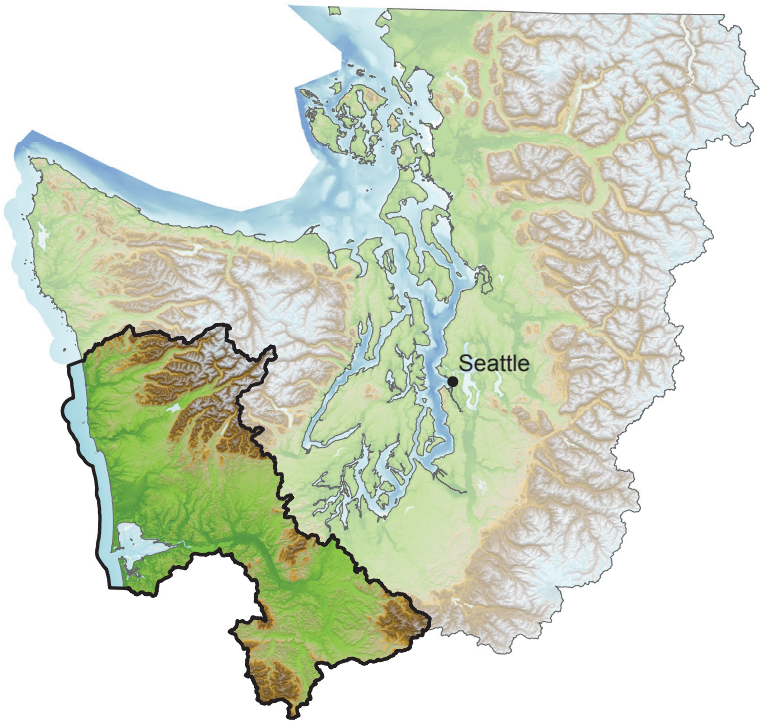
2016 State of Our Watersheds Report
Queets – Chehalis Basins

The evidence is abundantly clear. We know how to manage our fish. We understand sustainability. The problems fish are facing are not of our making. But we are definitely a big part of the solution, with the work we do in habitat restoration and protection, good management and education.

– Fawn Sharp, President
Quinault Indian Nation



Quinault Indian Nation

The Quinault Indian Nation (QIN) consists of the Quinault and Queets tribes and descendants of five other coastal tribes: Quileute, Hoh, Chehalis, Chinook and Cowlitz. Quinault ancestors lived on a major physical and cultural dividing line. Beaches to the south are wide and sandy, while to the north, they are rugged and cliff-lined. Quinault people shared in the cultures of the people to the south as well as those to the north. Living in family groups in longhouses up and down the river, they were sustained by the land and by trade with neighboring tribes. Salmon runs, abundant sea mammals, wildlife and forests provided substantial material and spiritual wealth. A great store of knowledge about plants and their uses helped provide for the people. The western red-cedar, the "tree of life," provided logs for canoes, bark for clothing, split boards for houses and more. The Quinault are the Canoe People, the people of the cedar tree. Tribal headquarters are located in Taholah, Washington.

Queets – Quinault – Chehalis Basins

Debbie Preston, NWIFC

A tree planting crew seeds Sitka spruce as part of the Quinault Indian Nation's work to restore native vegetation to the upper Quinault river valley floodplain to help improve production of blueback (sockeye) salmon. Crews planted 12,000 spruce seedlings at about 170 trees per acre, similar to the densities in naturally developing forests of the Hoh and Queets river bottoms.

The Quinault Indian Nation's Area of Interest for this report covers three Water Resource Inventory Areas (WRIAs) including the Queets-Quinault basin (WRIA 21) and Chehalis basin (WRIAs 22 and 23). WRIA 21 contains the tributaries to the Pacific Ocean from Kalaloch Creek in the north to near Grays Harbor in the south. Major watersheds include the Queets and Quinault, which originate from the Olympic Mountain range, as well as the Raft, Moclips and Copalis rivers and other independent drainages that head at the foothills of this range. All these streams provide suitable spawning and rearing habitat for salmon.[1] The Lower Chehalis (WRIA 22) comprises mainly the lower portion of the Chehalis River drainage, with major tributaries like the Wishkah, Wynoochee and Satsop rivers, as well as a number of independent streams like the Humptulips, Hoquiam and Johns rivers which drain into Grays Harbor. The Upper Chehalis (WRIA 23) includes the upper reaches of the Chehalis river drainage and a number of major tributaries such as the South Fork Chehalis, Newaukum, Black and Skookumchuck rivers. The three WRIAs in this report support Chinook, chum and coho salmon, as well as steelhead and cutthroat trout, and char. WRIA 21 also supports sockeye salmon. The Queets, Quinault and Chehalis basins have known bull trout use but in the Chehalis, the documented use is limited to foraging. Bull trout were listed as threatened under the federal Endangered Species Act in 1999. The salmon and steelhead runs in the Chehalis basin are significantly degraded from their historic levels. Modeling of salmon populations by the Governor's Chehalis Basin Workgroup shows spring-run Chinook populations reduced by 78%, Fall-run Chinook by 45%, coho by 69%, and steelhead by 44%.[2]

The majority of the area is forestland owned by corporations and government and includes the Capitol State Forest and Quinault Indian Reservation, as well as portions of Olympic National Forest, Gifford Pinchot National Forest and Olympic National Park. Although salmonids in this area have fared better than in Puget Sound,[3] several habitat factors limit salmonid production in the basin. These include channel incision, sedimentation, riparian loss or conversion, loss of large woody material, reduced channel complexity, water quality problems and reduction in streamflow.[4,5] Most of these problems are caused and or exacerbated by human activity.

Recovery Efforts Lagging

A review of key environmental indicators for the Queets to Chehalis basins area shows that priority concerns continue to be degradation of water quantity and quality, degradation of floodplain and riparian processes, loss of forest cover conditions and habitat blocked to fish access. Improvement has been observed in forest roads (RMAPs). 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 2012 State of Our Watersheds report shows an improvement for one indicator and a steady loss for others in habitat status:

Tribal Indicator	Status	Trend Since SOW 2012 Report
Water Quality	Between 2011 and 2013, there were widespread water temperature impairments in the Queets River watershed that exceeded Washington State numeric water quality standards. These violations, likely caused by forest practices activities and glacier loss, will have an impact on salmonid production in the watershed.	Declining
Water Quantity - Peak Flows	Peak flows have shown an increasing trend for both the Queets River and Chehalis River.	Declining
Water Quantity - Low Flows	Low flows on the Chehalis River have experienced an increasing trend.	Concerns
	Low flows on the Queets River have experienced a decreasing trend.	Declining
Forest Roads	About 61% of the RMAP culverts have been repaired and 39% are scheduled to be completed by 2021.	Improving
Road Densities & Crossings	Approximately 90% of the Quinault Area of Interest had road densities of greater than three miles/square mile, the level at which streams cease to function properly. Road crossings were highest in the East Fork Satsop River and Black River watersheds with values of greater than one per mile of stream. The Chehalis Basin Salmon Habitat Restoration and Preservation Strategy (2010 Update) calls for a reduction of sediment loading by reducing road densities in the basin.	Declining
Forestland Cover	Between 2006 and 2011, there was an overall negative trend (1- 14%) in forest cover conditions in watersheds on State and Private forestlands.	Declining
Water Wells	Between 1980-2009, 9,991 wells were completed at a rate of about 344 new wells per year. Between 2009-2014, 580 wells have been added at a lower rate of about 116 wells per year.	Declining
Impervious Surface	From 2006 to 2011 watersheds in the Chehalis River basin showed deteriorating impervious surface conditions with increases ranging from 1% to over 5%. Areas near the cities of Aberdeen, Centralia, and Chehalis have impervious surface conditions that were impacting (7-12%) or degrading (12-40%). Rest of area have impervious surface area 0-4%.	Declining

The Quinault Indian Nation continues to work toward the protection and restoration of healthy and functional nearshore, estuarine and river habitat, restoring those areas that are degraded, and conducting research to understand the organisms and the habitats they occupy.

