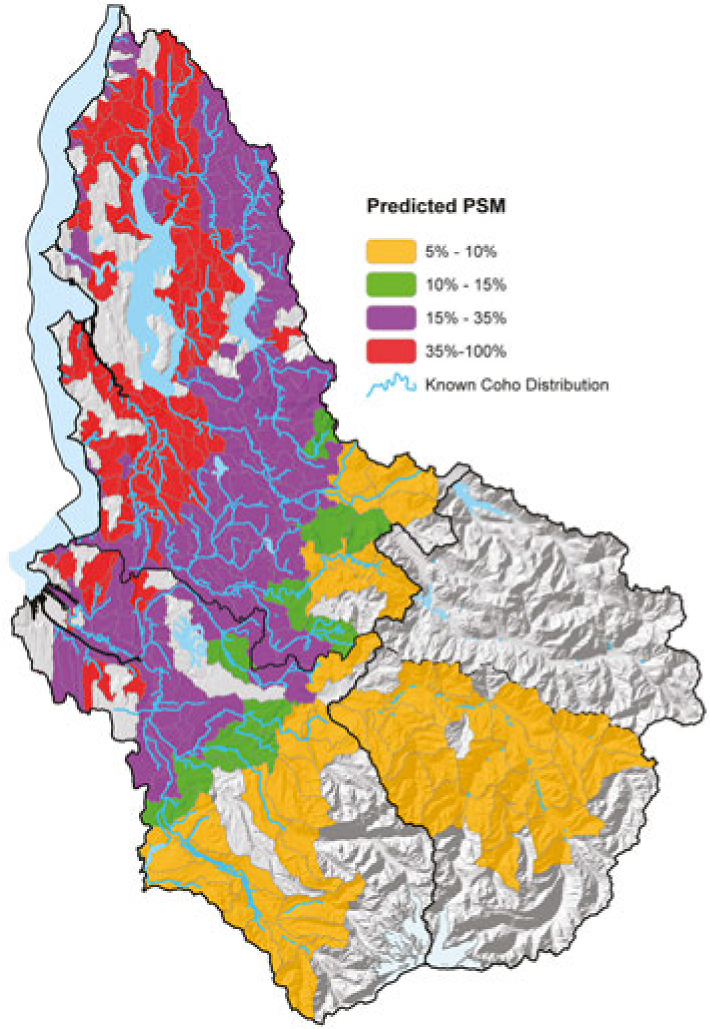
Researchers are trying to determine which chemicals in stormwater are contributing to the deaths of large numbers of coho salmon in Puget Sound. Stormwater may be Puget Sound's most well-known pollutant, and at the same time its least known. While the state has called stormwater Puget Sound's largest source of toxic contaminants, scientists are still having a tough time answering two basic questions about it: What is stormwater, exactly, and what does it do?[3]

Every year, the Puget Sound region receives up to 40 inches of precipitation, most of it as rain. In the past, which is to say before the I-5 corridor became the bustling urban matrix it is today, much of that rain seeped into the soil or collected on leaves and grass and then evaporated back into the atmosphere; less than 1% was thereafter left to trickle into the sound as surface runoff. Now, with more than 350,000 acres of impervious surfaces – streets, roads, highways, parking lots, building roofs and so on – between 20-30% of precipitation turns into surface runoff. This translates into more than 370 billion gallons of stormwater per year pouring into Puget Sound. As modern stormwater sluices downhill, it gathers whatever is in its path. By the time it becomes sound water, it is a formidable toxic stew.[4]

So which of the potentially thousands of chemical compounds found in stormwater might be killing the coho? Among the biggest suspects are the millions of cars that pass nearby, shedding potentially toxic substances such as synthetic rubber from tires, motor oil, windshield washer fluid, transmission fluid, brake dust and automobile exhaust.

Scientists who have identified possible toxics are testing those and other substances, but their precise origin remains as murky as the stormwater itself, at least in the published literature. Scientists were able to reduce the runoff's toxicity simply by running it through a vertical soil treatment column: essentially, a barrel full of sand, shredded bark and compost. After that, the coho were fine.

Scientists are also testing different lengths of swale for the extra removal of metals, running gallons of stormwater over a mix of Dutch clover and red fescue. The goal is to learn what a minimum effective length of swale might be, so Washington Department of Transportation engineers will know how much to plant next to roads. Once everyone has a better idea of the contaminants in stormwater, people can start to recommend changes in a policy sphere.[5]



Tiffany Royal, NWIFC

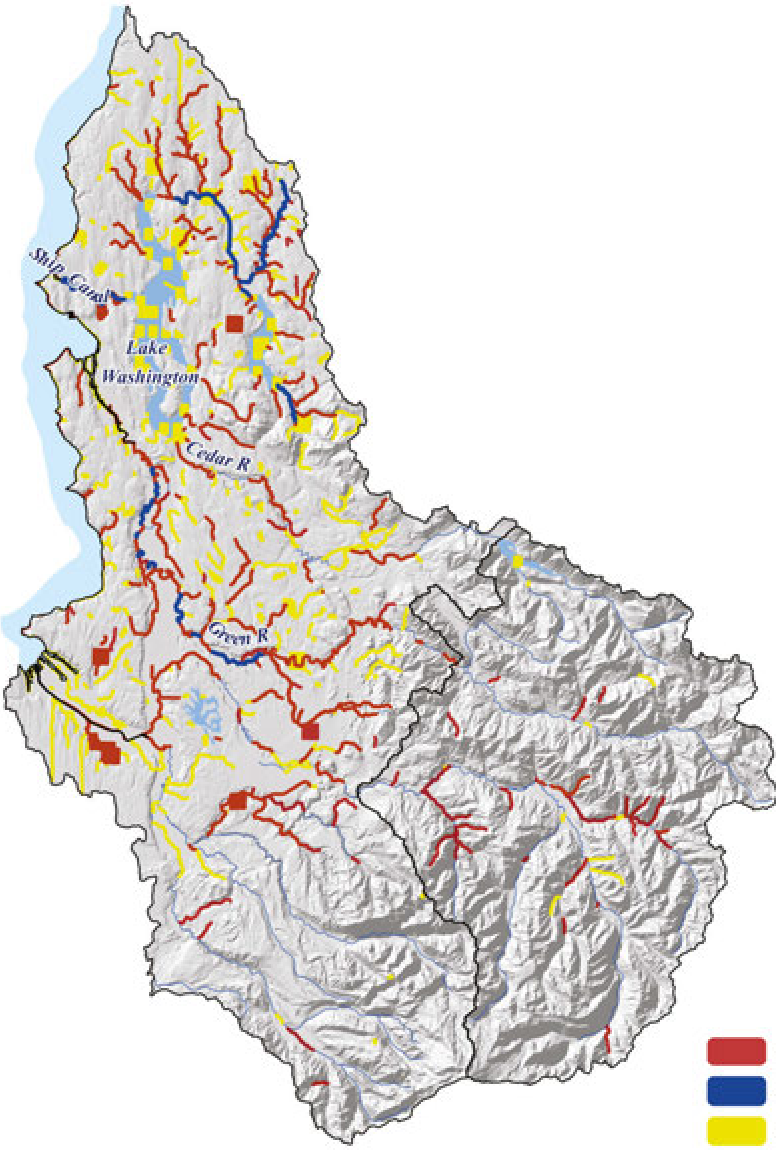
After six years of learning how coho and chum salmon are affected by runoff from urban streets, scientists are narrowing down which pollutant is killing fish. This year, they focused on how tire residue in water affects juvenile and adult coho and chum salmon.

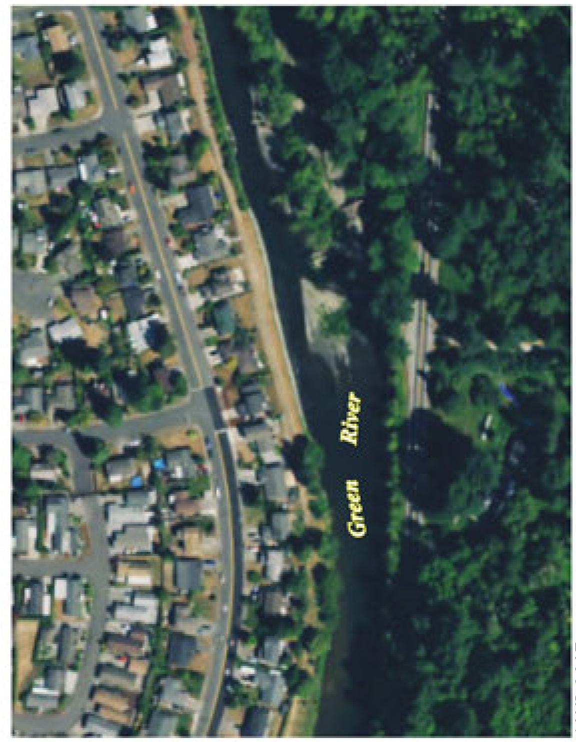
Map Data Sources: PSM Predictions 2017,[6] SSHIAP 2004,[7] SWIFD 2019,[8] WAECY 2000,[9] WAECY 2018b[10]

MUCKLESHOOT INDIAN TRIBE

Water Quality Requires Corrective Actions

The Washington State Department of Ecology 2014 Water Quality Assessment lists approximately 190 miles of stream in WRIAs 8, 9 and 10 as impaired waters.[1] An additional 42 miles in WRIAs 8 and 9 are assumed to exceed water temperature standards for fish based on adjacent impairments or other data.





NAIP 2017

The lower Green River between Auburn and Tukwila has severe shade deficits along each side of the river, elevating water temperatures to levels known to cause disease outbreaks and pre-spawning mortality in migrating salmon and trout.

Water temperature and dissolved oxygen are known to be significant limiting factors for both juvenile and adult salmon.[2] The Lake Washington Ship Canal, the sole migration route for salmon to and from Lake Washington, routinely reaches temperatures of 21-23˚+ Celsius by July each year. These high temperatures are believed to have contributed to disease leading to the pre-spawn mortality of approximately 40% of the Cedar River sockeye run in both 2014 and 2015. The Green-Duwamish river watershed is home to salmonid species listed under the federal Endangered Species Act (ESA). Summer temperatures in the Lower Green River typically reach 7-day average daily maximums greater than 21˚C. In 2015, July river temperatures reached as high as 24˚C. Many streams and rivers throughout King County exceed the 16˚C standard established for the protection of core summer salmonid habitat, with the exception of a few streams found in rural areas and streams within the urban growth boundary dominated by cold groundwater inputs and/or intact riparian cover.[3] A major cause is poor riparian conditions. With over 190 miles of impaired stream in WRIAs 8, 9 and 10 and an additional 42 miles in WRIAs 8 and 9 assumed to exceed temperature standards for fish, it is critical that more action be taken before any further degradation takes place. The lack of tall native trees along the banks of the Green River and its tributaries causes unhealthy and sometimes lethal conditions for chinook and other salmon. Shade levels generally range from zero to 20% of natural system potential.[4]

The Lower Green is the vital migration corridor used by Middle Green River fish going to and from the Duwamish estuary. It also provides limited rearing habitat for fish produced upstream. The Lower Green River has been highly engineered

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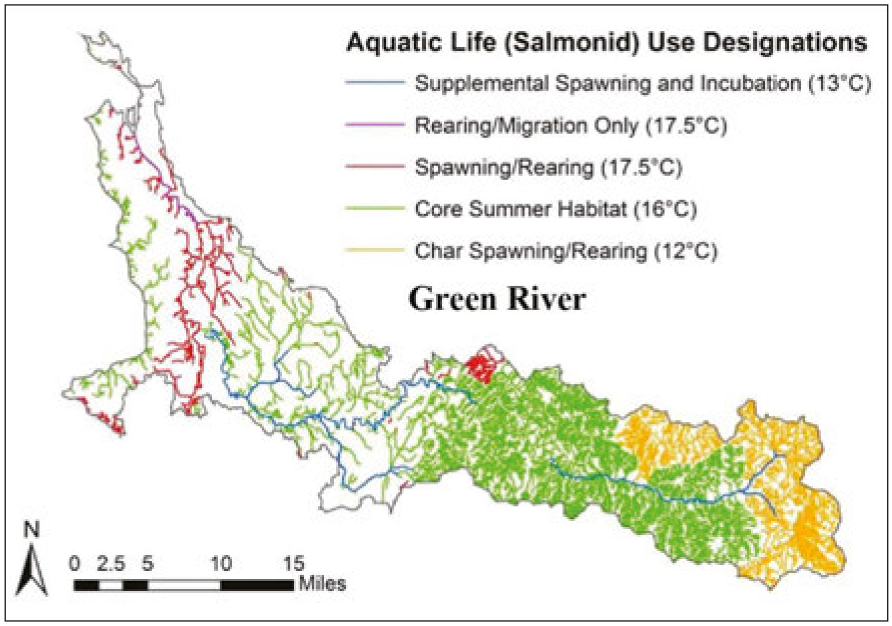
Map Data Sources: SSHIAP 2004,[9] USGS 2012,[10] WAECY 2014,[11] WAECY 2018,[12] WAECY 2000[13]

Most of the streams monitored within King County fall within the "Core Summer Salmonid Habitat" Aquatic Life Use Category, with a maximum 7-day average temperature allowance of 16°C. Many of these streams also have Supplemental Spawning and Incubation Criteria applied to specific months of the year. A few stream and river stations in King County are categorized as "Spawning and Rearing Habitat" with a 7-day average temperature maximum allowance of 17°C.[8]



King County

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over time. The King County Flood District manages approximately 18 miles of levees along the Lower Green River, 16 miles of which are currently enrolled in the Corps' PL-84-99 program. These levees cut off salmon access to side-channel habitats such as sloughs and adjacent wetlands where young salmon feed and take shelter. Local jurisdictions throughout the Green River basin are responsible for implementing salmon recovery plans under the ESA, complying with the Clean Water Act (CWA), the Federal Emergency Management Agency's (FEMA) development standards, and mitigating impacts on habitat that may result from flood risk reduction projects.[5]

In 2016, the WRIA 9 Riparian Revegetation Work Group developed the Re-Green the Green: Riparian Revegetation Strategy for the Green/Duwamish and Central Puget Sound Watershed. This fund supports projects that enhance riparian shade to improve conditions for salmon and meet water quality standards. There is a need to restore trees and native vegetation on all land-use types, urban and rural, along the entire length of the Green River and its tributaries. Riparian revegetation projects improve water quality, salmon habitat and contribute to the urban tree canopy.[6] Even with such programs as Re-Green the Green, water quality modeling indicates that even the most urban leveed areas along the lower Green River will require 100-foot-plus buffers of tall trees with dense canopy cover to approach state temperature standards and restore a river that can sustain salmon including chinook that migrate upstream in summer. Climate change, particularly predicted increases in air temperature, is expected to result in warmer stream conditions without substantial investment in restoring riparian shade and summer flow conditions.[7]