Looking Ahead

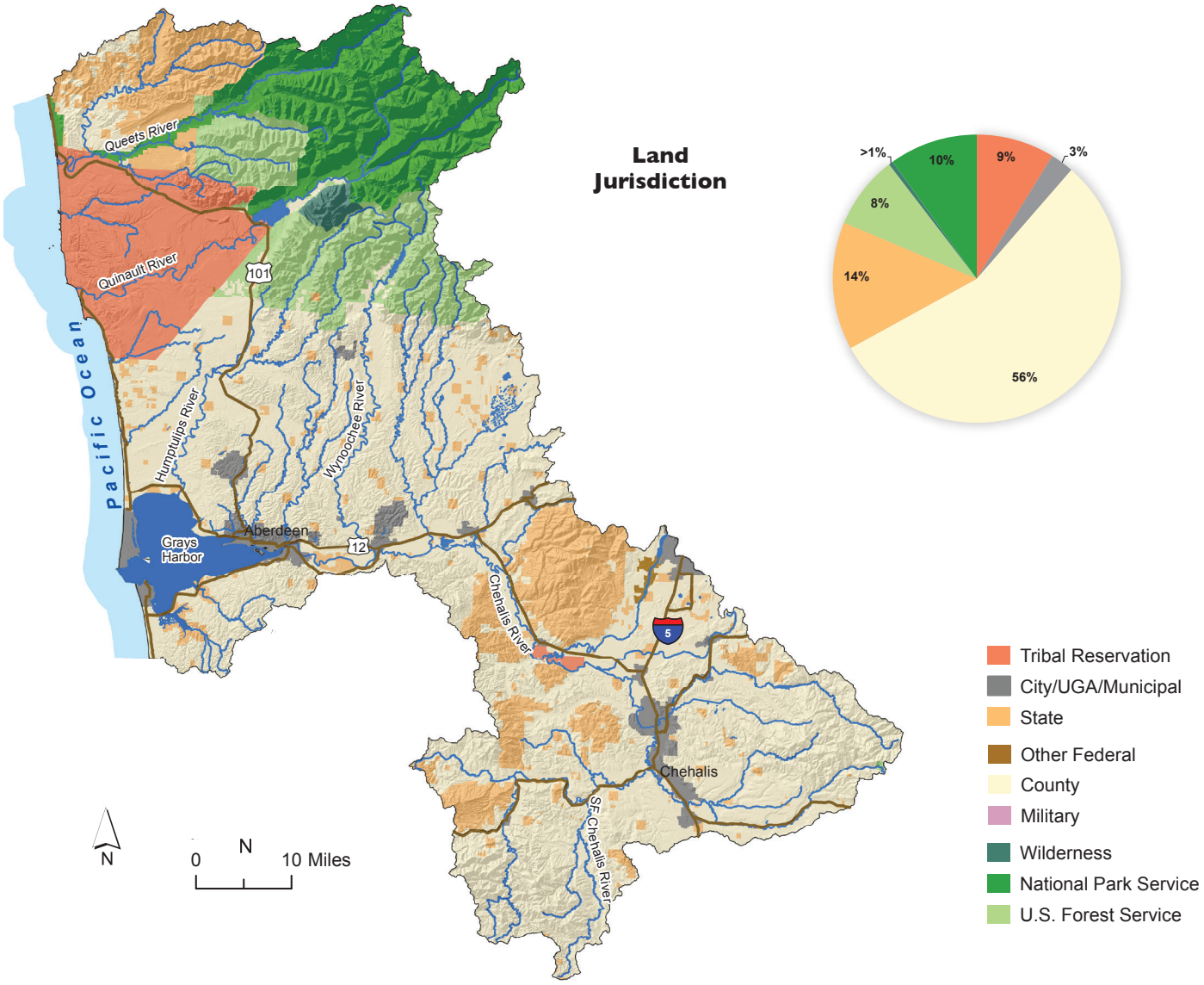
Pressure from population growth, agricultural practices and timberland use within the Chehalis River basin will continue to present challenges to salmon conservation and recovery efforts. Land-use management and forest practice regulations continue to allow the further degradation of floodplain and riparian habitat throughout the watershed.

Current trends indicate that land-use regulation reform is required and continued funding of habitat restoration activities is necessary in order to achieve salmon recovery goals. The Chehalis Basin Salmon Habitat Restoration and Preservation Strategy for WRIA 22 and 23 relies almost exclusively on restoration to address limiting factors within the basin.

However, we are still witnessing the continued loss and fragmentation of habitat through barrier culverts, high road densities and crossing, forest cover removal and wells. The lack of progress on the protection of existing habitat remains the biggest impediment to salmon recovery.

Quinault Indian Nation

The Queets, Quinault, and Chehalis Watersheds



The Quinault Indian Nation's Area of Interest for this report is the Queets-Quinault basin (WRIA 21) and Chehalis basin (WRIAs 22 and 23), but most of the data analysis will focus on the Queets and Chehalis watersheds. WRIA 21 contains the tributaries to the Pacific Ocean from Kalaloch Creek in the north to near Grays Harbor in the south. Major watersheds include the Queets and Quinault, which originate from the Olympic Mountain range, as well as the Raft, Moclips, and Copalis rivers, and other independent drainages that start at the foothills of this range. All these streams provide suitable spawning and rearing habitat for salmon.[1]

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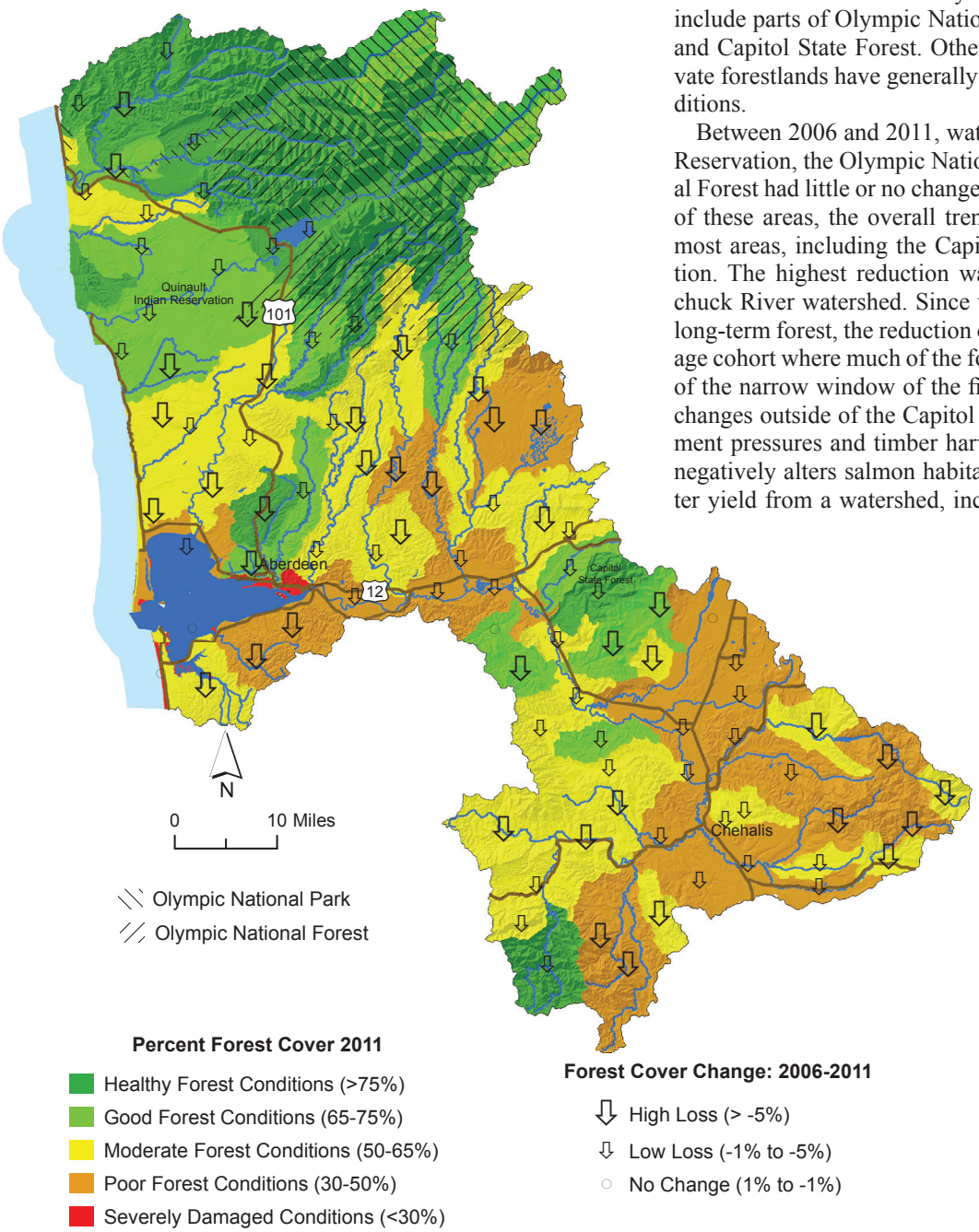
Although salmonids in this area have fared better than in Puget Sound,[4] several habitat factors limit salmonid production in the basin. These include channel incision, sedimentation, riparian loss or conversion, loss of large woody material, reduced channel complexity, water quality problems and reduction in streamflow.[5,6] Most of these problems are caused and/or exacerbated by human activity.