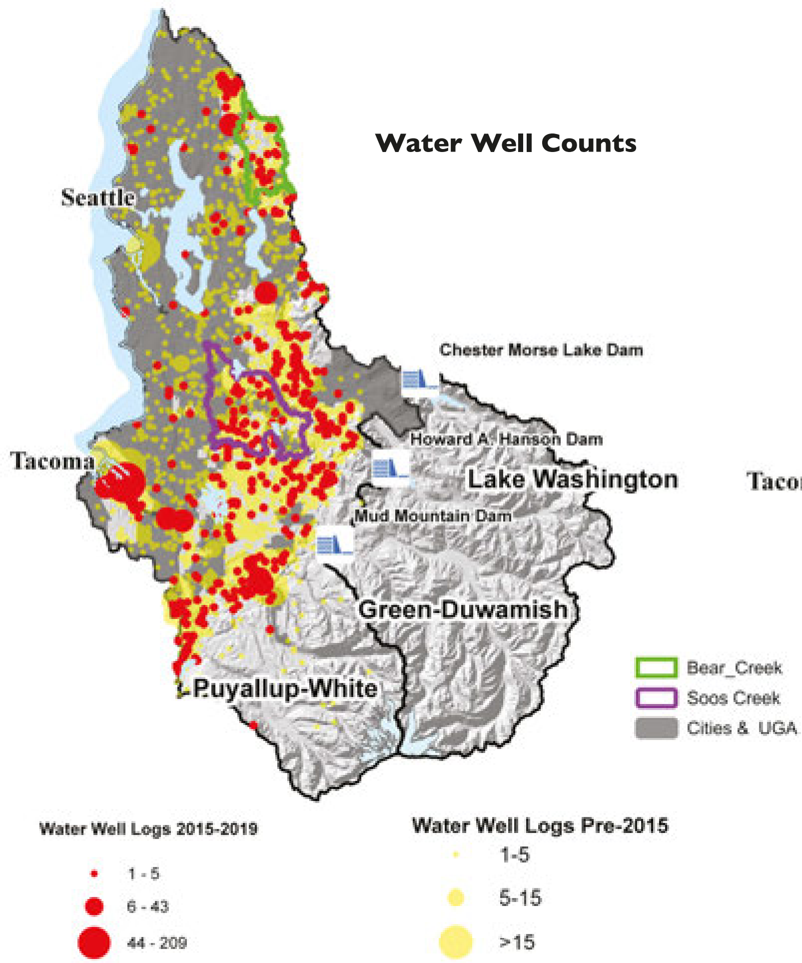
Loss of riparian vegetation, altered streamflow, and pollution from adjacent land uses limit fish production and survival in much of the Green-Duwamish, Lake Washington and White-Puyallup basins. While some efforts by local jurisdictions have been made, more action is needed to improve water quality and avoid further degradation.

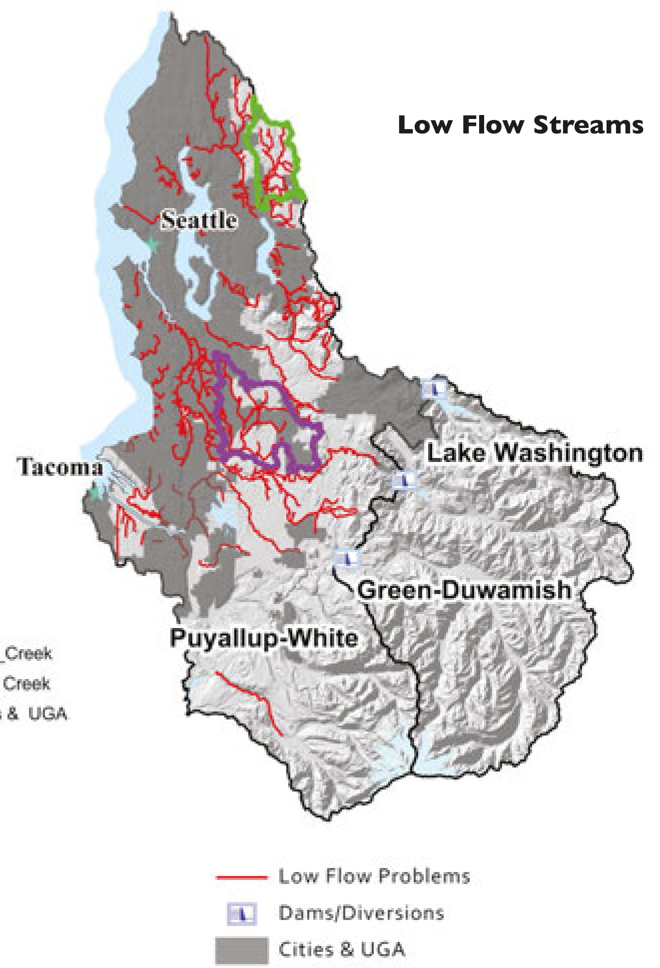
Re-Green the Green

Typical levee on the Lower Green River, with nonnative shrubs offering very little shade.

Summer-Fall Flows Decreasing as Water Resource Development Continues

From 2015-2019, 398 new water wells (7% increase) were added to the Lake Washington and Green-Duwamish basins, while the Puyallup-White basin saw an increase of 462 new water wells (18% increase).[1] A total of 482 miles of streams in the Lake Washington and Green-Duwamish basins are identified as having low streamflow problems, while in the Puyallup-White basin there are 122 miles of low flow concerns.[2]





On October 6, 2016, the Hirst decision of the Washington State Supreme Court established that counties had to make their own decisions about whether there was enough water, both physically and legally, to approve any building permit that would rely on a well.[1] In response, the Washington State Legislature passed the Streamflow Restoration Act in January 2018. This law directs local planning groups to develop watershed plans that offset impacts and achieve a net ecological benefit from new domestic permit-exempt wells.[2]

An estimated 30% of King County's population relies on groundwater wells for drinking water. That is over half a million people. Groundwater also feeds surface streams in the summer months, and provides water for salmon and other fish when there is little rain.[3] Both the natural environment and the community water supplies rely on healthy streamflows. Yet many streams around the state are often

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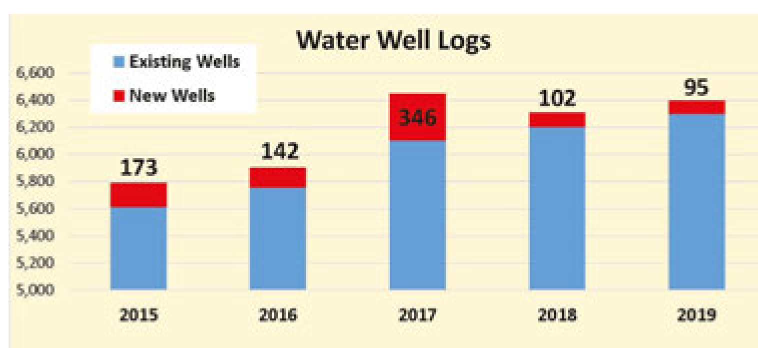

Map Data Sources: King Co. 2014,[14] SSHIAP 2004,[15] WADOT 2010,[16] WAECY 2000,[17] WAECY 2014,[18] WAECY 2018b,[19] WAECY 2019[20]

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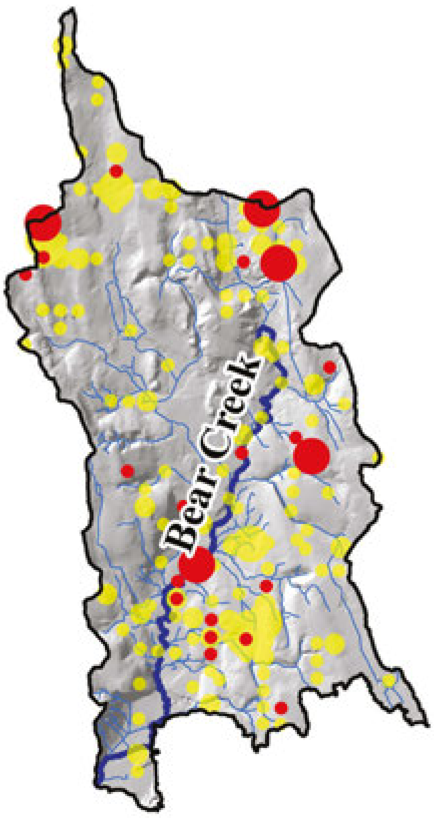
below or quickly approaching critical low flow levels. As more streams drop to historic lows, community and instream values are impacted. In the future, the rate of declining streamflow levels will likely increase, as population growth and reduced snowpack continue to put more stress on this finite resource.[4] From 2015-2019, 398 new water wells (7% increase) were added to the Lake Washington and Green-Duwamish basins, while the Puyallup-White basin saw an increase of 462 new water wells (18% increase).

Stream and river flows in King County were lower than normal in 2019. For example, the mouth of Bear Creek has a flow of 30 cubic feet per second (cfs), which is a little under half of the average flow of 55 cfs. The average monthly flows for monitored King County streams in 2019 tended be below typical, particularly in March, May and through June 26.[5]

The 2005 Lake Washington and Green-Duwamish Salmon Conservation Plans call for maintenance of adequate streamflows. Ground and surface water extractions are estimated to be 37% of the current summer low flows in the Green-Duwamish river basin.[9] Summer low flows in the Bear Creek drainage have been reduced by 39%.[10] Private and municipal well extractions in the Soos Creek sub-basin were estimated to equal 52% of the current summer low flow,[11] reducing habitat for chinook, coho and steelhead.

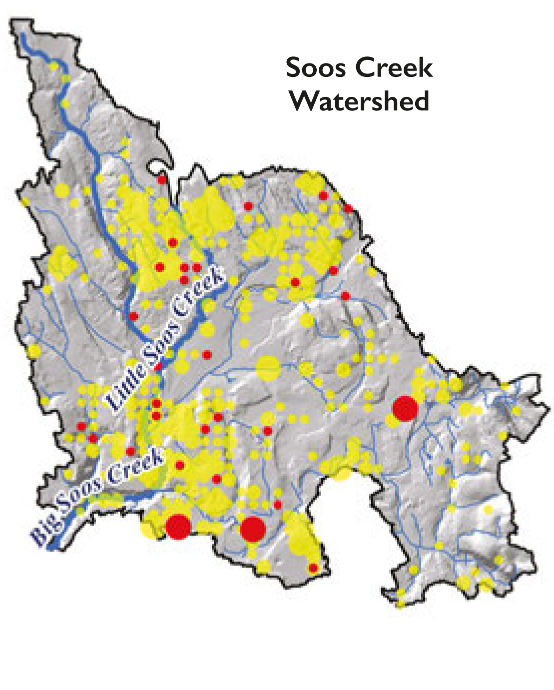


Bear Creek Watershed

Bear Creek watershed is located in King County in Water Resource Inventory Area (WRIA) 8 and drains into the Sammamish River. Bear Creek is typical of the low-gradient, meandering character of King County's lowland creeks. Along its path, Bear Creek flows from headwater forests and wetlands, alongside a golf course, through an occasional subdivision, past old farms and horse pastures, and finally, through urban development before it enters the Sammamish River. Despite the urbanization and other development, the creek retains considerable habitat for salmon: chinook, sockeye, coho, and cutthroat trout are found throughout the stream, even into its uppermost reaches.[7] From 2015-2019, 27 new water wells were added to the Bear Creek Watershed. This number is up from 6 new water wells in 2010-2014.

The Soos Creek watershed is located in South King County in Water Resource Inventory Area (WRIA) 9 and drains into the Middle Green River. The drainage basin covers an area of approximately 70 square miles. There are 25 tributaries to Soos Creek totaling over 60 linear miles. The main tributaries to Soos Creek are Covington Creek, Jenkins Creek, Little Soos Creek, Little Soosette Creek and Soosette Creek. Land use in the Soos Creek basin consists of rural residential, agriculture, and highly urban commercial and residential areas. The western area in particular has been subject to heavy urbanization in recent years. Increased impervious surface area has contributed to decreases in summertime low flows. Chinook, coho, sockeye, pink and chum salmon, as well as winter steelhead, have been observed spawning in Soos Creek.[8] Summer-fall flow in Big Soos Creek shows a statistically significant decline that coincides with development of municipal and private wells in the sub-basin. From 2015-2019, 44 new water wells were added. This number is up from 26 new water wells in 2010-2014.

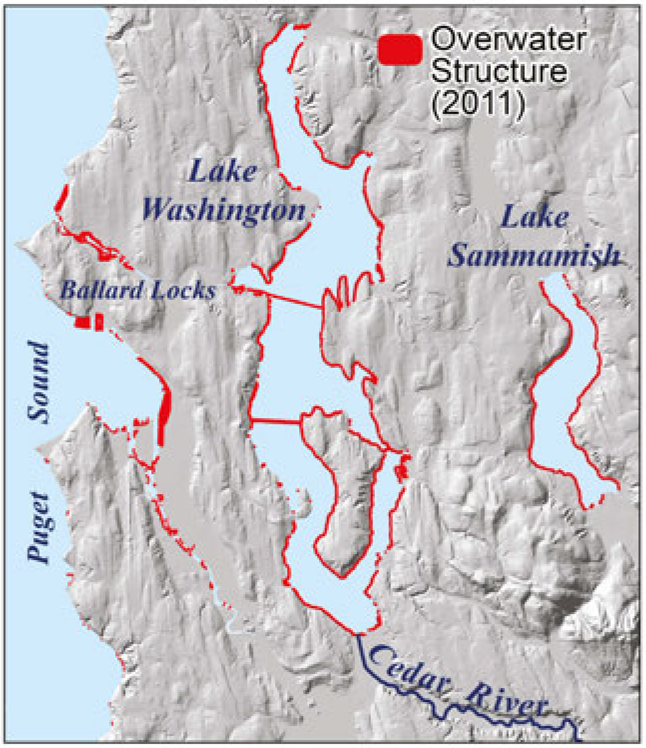
Soos Creek Watershed

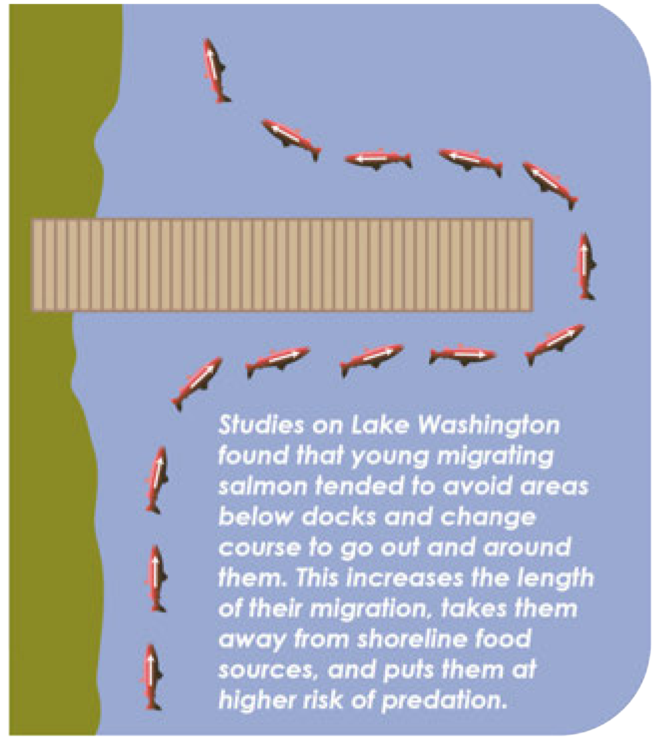


Muckleshoot Indian Tribe

Overwater Structures Impact Lakeshore Habitat in Lake Washington

Along Lake Washington alone, there are about 3,000 residential piers and marinas.[1] The number of new docks since 2016 is minimal as most homes already have docks and there is no more room for further development. An estimated 82% of Lake Washington's shoreline remains heavily modified with bulkhead and riprap.





Docks cause overwater shading that harms bottom habitat and disrupts the movement of young fish, such as salmon. Docks also disrupt the natural flow of sediments, causing beach erosion, creating shallower water around neighboring docks, and eliminating places for fish to spawn and feed.[2] The most critical area for juvenile salmon is the first 30 feet from the edge of the shoreline.

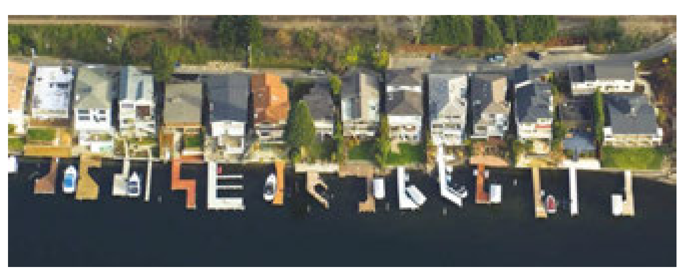
In order to minimize the impacts of docks in this nearshore region, it is important to reduce conditions favored by predators, including pilings, dark shadows, and the sense of a dock that would force chinook out into deeper water.[3] While it takes a human eye only a few seconds to a few minutes to adjust from light to dark, it can take 20-40 minutes for a salmon eye to adjust. Instead of going into the dark shadow cast by a dock, juvenile salmon swim out around the structure. This takes them into deeper water where predators may lurk. Young salmon need safe, shallow water where predators can't come and where they can find food and shelter.[4]

Along Lake Washington alone, there are about 3,000 residential piers and marinas so you can imagine what a challenge they pose to young salmon trying to make their way out to sea.