Data Sources: SSHIAP 2004,[7] USFWS 2014,[8] WADNR 2014a,[9] WADNR 2014b,[10] WADOT 2012,[11] WADOT 2013,[12] WAECY 1994,[13] WAECY 2011a,[14] WAECY 2013[15]

Forest Cover Conditions

A total of 47 watersheds (representing 42% of the land area) within the Quinault Tribe's Area of Interest are in healthy and good forest conditions with over 65% forest cover. Other areas which are predominantly private forestlands are in moderate (<65%) to poor (<50%) forest cover conditions. Between 2006 and 2011, there was an overall negative trend in forest cover in watersheds outside the Tribal Reservation, Park and Forest Service lands, with a forest cover loss of up to 14.3%.



Forest cover conditions impact the ecological processes that create and maintain fish habitat. Large sections of the Quinault Area of Interest remain in healthy and good forest conditions. These include parts of Olympic National Forest, Olympic National Park and Capitol State Forest. Other areas that are predominantly private forestlands have generally moderate to poor forest cover conditions.

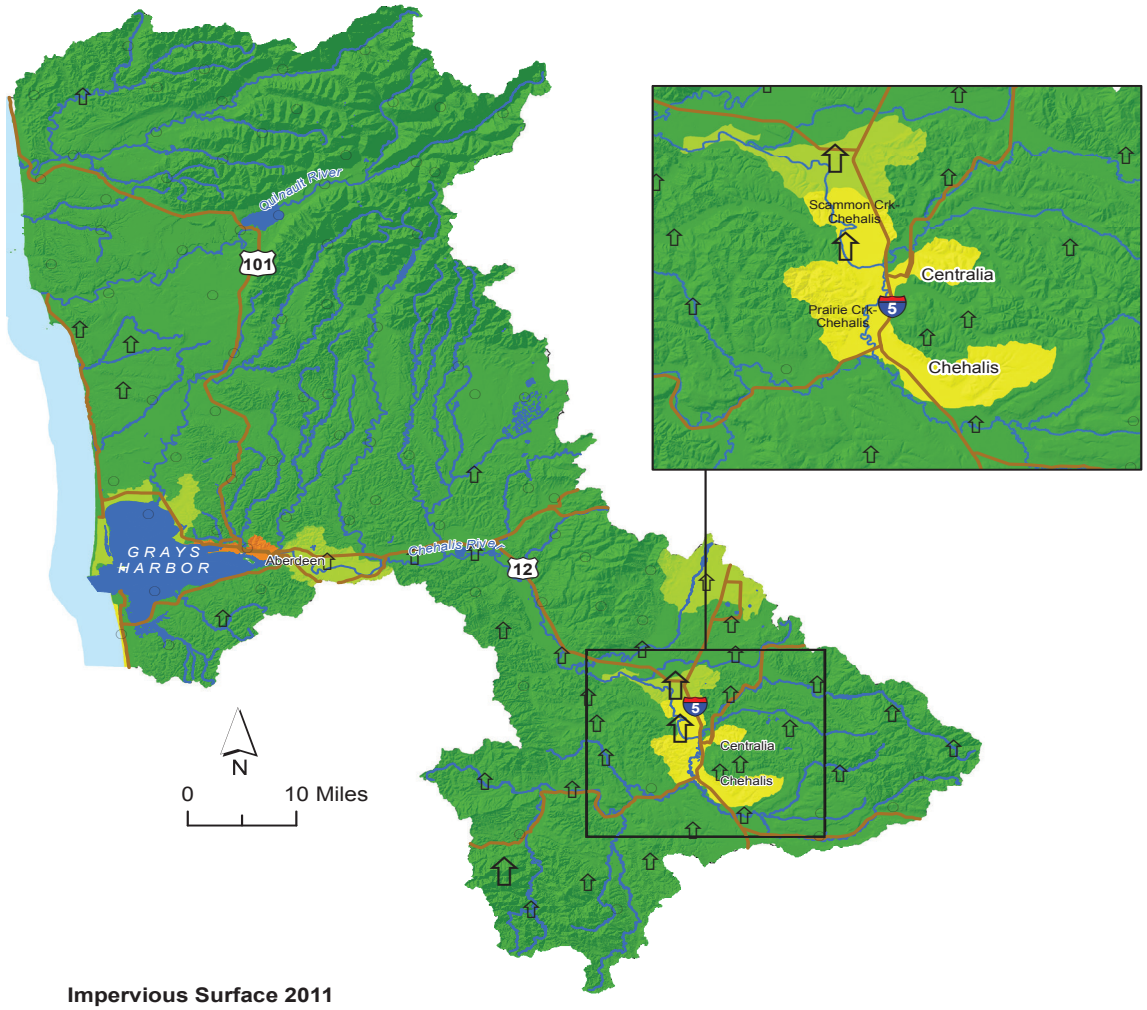
Between 2006 and 2011, watersheds within the Quinault Indian Reservation, the Olympic National Park, and the Olympic National Forest had little or no change in forest cover conditions. Outside of these areas, the overall trend in forest cover is negative with most areas, including the Capitol State Forest, showing a reduction. The highest reduction was 14.3% in the Upper Skookumchuck River watershed. Since the Capitol Forest is managed as a long-term forest, the reduction of forest cover there may reflect the age cohort where much of the forest is merchantable age as a result of the narrow window of the first harvest. On the other hand, the changes outside of the Capitol Forest most likely reflect development pressures and timber harvesting. A decrease in forest cover negatively alters salmon habitat by increasing peak flow and water yield from a watershed, increasing sediment supply, reducing wood recruitment, decreasing water quality and raising water temperatures.[1,2]

The overall negative trend in forest cover makes it critical to protect and preserve those watersheds with good or better forest conditions. The extensive loss of riparian vegetation (coupled with the conversion of conifer to hardwoods), mainly from agriculture and urbanization, has been identified as a factor limiting the production of salmonids in the basin.[3] The Chehalis Basin Habitat Restoration and Preservation Strategy adopted the restoration and preservation of properly functioning riparian areas as an important strategy for addressing this limiting factor.[4]

Data Sources: SSHIAP 2004,[5] USGS 2014,[6] WADOT 2012,[7] WAECY 2006,[8] WAECY 2011a,[9] WAECY 2011b[10]

Impervious Surface

A total of 103 watersheds (representing 92% of the land area) in the Quinault Area of Interest currently have impervious surface levels of 0-4%, showing little to no impact from those conditions. However, areas near Aberdeen, Chehalis and Centralia had impervious surface conditions that were impacting (7-12%) or degrading (12-40%). Between 2006 and 2011, watersheds in the southern half of the area showed deteriorating impervious surface conditions with increases from 1% to 11.4%.



Imperviousness, an indicator of urbanization, negatively impacts fish habitat by increased erosion, stream channel destabilization, loss of pool habitat, excessive sedimentation and scour, and large woody debris reduction. A high percentage of impervious surface also leads to higher peak streamflows, increased sediment and pollutant delivery, and decreases in stream biodiversity.[1]

Based on 2011 data, most of the watershed units in the Quinault Area of Interest have impervious surface levels of 0-4%, showing little to no impact from impervious surface conditions. This is an indication that urbanization is not a major limiting factor in this area. Exceptions to this are a few watersheds near Aberdeen as well as Chehalis and Centralia where impervious surface conditions were impacting (7-12%) or degrading (12-40%).