Federal and state law requires that overwater structures be designed to protect habitat and migration corridors for species that depend on the nearshore environment. Local shoreline programs must comply with state law. New updates to Shoreline Master Programs may require new residential developments to provide joint use or community docks rather than individual docks for each home.[5]

Map Data Sources: WADNR 2007,[8] WAECY 2018,[9] SSHIAP 2004[10]

The listing of chinook as threatened under the Endangered Species Act has resulted in much scientific research about the specific habitat needs of salmon, and has brought about improvements to the lakeshore. There are now design alternatives that enable the presence of fish-friendly docks. Light permeable docks have narrower ramps, surface grating for decking, or in some conditions, glass light tubes to let more light down under the dock. These features all result in a dappled light pattern similar to being under shoreline vegetation. Salmon-friendly dock designs can be architecturally graceful. The use of glue-laminated beams and steel pilings enables a span of 20 feet between pilings. For a continuous 30-foot span without any pilings, a prefabricated aluminum bridge can be employed.[6] Smaller docks, and docks with grating or other design features that let light through, can help endangered salmon survive.[7]



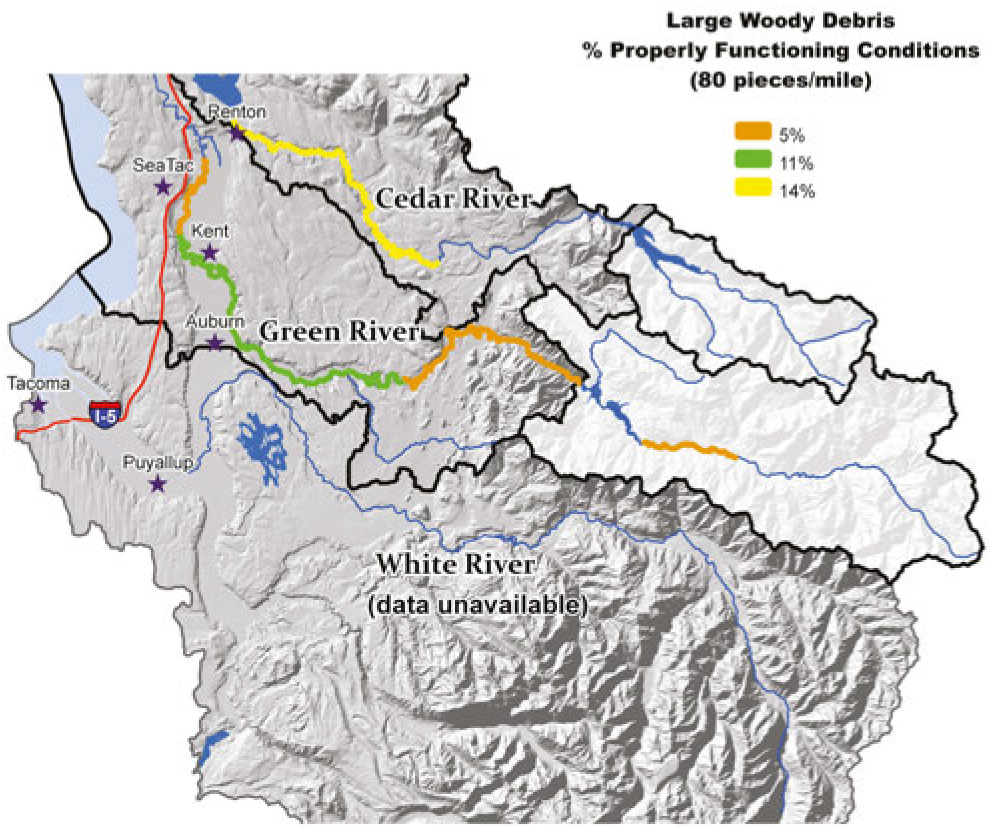
WADOE Coastal Atlas

Example of large numbers of docks on the shore of Lake Washington.

Muckleshoot Indian Tribe

Streams Still Lack Large Wood and Natural Habitat Features

Wood counts in the lower Cedar and Green rivers continue to have less than 5% of the expected key piece quantities.[1]



In-channel large woody debris (LWD) and wood recruitment have been diminished compared to historic levels in many Pacific Northwest rivers, including the Green and Cedar rivers, due to logging of the streambank and clearing of floodplain forests for agriculture. Wood was also removed from the Green River to address concerns about flooding, to facilitate navigation, and up until the late 1970s, to eliminate perceived barriers to upstream migration of salmonids. Reduction in instream LWD has been demonstrated to reduce fish population densities.[2]

Estimates of LWD in the Green and Cedar rivers meeting NMFS size and frequency criteria are 89% to 95% below the levels necessary for properly functioning conditions for salmon habitat.[3] Comparing the wood loads in these rivers to estimated historic conditions[4] and expected natural wood loads to which salmon have adapted,[5] these rivers have a mere fraction of the wood they once contained. The potential to restore large woody debris to improve salmon habitat in the Green-Duwamish and Lake Washington basins is restricted by land use and by policies that address river recreation safety. The Cedar, Green and Sammamish rivers are all designated by King County as recreational waterways where wood placement for restoration and mitigation purposes is restricted. The removal, lopping or repositioning of artificially placed or naturally recruited wood deemed hazardous to boaters commonly occurs.

Large woody debris enhances the quality of fish habitat in all sizes of stream. Removal of most trees in the riparian zone during logging, combined with thorough stream cleaning and short-rotation timber harvest, has altered the sources, delivery mechanisms and redistribution of debris in drainage systems, leading to changes in fish population abundance and species composition. There is an urgent need for controlled field experiments and long-term studies that focus on the protection of existing large woody debris in stream channels and the recruitment of new debris from the surrounding forest.[6]

Most evaluations of fish response to wood placement have shown positive responses for salmonids, though few studies have looked at long-term, watershed-scale response. Scientists need to focus on understanding where wood occurs naturally in different systems as well as how much, where and what type of wood placement should occur, and apply the information to guide and develop more natural and effective use of wood placement for restoration projects.[7]

NOAA, Northwest Fisheries Science Center

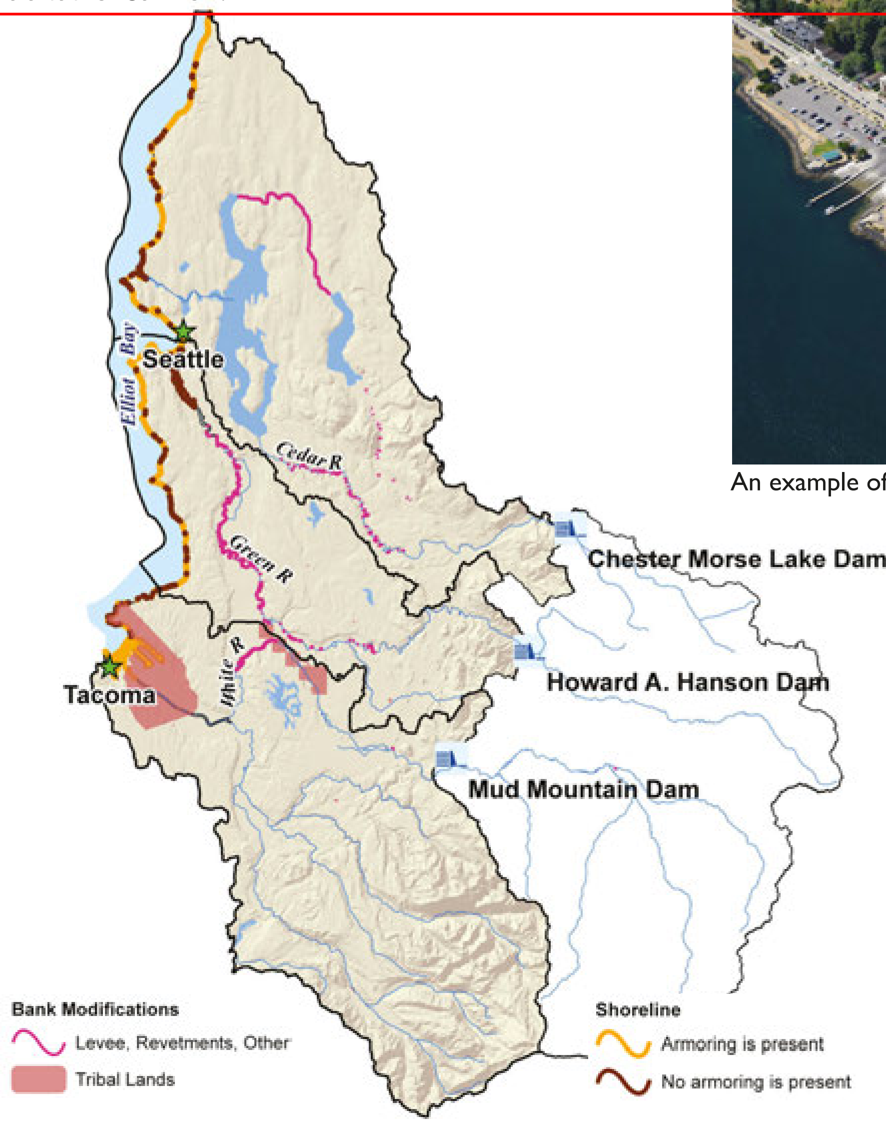
Large wood such as logs and root wads has always played a natural role in most river systems, and most studies have concluded that wood placed in rivers remains stable, improves habitat conditions and increases fish numbers – particularly for salmon and trout. Woody debris often improves habitat quality by creating pools and providing cover. Wood also increases the retention of organic matter and nutrients and helps create islands and new channels that provide additional refuge and habitat, especially for rearing juvenile fish.[8]