Between 2006 and 2011, there was little or no change in impervious conditions in watersheds in the upper half of this Area of Interest. In the lower half of the area, there is a general negative trend in many watersheds. The Scammon Creek-Chehalis River and Prairie Creek-Chehalis watersheds near Chehalis and Centralia in the Interstate 5 corridor had the highest increase (over 5%) in impervious surface levels. This is particularly significant because these watersheds already had impervious surface values that were impacting fish habitat. These conditions are likely caused by population changes and urbanization in the Chehalis/Centralia area.

While the current status of the impervious surface indicator is good in most watersheds, the general direction in the southern half of the Area of Interest is negative.

Data Sources: NLCD 2006,[2] NLCD 2011,[3] SSHIAP 2004,[4] USGS 2014,[5] WAECY 2011a[6]

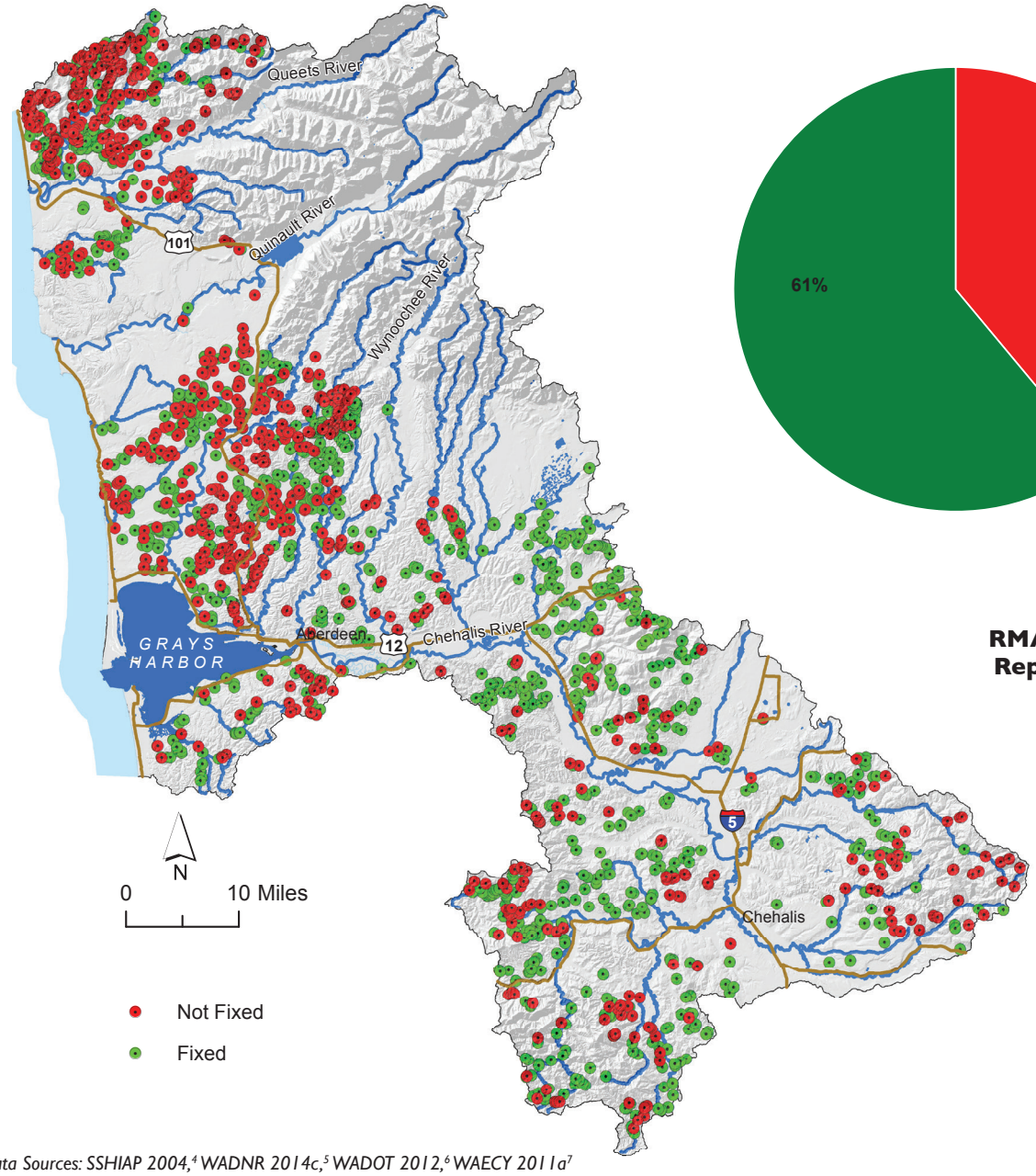
Impact of Culverts on Habitat

Under the Road Maintenance and Abandonment Plan (RMAP), about 61% of the identified 2,439 culverts in the Quinault Area of Interest have been fixed, but another 39% were yet to be repaired, and create barriers to fish passage. Overall, the RMAP program appears to be working.

Roads are an important component of the human use of forested systems. If not properly constructed or maintained, forests roads can be a source of sediments to streams that degrade fish habitat and water quality.[1] Furniss et al. concluded that the sediment contribution per unit area from roads is often much greater than all other forest activities combined.[2] Also, many culverts at forest road crossings may constitute fish barriers. The Chehalis Basin Salmon Habitat Restoration and Preservation Strategy identified the replacing of dysfunctional culverts as a very high priority because they eliminate access by wild salmonids to upstream habitat.[3]

In order to reduce the adverse effects of roads, Washington State Forests and Fish Law requires most forest landowners to have a Road Maintenance and Abandonment Plan (RMAP), a schedule for any repair work needed to upgrade road systems at stream crossings, and address aquatic habitat and fish passage issues. RMAP's are only required in forestlands and there is no process in place to consistently inventory or repair blocking culverts outside of forestlands. Also, since the law exempts small forest landowners, the RMAP culvert numbers here are likely understated.

The RMAP data shows that about 61% of the identified 2,439 culverts in the Quinault Area of Interest have been fixed, but another 39% were yet to be repaired and create barriers to fish passage. Overall, the RMAP program appears to be working. This should have a positive impact on fish habitat and water quality in the Quinault Area of Interest.



RMAP Culvert Repair Status

Data Sources: SSHIAP 2004,[4] WADNR 2014c,[5] WADOT 2012,[6] WAECY 2011a[7]

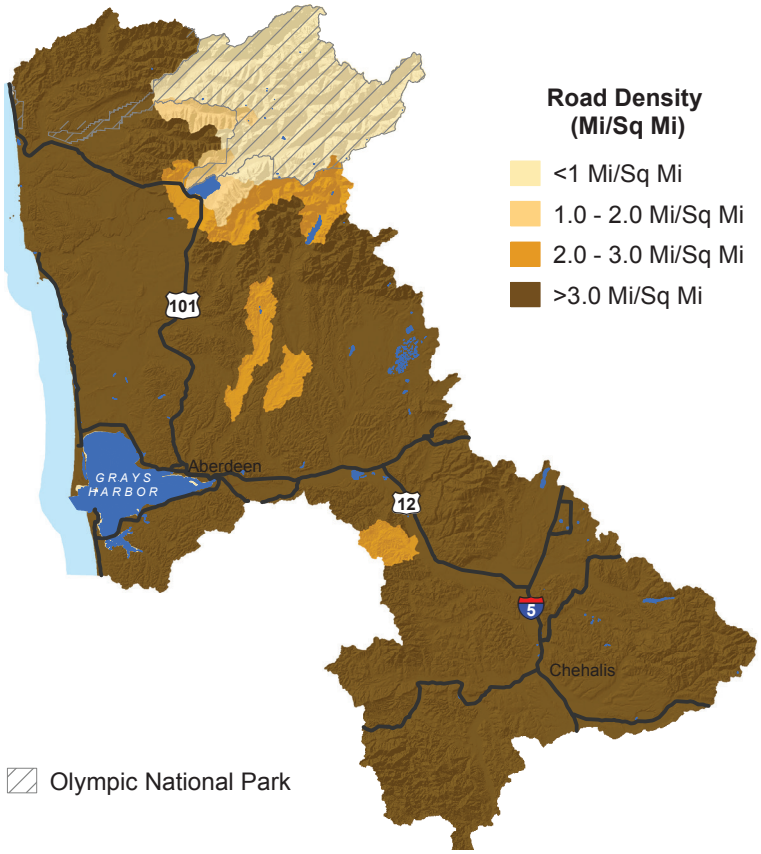
The Impact of Road Densities and Crossings