Map Data Sources: King Co. 2011,[9] SSHIAP 2004,[10] USGS 2012,[11] WADOT 2018a,[12] WAECY 2018,[13] WAECY 2000[14]

Muckleshoot Indian Tribe

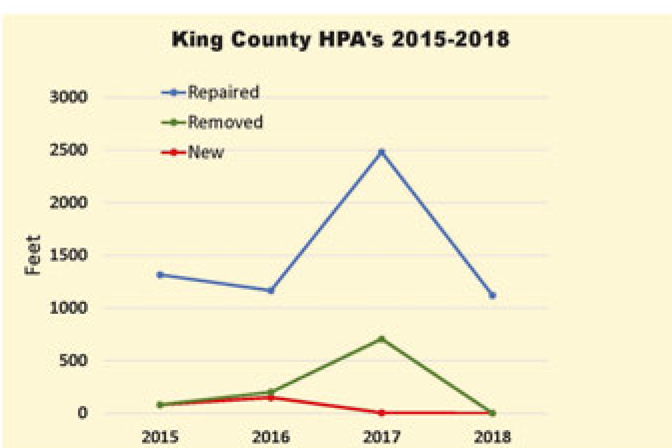
Riverbank and Shoreline Modifications Limit Fish Habitat in Fresh and Marine Waters

From 2015-2018, marine shoreline conditions in King County have continued to change very little. During this time, 750 feet of armoring was removed, while 235 feet of new armoring was constructed. Almost 1 mile of armoring was replaced.[1] A total of 125 miles of artificial shoreline negatively affect nearshore and freshwater habitat for salmon.



An example of shoreline armoring in King County.

WADOE Coastal Atlas



Map Data Sources: King County 2012,[7] SSHIAP 2004,[8] WADOT 2010,[9] WADOT 2018b,[10] WAECY 2000,[11] WAECY 2018b[12]

Bulkheads and other forms of armoring line 92% of Seattle's marine shoreline. From 2015-2018, 750 feet of armoring was removed while 235 feet of new armoring was constructed. Three Hydraulic Project Approval (HPA) projects were issued for new bulkheads, 2 HPA projects were issued to remove bulkhead, while 43 projects were issued to replace bulkhead in King County.

Science shows that shoreline armoring – which includes structures such as bulkheads, riprap and seawalls – can profoundly disrupt the connection between land and Puget Sound's waters, degrading habitat for insects, birds and fish, including endangered chinook salmon and orcas that rely on salmon for food.

The Washington Department of Fish and Wildlife and the Puget Sound Partnership have each set a goal: that the total miles of Puget Sound armoring removed should be greater than the total miles added from 2011 to 2020.

Armoring can be devastating for sand lance and surf smelt that spawn on local beaches. Armoring buries their habitat, leaving them no place to spawn. These forage fish provide food for salmon, seabirds and other life.[2]

Revetments are very similar to bulkheads, but are typically constructed along the banks of rivers and streams to prevent erosion and horizontal movement of stream channels. They can also have a variety of negative impacts on fish and wildlife including increased erosion and increased rate of transport. Revetments also alter or reduce habitats along the edges of rivers and streams that are extremely important areas for juvenile salmon.

Generally, shoreline or riparian vegetation is

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The new Seattle seawall below the sidewalk at low tide.

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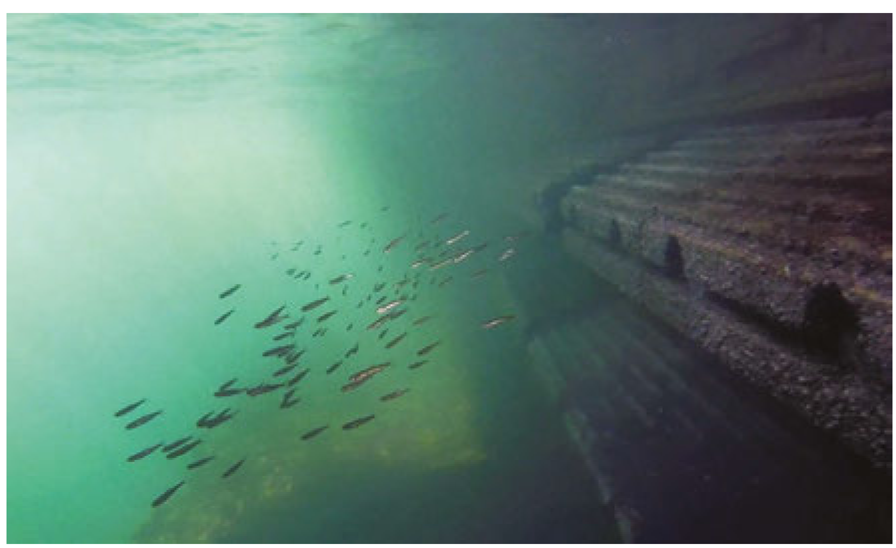
removed for revetment construction, and afterward the area is kept free of woody vegetation for structural purposes. However, riparian vegetation is very important for good water quality, as well as for fish and wildlife species. It shades rivers and streams, keeping water cold enough to maintain salmon. Branches and leaves hanging low over the water provide places for fish and wildlife to hide from predators. Currently King County has approximately 70 miles of levees and revetments that are negatively affecting salmon and their habitat.[3]

Removing armoring can help restore habitat. When armoring is removed, beach health can improve quickly.[4] An example is the new Seattle seawall. For close to a century, the seawall along Seattle's sprawling waterfront has protected waterfront buildings and other structures from the pounding waves of Elliott Bay. More than a hundred years of city development have left its tidelands covered in fill, flanked with concrete and overshadowed by industrial piers. Under natural conditions, juvenile salmon tend to stay in shallow waters along the shoreline to avoid larger predators as they search for food. One of the major problems caused by shoreline armoring is that shallow water disappears when the tide comes in. In fact, where tidelands have been filled in – such as in older downtown and industrial areas – the water may never leave the wall.[5]

The Seattle seawall lies on the migratory pathway used by juvenile chinook, chum, pink and coho salmon making their way to the Pacific Ocean from the Duwamish River and Green River. Since the replacement of the old downtown seawall, salmon habitat seems to be improving, scientists say, thanks to new features installed. The enhanced seawall, which has been called the largest eco-engineering project of its kind, may be boosting the fitness and chances of survival for young salmon as they migrate through a treacherous section of waterfront on their way to the ocean.