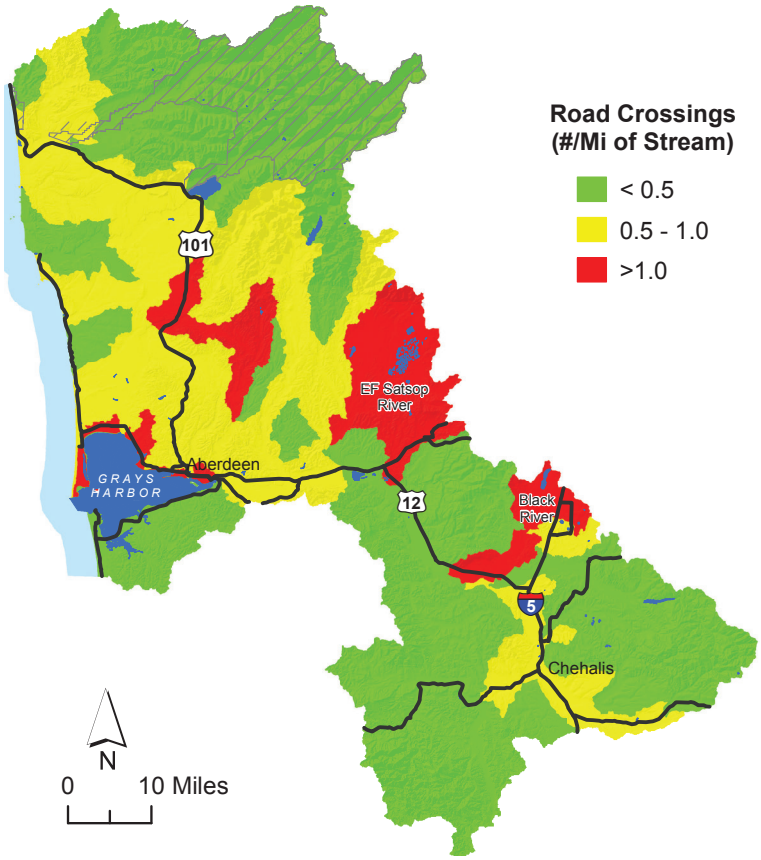
Approximately 90% of the Quinault Area of Interest had road densities of greater than 3 miles/square mile, the level at which streams cease to function properly. Road crossings were highest in the East Fork Satsop River and Black River watersheds with values of greater than 1 per mile of stream.

Roads can adversely affect stream ecosystems through multiple pathways. Due to increased imperviousness, roads indirectly bring about increased erosion rates in watersheds,[1] leading to altered stream discharge patterns, mass wasting, and increased sediment delivery to streams. Elevated fine sediment levels, identified as a limiting factor by the Chehalis Basin Salmon Habitat Restoration and Preservation Strategy, decrease the quality of spawning gravels.[2]

Road density values were over 2 miles/square mile in most watersheds outside Olympic National Park where the values were less than 1 mile/square mile. This is the direct result of the network of roads built notably for harvest of timber. Several studies have correlated road density or indices of roads to fish density and diversity.[3] Cederholm et al. found increases in fine sediment in fish-spawning habitat when road density exceeded 2.5% of the total basin area in the Clearwater watershed.[4] The proper functioning of salmon-bearing streams may be at risk when road densities exceed 2 miles of road per square mile of area and cease to function properly at densities over 3 miles per square mile.[5] A vast majority of watersheds in the Quinault Area of Interest had road densities that exceeded this value.

At road crossings, roads can directly impact stream ecosystems, for example by altering stream geomorphology. Road crossings were highest in the East Fork Satsop River and Black River watersheds (near the I-5 corridor) with values of over 1 per mile of stream. Crossings were lowest in watersheds within the National Park.





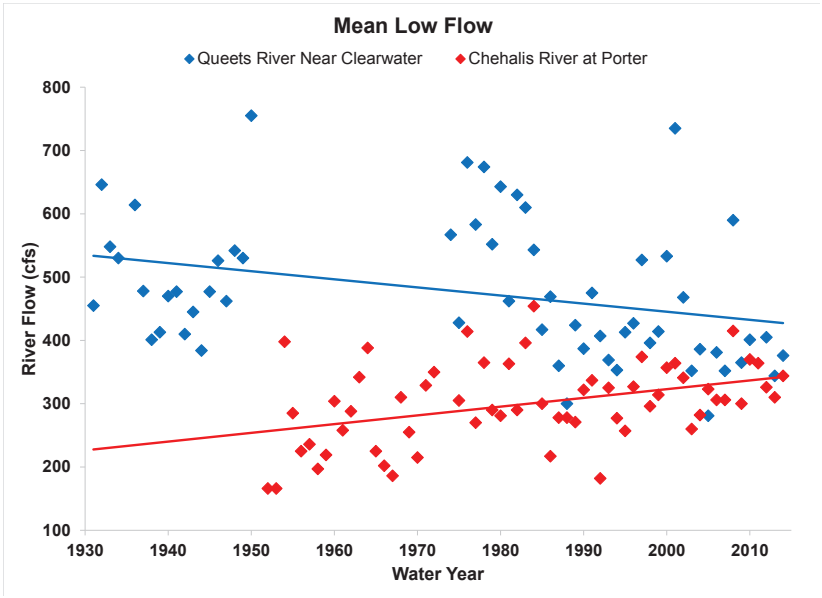
Data Sources: SSHIAP 2004,[6] USGS 2014,[7] WADNR 2014c,[8] WADNR 2014d,[9] WADOT 2012,[10] WAECY 2011a[11]

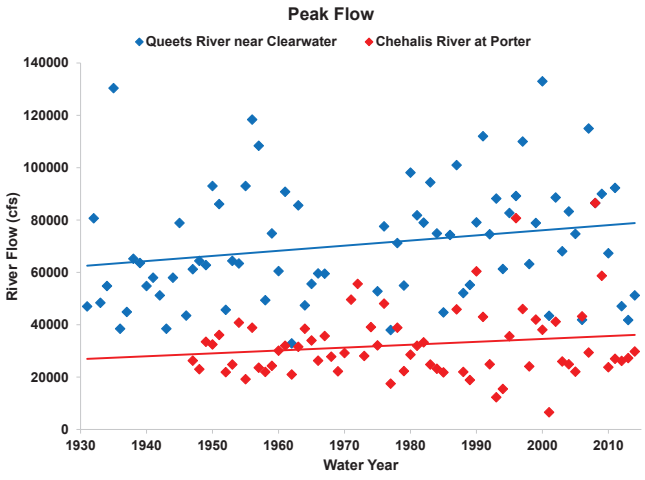
Streamflow

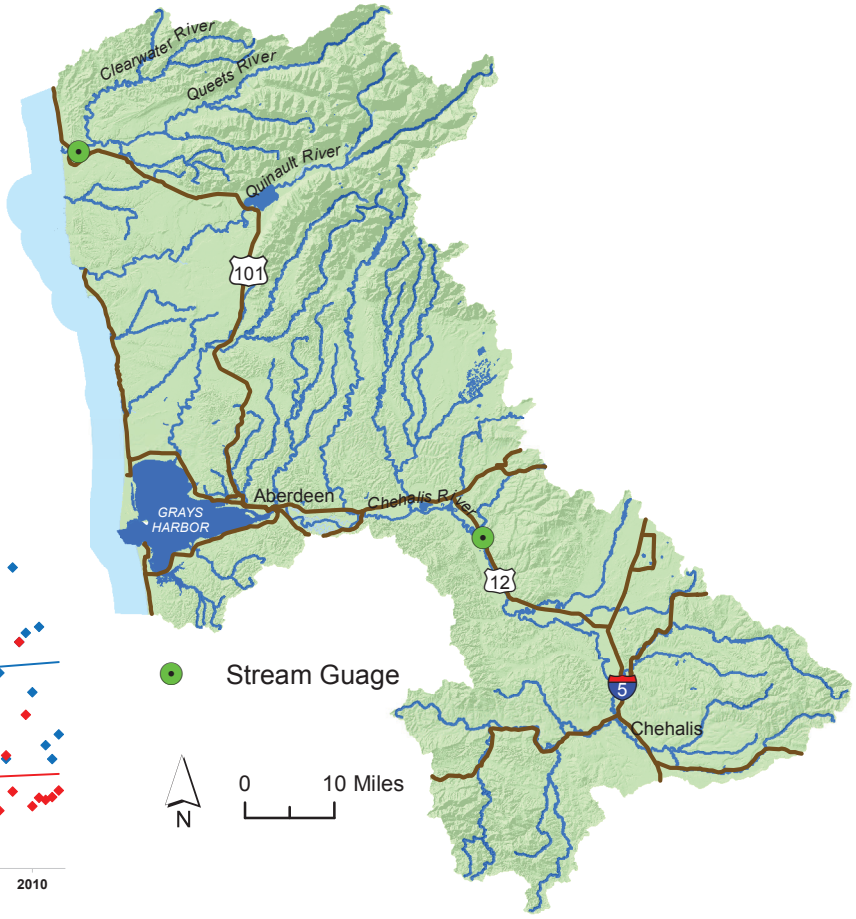
Peak flows for the glacier-fed Queets River show an increasing trend over time, while mean low flows show a decreasing trend. In the rain-dominated Chehalis River, both peak flows and mean low flows are increasing. If these trends continue as a result of climate change, the altered streamflows may have a significant impact on salmon populations.

Streamflow data are important in determining the instream resources available for fish survival and productivity. The variation and timing of average streamflows plotted for the Queets River near Clearwater and the Chehalis River at Porter show a similar pattern of peak flows in the winter months and low flows in the summer months. However, while the winter peak flow values were similar for both rivers, the summer low flows were consistently lower for the Chehalis. The lower summer flows in the Chehalis were likely the result of diversions for irrigation and domestic use, as well as groundwater withdrawals, which typically increase in the drier and warmer summer months. Low streamflows have been identified as a factor limiting salmonid production in the Chehalis.[1]

Peak flows for the glacier-fed Queets River show an increasing trend over time while mean low flows show a decreasing trend. This means that in the days of lowest flow, it was carrying less water than before. One major concern is the loss of glaciers and spring snow melt to refill the groundwater and replenish the surface flows. The system changing to a rain-dominated system may have a significant impact on the fisheries. In the rain-dominated Chehalis River, both peak flows and mean low flows show an increasing trend, meaning that in the days of lowest flows, it was carrying more water. If these trends continue as a result of climate change, the altered streamflows (as well as warming summertime stream temperatures) will likely reduce the reproductive success of salmon populations.[2]







Data Sources: SSHIAP 2004,[3] USGS 2015a,[4] USGS 2015b,[5] WADOT 2012,[6] WAECY 2011a[7]

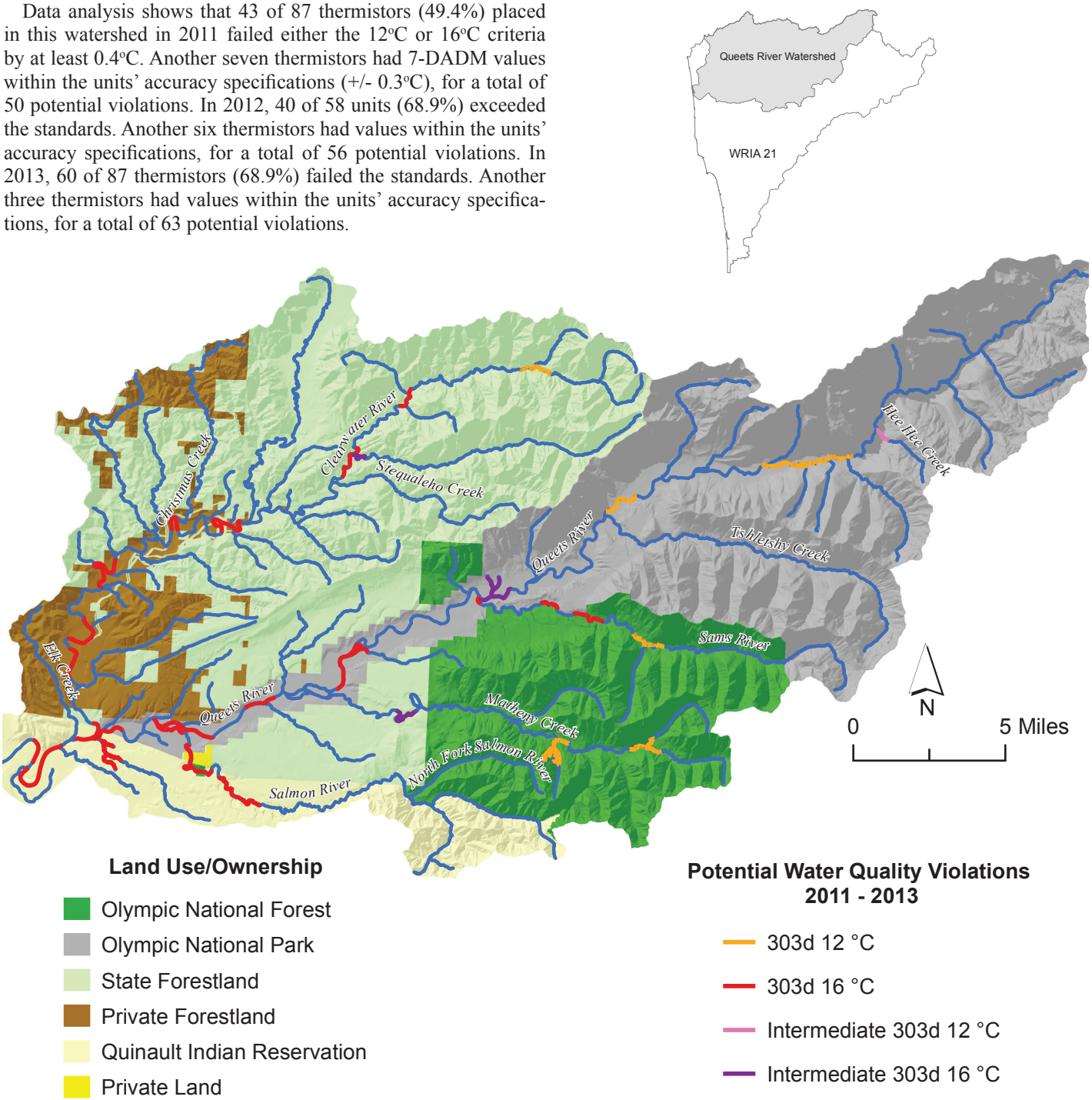
Queets River Watershed Water Temperature

Between 2011 and 2013, there were widespread water temperature impairments in the Queets River watershed that exceeded Washington state numeric water quality standards. These violations, likely caused by forest practice activities and glacier loss, will have an impact on salmonid production in the watershed.

Water temperature monitoring throughout the Queets River watershed was carried out between 2011 and 2013 to determine compliance with water quality standards for surface waters of the State of Washington.[1] The temperature values were used to determine compliance for stream reaches with designated uses of "Char Spawning and Rearing" (7-DADM or 7-day average of the daily maximum temperatures of 12°C) and "Core Summer Salmonid Habitat" (7-DADM of 16°C).

Data analysis shows that 43 of 87 thermistors (49.4%) placed in this watershed in 2011 failed either the 12°C or 16°C criteria by at least 0.4°C. Another seven thermistors had 7-DADM values within the units' accuracy specifications (+/- 0.3°C), for a total of 50 potential violations. In 2012, 40 of 58 units (68.9%) exceeded the standards. Another six thermistors had values within the units' accuracy specifications, for a total of 56 potential violations. In 2013, 60 of 87 thermistors (68.9%) failed the standards. Another three thermistors had values within the units' accuracy specifications, for a total of 63 potential violations.

These potential violations are likely caused by forest practice activities and glacier loss. Insufficient accumulation of snow in the glacier during winter results in low spring flow of glacier water to cool surface waters in warmer summer months. Salmonid fish in general and bull trout in particular require cool and well-oxygenated water, and these widespread water temperature impairments will have an impact on fish production in the Queets River watershed.