Instead of encountering a barren slab of concrete, salmon can now swim across a "bench" in front of the seawall. The bench forms a narrow strip of intertidal habitat, effectively providing a shallow-water pathway for juvenile salmon. Glass blocks in the sidewalk above the seawall allow light to penetrate to the water below, and a rough surface on the wall itself has horizontal shelves to encourage the growth of algae and invertebrates. New scientific findings about marine organisms growing on or near the seawall, plus behavioral changes in young salmon swimming through the area suggest a real payoff from these enhancements. After construction, researchers observed a notable increase in feeding behaviors under the piers, where the fish had never been known to feed before.[6]



Juvenile chum salmon swim along the new Seattle seawall.

Citations

Chapter Summary

1 National Marine Fisheries Service. 1996. Making endangered species act determinations of effect for individual or grouped actions at the watershed scale. Environmental and Technical Services Division, Habitat Conservation Branch.

Muckleshoot Tribe: Lake Washington, Green-Duwamish & White-Puyallup River Basins

1 WAOFM. 2018. Estimates of Total Population for Water Resource Inventory Areas Olympia, WA: Washington Office of Financial Management, Small Area Estimate Program (SAEP)

2 Ibid.

3 Judge, M. 2011. 2011 Implementation Status Assessment. Final Report. A qualitative assessment of implementation of the Puget Sound Chinook Recovery Plan. National Marine Fisheries Services.

4 WAOFM. 2018.

5 SSHIAP. 2004. Hillshade derived from University of Washington Digital Elevation Model (DEM). Northwest Indian Fisheries Commission.

6 USFWS. 2018. Polygons of FWS Approved Boundaries. Falls Church, VA: U.S Fish and Wildlife Service.

7 USGS 2012. Geographic Names Information System (GNIS) Points. Reston, VA: U.S. Geological Survey.

8 WADNR. 2016. Washington Non-DNR Major Public Lands (NDMPL) Polygons. Olympia, WA: Washington Department of Natural Resources.

9 WADNR. 2018. Washington DNR Managed Land Parcels. Olympia, WA: Washington Department of Natural Resources.

10 WADOT. 2018a. Linear Representation of Washington State Routes (GIS Feature Class SR500kLRSSPS). Olympia, WA: Washington Department of Transportation.

11 WADOT. 2018b. Polygons depicting the boundaries of Tribal Lands in Washington State. Olympia, WA: Washington Department of Transportation.

12 WAECY. 1994. Polygons of Washington State Shorelines and Boundary. Olympia, WA: Washington Department of Ecology.

13 WAECY. 2018a. City Boundaries and Urban Growth Areas Polygons. Olympia, WA: Washington Department of Ecology.

14 WAECY. 2018b. NHD Major Areas, Streams, and Waterbodies. 1:24000. From U.S. Geological Survey (in cooperation with others) National Hydrography Dataset. Olympia, WA: Washington Department of Ecology.

Impervious Surface Continues to Increase

1 NLCD. 2011. National Land Cover Dataset Percent Developed Impervious. 2016 edition: Multi-Resolution Land Characteristics.

2 NLCD. 2016. National Land Cover Dataset Percent Developed Impervious. 2016 edition: Multi-Resolution Land Characteristics.

3 Earth Economics. 2009. WRIA 9 Funding Mechanism Report: Generating Payments for Ecosystem Services. Prepared for the WRIA 9 Watershed Ecosystem Forum.

4 King County. Natural Resources and Parks. Solid Waste Division. Sustainable landscaping. From: https://www.kingcounty.gov/depts/dnrp/solid-waste/programs/natural-yard-care/sustainable-landscaping.aspx

5 NLCD. 2011. National Land Cover Dataset Percent Developed Impervious. 2016 edition: Multi-Resolution Land Characteristics.

6 NLCD. 2016. National Land Cover Dataset Percent Developed Impervious. 2016 edition: Multi-Resolution Land Characteristics.

7 WAECY. 2018b. NHD Major Areas, Streams, and Waterbodies. 1:24000. From U.S. Geological Survey (in cooperation with others) National Hydrography Dataset. Washington Department of Ecology.

8 WADNR. 2006. Watershed Administrative Units. Polygons. Olympia, Washington: Washington Department of Natural Resources.

Stormwater Runoff Increases Coho Pre-Spawning Mortality

1 Feist, B.E., E.R. Buhle, D.H. Baldwin, J.A. Spromberg, S.E. Damm, J.W. Davis & N.L. Scholz (2017) Roads to ruin: conservation threats to a sentinel species across an urban gradient. Ecological Applications 27(8): 2382-2396. DOI: 10.1002/eap.1615

2 Scholz, N. 2009. Predicted PSM shapefile. NOAA Fisheries, Northwest Fisheries Science Center.

3 Encyclopedia of Puget Sound. Eric Wagner. 12/05/2017. What is killing the coho? Puget Sound Institute. University of Washington.

4 Ibid.

5 Ibid.

6 PSM Predicitions. 2017. Polygons. Refer to Feist et al. 2017 Ecological Applications GIS data documentation.xlsx for full metadata

7 SSHIAP. 2004. Hillshade derived from University of Washington Digital Elevation Model (DEM). Olympia, WA: Northwest Indian Fisheries Commission.

8 SWIFD. Statewide Washington Integrated Fish Distribution. 2019. Washington State Department of Fish and Wildlife & Northwest Indian Fisheries Commission. 2019 WDFW Culverts. 2019 WDFW Habitat Program

9 WAECY. 2000. Water Resource Inventory Area (WRIA) Polygons. Olympia, WA: Washington Department of Ecology.

10 WAECY. 2018b. NHD Major Areas, Streams, and Waterbodies. 1:24000. From U.S. Geological Survey (in cooperation with others) National Hydrography Dataset. Washington Department of Ecology.

Water Quality Requires Corrective Actions

1 WAECY. Washington 305(b) List (2014). Water Quality Assessment. Polygons. Olympia, WA: Washington Department of Ecology.

2 Kerwin, J. & T. Nelson (eds.). 2000. Habitat Limiting Factors and Reconnaissance Assessment Report, Green/Duwamish and Central Puget Sound Watersheds (WRIA 9 and Vashon Island). Washington Conservation Commission and the King County Department of Natural Resources.

3 King County. Indicators and performance. 2016 Freshwater water quality. From: https://www.kingcounty.gov/services/environment/data-and-trends/indicators-and-performance/kingstat/2016/indicators/aquatic-environment/fresh-water-quality.aspx

4 DeGasperi, C. 2005. Riparian Shade Characterization Study. King County. Department of Natural Resources and Parks, Water and Land Resources Division, Science Section.

5 King County. Natural Resources and Parks. Water and Land Resources Division. Green River System-Wide Improvement Framework. From: https://www.kingcounty.gov/depts/dnrp/wlr/sections-programs/river-floodplain-section/capital-projects/green-river-system-wide-improvement-framework.aspx

6 King County. Salmon Conservation and Restoration. Green/Duwamish and Central Puget Sound Watershed. Re-Green the Green. From: https://www.govlink.org/watersheds/9/plan-implementation/Re-Green.aspx#:~:text=Re-Green%20the%20Green%20Strategy%20to%20grow%20trees%20along,sometimes%20lethal%20conditions%20for%20Chinook%20and%20other%20salmon.

7 King County. Indicators and performance. 2016 Freshwater water quality. From: https://www.kingcounty.gov/services/environment/data-and-trends/indicators-and-performance/kingstat/2016/indicators/aquatic-environment/fresh-water-quality.aspx

8 King County Watersheds and Rivers Continuous Temperature Monitoring. From: https://green2.kingcounty.gov/streamsdata/TemperatureMonitoring.aspx

9 SSHIAP. 2004. Hillshade derived from University of Washington Digital Elevation Model (DEM). Olympia, WA: Northwest Indian Fisheries Commission.

10 USGS 2012. Geographic Names Information System (GNIS) Points. U.S. Geological Survey.

11 WAECY. Washington 305(b) List (2014). Water Quality Assessment. Polygons. Olympia, WA: Washington Department of Ecology.

12 WAECY. 2018. NHD Major Areas, Streams, and Waterbodies. 1:24000. From U.S. Geological Survey (in cooperation with others) National Hydrography Dataset. Washington Department of Ecology.

13 WAECY. 2000. Water Resource Inventory Area (WRIA) Polygons. Olympia, WA: Washington Department of Ecology.

Summer-Fall Flows Decreasing as Water Resource Development Continues

1 WAECY. 2019. Water Well Logs Points. Olympia, WA: Washington Department of Ecology.

2 WAECY. Washington 305(b) List (2014). Washington State Department of Ecology. Olympia, WA.

3 WAECY. 2019. Hirst Decision: https://ecology.wa.gov/Water-Shorelines/Water-supply/Water-rights/Case-law/Hirst-decision

4 WAECY. 2019. Streamflow Restoration: https://ecology.wa.gov/Water-Shorelines/Water-supply/Streamflow-restoration

5 King County. Groundwater management. From https://www.kingcounty.gov/services/environment/water-and-land/groundwater.aspx

6 WA Department of Ecology. Frequently Asked Questions. Revised February 2014. Water Resources Program. Setting Instream Flows in Washington State.

7 King County Department of Natural Resources and Parks. Streams Monitor. King County Streams Monitoring Update for May 2019.

8 Encyclopedia of Puget Sound. University of Washington. King County. 2007. King County rivers and streams.

9 King County. 2016. King County Water Quality Monitoring. From: https://green2.kingcounty.gov/streamsdata/watershedinfo.aspx?locator=A320

10 National Hydraulic Consultants. 2005. Assessment of current water quality conditions in the Green River Basin. Prepared for WRIA 9 Steering Committee.

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

12 National Hydraulic Consultants. 2005. Assessment of current water quality conditions in the Green River basin.

13 King County. 2014. Basin boundaries derived from terrain data. Seattle, WA: King County, GIS Center.

14 SSHIAP. 2004. Hillshade derived from University of Washington Digital Elevation Model (DEM). Olympia, WA: Northwest Indian Fisheries Commission.

15 WADOT. 2010. City Points. Olympia, WA: Washington Department of Transportation.

16 WAECY. 2000. Water Resource Inventory Area (WRIA) Polygons. Olympia, WA: Washington Department of Ecology.

17 WAECY. Washington 305(b) List (2014). Washington State Department of Ecology. Olympia, WA.

18 WAECY. 2018b. NHD Major Areas, Streams, and Waterbodies. 1:24000. From U.S. Geological Survey (in cooperation with others) National Hydrography Dataset. Washington Department of Ecology.

19 WAECY. 2019. Water Well Logs Points. Olympia, WA: Washington Department of Ecology.

Overwater Structures Impact Lakeshore Habitat in Lake Washington

1 Salmon Conservation and Restoration Lake Washington/Cedar/Sammamish Watershed. Lakeside Living. Better docks for salmon. Have your dock and salmon, too. Why are docks bad for salmon. 2008. From: https://govlink.org/watersheds/8/action/lakeside-living/docks.aspx

2 Docks and Shoreline Permits. November 2012. From: www.govlink.org/watersheds/8/action/greenshorelines/

3 Salmon Conservation and Restoration. Lake Washington/Cedar/Sammamish Watershed. Lakeside Living.

4 Docks and Shoreline Permits. November 2012. From: www.govlink.org/watersheds/8/action/greenshorelines/

5 Ibid.

6 Salmon Conservation and Restoration. Lake Washington/Cedar/Sammamish Watershed. Lakeside Living.

7 Docks and Shoreline Permits. November 2012. From: www.govlink.org/watersheds/8/action/greenshorelines/

8 WA DNR . 2007. Marine, Lakes, and Rivers Overwater Structure. (OWS) Polygons. Olympia, WA: Washington Department of Natural Resources.

9 WAECY. 2018. NHD Major Areas, Streams, and Waterbodies. 1:24000. From U.S. Geological Survey (in cooperation with others) National Hydrography Dataset. Washington Department of Ecology.

10 SSHIAP. 2004. Hillshade derived from University of Washington Digital Elevation Model (DEM). Olympia, WA: Northwest Indian Fisheries Commission.

Streams Lack Large Wood and Natural Habitat Features

1 Fox, M. & S. Bolton. 2007. A Regional and Geomorphic Reference for Quantiles and Volumes of Instream Wood in Unmanaged Forested Basins of Washington State. North American Journal of Fisheries Management

2 WRIA 9 Habitat-limiting Factors and Reconnaissance Report–Part II 2.3 Hydromodification.

3 National Marine Fisheries Service. 1996. Making Endangered Species Act determination of effect for individual or grouped actions at the watershed scale. Environmental and Technical Services Division Habitat Conservation Branch.

4 Collins, B. & A. Sheikh. 2005. Historic reconstruction, classification and change analysis of Puget Sound tidal marshes; Olympia, WA: Washington Department of Natural Resources, Aquatic Resources Division.

5 Fox & Bolton. A Regional & Geomorphic Reference.

6 Bisson, P. A., R. E. Bilby, M. D. Bryant, C. A. Dolloff, G. B. Grette, R. A. House, M. L. Murphy, K. V. Koski, and J. R. Sedell. 1987. Large Woody Debris in Forested Streams in the Pacific Northwest: Past, Present, and Future, in Streamside Management: Forestry and Fishery Interactions. E.O. Salo and T.W. Cundy, eds. Institute of Forest Resources, University of Washington, Seattle, Washington. Contribution 57. p. 143-190.

7 NOAA Fisheries. Michael Milstein and Phil Roni. January 2015. Northwest Fisheries Science Center. Research finds woody debris benefits fish.

8 Bisson, P.A., R.E. Bilby, M.D. Bryant, C.A. Dolloff, G.B. Grette, R.A. House, M.L. Murphy, K.V. Koski, and J.R. Sedell. 1987.

9 King County. 2011. Large woody debris percent properly functioning conditions. From: Martin Fox, Muckleshoot. Personal communication.

10 SSHIAP. 2004. Hillshade derived from University of Washington Digital Elevation Model (DEM). Olympia, WA: Northwest Indian Fisheries Commission.

11 USGS 2012. Geographic Names Information System (GNIS) Points. U.S. Geological Survey.

12 WADOT. 2018a. Linear Representation of Washington State Routes (GIS Feature Class SR500kLRSSPS). Olympia, WA: Washington Department of Transportation.

13 WAECY. 2018. NHD Major Areas, Streams, and Waterbodies. 1:24000. From U.S. Geological Survey (in cooperation with others) National Hydrography Dataset. Washington Department of Ecology.

14 WAECY. 2000. Water Resource Inventory Area (WRIA) Polygons. Olympia, WA: Washington Department of Ecology.

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1 WDFW. 2018. HPA Permitted Shoreline Armoring Projects on Puget Sound. Spreadsheet PSSA_2014-2018_Data_summaries_for_NWIFC.xlsx received 2019-10-29, in email from D. Small. Olympia, WA: Washington Department of Fish and Wildlife.

2 Dolan, Maria. December 2016. Seattle Magazine. News. Seattle Seawalls No Longer a Shore Thing.

3 King County. Bulkheads. King County Department of Natural Resources and Parks. King County, WA. From: https://your.kingcounty.gov/dnrp/library/water-and-land/shorelines/0709-fact-sheets/Bulkheads.pdf

4 Encyclopedia of Puget Sound. Christopher Dunagan. June 2020. New Seattle seawall improves migratory pathway for young salmon.

5 Ibid.

6 Ibid.

7 King County. 2012. King County GIS. Levees and Revetments. Polylines. King County, WA.

8 SSHIAP. 2004. Hillshade derived from University of Washington Digital Elevation Model (DEM). Olympia, WA: Northwest Indian Fisheries Commission.

9 WADOT. 2010. City Points. Olympia, WA: Washington Department of Transportation.

10 WADOT. 2018b. Polygons depicting the boundaries of Tribal Lands in Washington State. Olympia, WA: Washington Department of Transportation.

11 WAECY. 2000. Water Resource Inventory Area (WRIA) Polygons. Olympia, WA: Washington Department of Ecology.

12 WAECY. 2018b. NHD Major Areas, Streams, and Waterbodies. 1:24000. From U.S. Geological Survey (in cooperation with others) National Hydrography Dataset. Washington Department of Ecology.