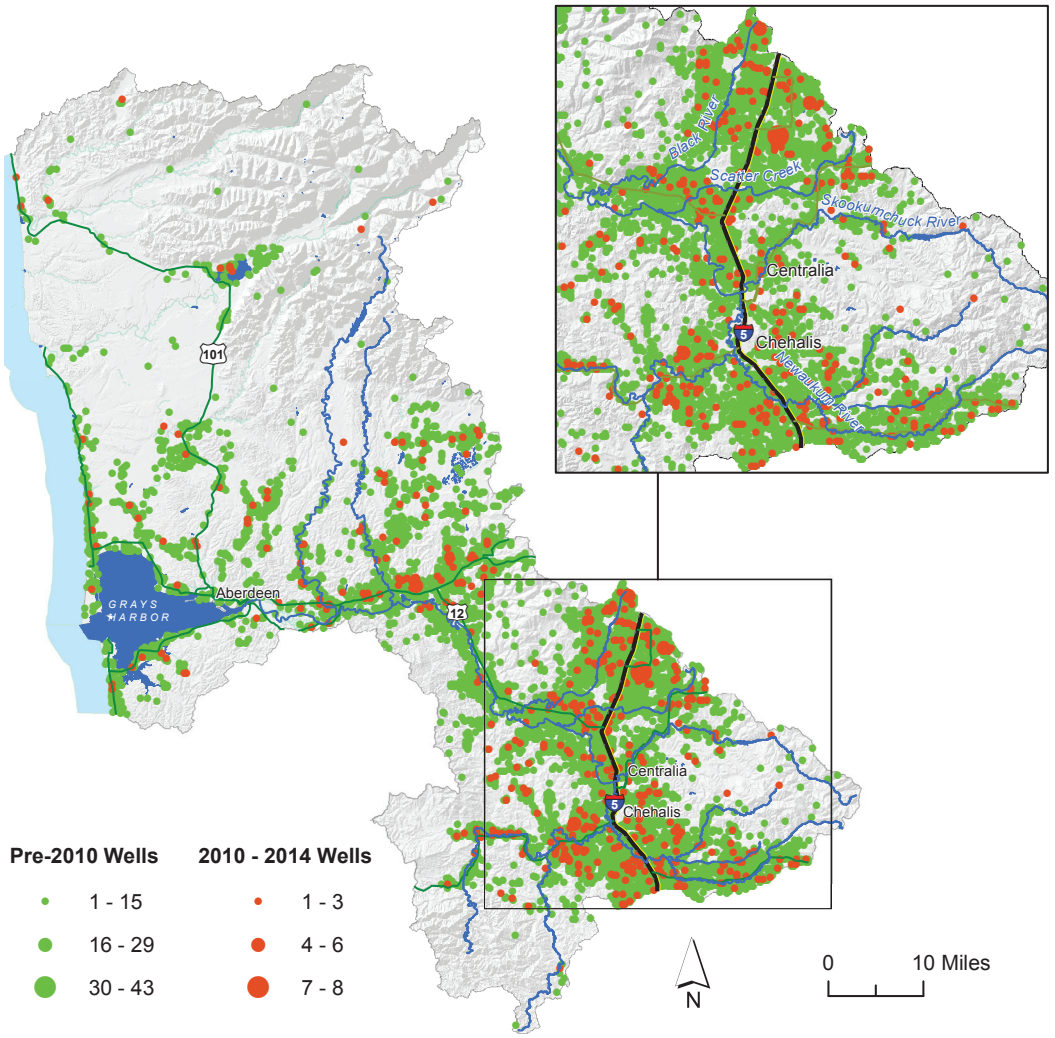
Data Sources: Quinault 2013,[2] SSHIAP 2004,[3] WADNR 2014a,[4] WADNR 2014b,[5] WADOT 2013,[6] WAECY 2000,[6] WAECY 2011a[7]

Water Wells

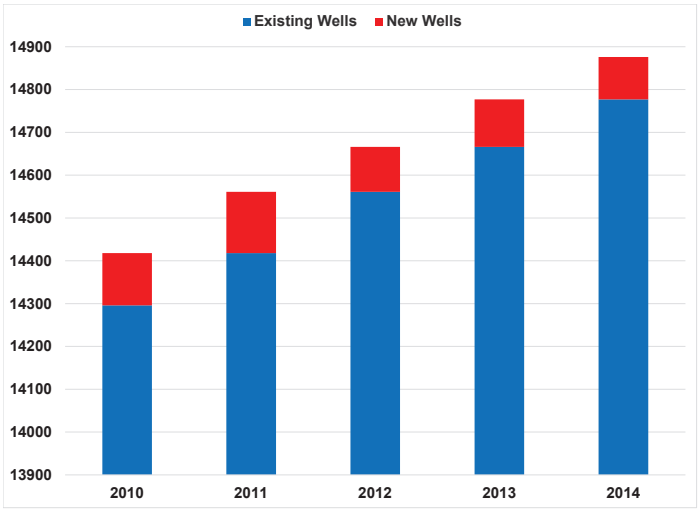
Currently, there are 14,876 water wells that may affect groundwater supply and instream flows in the Quinault Area of Interest. Between 1980 and 2009, 9,991 wells were completed in this Area of Interest, at a rate of about 344 new wells per year. Since 2009, 580 wells have been added at a lower rate of about 116 new wells per year.

Water wells are a source of water for many landowners. Although each well withdraws a relatively small amount of water, their cumulative impact can be significant and affect water quality, salmonid habitat and instream flows. The Chehalis Basin Salmon Habitat Restoration and Preservation Strategy identified low summertime flows in some sub-basins as a problem.[1] An earlier assessment found that in many streams and rivers, minimum streamflows are not met on many days from July through October.[2] Because very little water is used for agriculture or urban purposes in the Queets-Quinault basin, water withdrawal impacts there are expected to be low.[3]

There are currently 14,876 wells in the Quinault Area of Interest. The majority of wells are in the higher population areas of around Aberdeen, Centralia, Chehalis, and the I-5 corridor as well as in the agriculture areas, particularly in the upper Chehalis basin. Between 1980 and 2009, 9,991 wells were completed in the Quinault Area of Interest at a rate of about 344 new wells per year. Between 2010 and 2014, an additional 580 wells were added at a rate of about 116 new wells per year. Although the total number of wells has increased since 2010, the rate of increase has slowed compared to the pre-2010 period. The reduced rate of increase for wells may be the result of a slower population growth, a lesser dependence on wells for their water supply by landowners, the result of a slowdown in economic activities during that time period, or a combination of these factors.



Many streams in the Chehalis basin, including Scatter Creek, as well as Black, Skookumchuck and Newaukum rivers, are closed to further consumptive appropriations in the summer.[4] The impact of wells is expected to be greater in those areas where streamflows already do not meet regulatory minimums.



Data Sources: SSHIAP 2004,[5] WADOT 2012,[6] WAECY 2011a,[7] WAECY 2015[8]

Citations

Chapter Summary

1 Phinney, L. & P. Bucknell. 1975. A Catalog of Washington Streams and Salmon Utilization, Volume 2: Coastal Region. Olympia, WA: Washington Department of Fisheries.

2 Chehalis Basin Strategy. 2014. Governor's Chehalis Basin Workgroup Recommendation Report. Prepared by the William D. Ruckelshaus Center, a joint effort of the University of Washington and Washington State University.

3 Chehalis Basin Partnership. 2010. Chehalis Basin Level 1 Assessment. Olympia, WA: Envirovision Corporation.

3 Smith, C. & J. Caldwell. 2001. Salmon and Steelhead Habitat Limiting Factors in the Washington Coastal Streams of WRIA 21. Lacey, WA: Washington State Conservation Commission.

4 Smith, C. & M. Wegner. 2001. Salmon and Steelhead Habitat Limiting Factors: Chehalis Basin and Nearby Drainages, Water Resource Inventory Areas 22 and 23. Lacey, WA: Washington State Conservation Commission.

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1 Phinney, L. & P. Bucknell. 1975. A Catalog of Washington Streams and Salmon Utilization, Volume 2: Coastal Region. Olympia, WA: Washington Department of Fisheries.

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5 Smith, C. & J. Caldwell. 2001. Salmon and Steelhead Habitat Limiting Factors in the Washington Coastal Streams of WRIA 21. Lacey, WA: Washington State Conservation Commission.

6 Smith, C. J. and M. Wegner. 2001. Salmon and Steelhead Habitat Limiting Factors: Chehalis Basin and Nearby Drainages, Water Resource Inventory Areas 22 and 23. Washington State Conservation Commission, Lacey, WA.

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

8 USFWS. 2014. Polygons of FWS Approved Boundaries. Falls Church, VA: U.S Fish and Wildlife Service.

9 WADNR. 2014a. Washington State DNR Managed Land Parcels. Olympia, WA: Washington Department of Natural Resources.

10 WADNR. 2014b. Washington State Non-DNR Major Public Lands (NDMPL) Polygons. Olympia, WA: Washington Department of Natural Resources.

11 WADOT. 2012. Linear representation of Washington State Routes (GIS Feature Class SR500kLRSSPS). Olympia, WA: Washington Department of Transportation.

12 WADOT. 2013. Polygons depicting the boundaries of Tribal Lands in Washington State. Olympia, WA: Washington Department of Transportation.

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

14 WAECY. 2011a. 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.

15 WAECY. 2013. City Boundaries and Urban Growth Areas Polygons. Olympia, WA: Washington Department of Ecology.

Forest Cover Conditions

1 Meehan, W., ed. 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19.

2 Booth, D., D. Hartley & C. Jackson. 2002. Forest cover, impervious-surface area, and the mitigation of stormwater impacts. Journal of the American Water Resources Association 38(3):835-845.

3 Smith, C. & M. Wegner. 2001. Salmon and Steelhead Habitat Limiting Factors: Chehalis Basin and Nearby Drainages, Water Resource Inventory Areas 22 and 23. Lacey, WA: Washington State Conservation Commission.

4 Chehalis Basin Partnership. 2010. The Chehalis Basin Salmon Habitat Restoration and Preservation Strategy for WRIA 22 and 23. The Chehalis Basin Partnership, Habitat Work Group.

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

6 USGS. 2014. Watershed Boundary Dataset 12-Digit (Sixth Level) Hydrologic Unit Codes (HUCs) Polygons. Downloaded from Washington Department of Ecology. U.S. Geological Survey, in cooperation with others.

7 WADOT. 2012. Linear representation of Washington State Routes (GIS Feature Class SR500kLRSSPS). Olympia, WA: Washington Department of Transportation.

8 WAECY. 2006. C-CAP Land Cover. Modified from National Oceanographic and Atmospheric Administration (NOAA) Coastal Services Center (CSC)/Coastal Change Analysis Program (C-CAP). Olympia, WA: Washington Department of Ecology.

9 WAECY. 2011a. 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

10 WAECY. 2011b. C-CAP Land Cover. Modified from National Oceanographic and Atmospheric Administration (NOAA) Coastal Services Center (CSC)/Coastal Change Analysis Program (C-CAP). Olympia, WA: Washington Department of Ecology.

Impervious Surface

1 Schueler, T. 2003. Impacts of impervious cover on aquatic systems. Watershed protection research monograph no. 1. Ellicott City, MD: Center for Watershed Protection.

2 NLCD. 2006. National Land Cover Dataset Percent Developed Impervious. 2011 edition. Multi-Resolution Land Characteristics.

3 NLCD. 2011. National Land Cover Dataset Percent Developed Impervious. 2011 edition. Multi-Resolution Land Characteristics.

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

5 USGS. 2014. Watershed Boundary Dataset 12-Digit (Sixth Level) Hydrologic Unit Codes (HUCs) Polygons. Downloaded from Washington Department of Ecology. U.S. Geological Survey, in cooperation with others.

6 WAECY. 2011a. 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.

Impact of Culverts on Habitat

1 Cederholm C., L. Reid & E. Salo. 1981. Cumulative effects of logging road sediment on Salmonid populations in the Clearwater River, Jefferson County, Washington. In: Salmon Spawning Gravel: a Renewable Resource in the Pacific Northwest Proceedings, pp. 38–74. Pullman, WA: Washington State University, State of Washington Water Research Center.

2 Furniss, M., T. Roelofs & C. Yee. 1991. Road construction and maintenance. In: W. Meehan, ed. Influences of forest and rangeland management on salmonid fishes and their habitats. Bethesda, MD: American Fisheries Society, Special Publication 19. pp. 297-324.

3 Chehalis Basin Partnership. 2010. The Chehalis Basin Salmon Habitat Restoration and Preservation Strategy for WRIA 22 and 23. The Chehalis Basin Partnership, Habitat Work Group.

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

5 WADNR. 2014c. Washington State Road Maintenance and Abandonment Planning (RMAPs) Points. Olympia, WA: Washington Department of Natural Resources.

6 WADOT. 2012. Linear representation of Washington State Routes (GIS Feature Class SR500kLRSSPS). Olympia, WA: Washington Department of Transportation.

7 WAECY. 2011a. 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.

The Impact of Road Densities and Crossings

1 Beschta, R. 1978. Long-term patterns of sediment production following road construction and logging in the Oregon Coast Range. Water Resources Research 14. pp 1011-1016.

2 Chehalis Basin Partnership. 2010. The Chehalis Basin Salmon Habitat Restoration and Preservation Strategy for WRIA 22 and 23. The Chehalis Basin Partnership, Habitat Work Group.

3 Gucinski, M., M. Furniss, R. Ziemer & M. Brookes. 2001. Forest Roads: A Synthesis of Scientific Information. Gen. Tech. Rep. PNW-GTR-509. Portland, OR: United States Department of Agriculture, Forest Service, Pacific Northwest Research Station.

4 Cederholm, C., L. Reid & E. Salo. 1981. Cumulative effects of logging road sediment on Salmonid populations in the Clearwater River, Jefferson County, Washington. In: Salmon Spawning Gravel: a Renewable Resource in the Pacific Northwest Proceedings. Pullman, WA: Washington State University, State of Washington Water Research Center. pp. 38–74.

5 NMFS. 1996. Coastal Salmon Conservation: Working Guidance for Comprehensive Salmon Restoration Initiatives on the Pacific Coast. Washington, DC: National Marine Fisheries Service.

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

7 USGS. 2014. Watershed Boundary Dataset 12-Digit (Sixth Level) Hydrologic Unit Codes (HUCs) Polygons. Downloaded from Washington Department of Ecology. U.S. Geological Survey, in cooperation with others.

8 WADNR. 2014c. Washington State Road Maintenance and Abandonment Planning (RMAPs) Points. Olympia, WA: Washington Department of Natural Resources.

9 WADNR. 2014d. Washington State DNR Transportation Polylines. Olympia, WA: Washington Department of Natural Resources.

10 WADOT. 2012. Linear representation of Washington State Routes (GIS Feature Class SR500kLRSSPS). Olympia, WA: Washington Department of Transportation.

11 WAECY. 2011a. 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.

Streamflow

1 Smith, C. & M. Wegner. 2001. Salmon and Steelhead Habitat Limiting Factors: Chehalis Basin and Nearby Drainages, Water Resource Inventory Areas 22 and 23. Lacey, WA: Washington State Conservation Commission.

2 Mantua, N., I. Tohver & A. Hamlet. 2009. Impacts of Climate Change on Key Aspects of Freshwater Salmon Habitat in Washington State. In: Climate Impacts Group. 2009. The Washington Climate Change Impacts Assessment. M. McGuire Elsner, J. Littell & L. Whitely Binder (eds). Seattle, WA: University of Washington, Joint Institute for the Study of the Atmosphere and Oceans, Center for Science in the Earth System.

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

4 USGS. 2015a. Online data from USGS gauge #12031000 at Chehalis River at Porter, WA. U.S. Geological Survey.

5 USGS. 2015b. Online data from USGS gauge #12040500 at Queets River near Clearwater, WA. U.S. Geological Survey.

6 WADOT. 2012. Linear representation of Washington State Routes (GIS Feature Class SR500kLRSSPS). Olympia, WA: Washington Department of Transportation.

7 WAECY. 2011a. 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.

Queets River Watershed Water Temperature

1 WAECY. 2012. Water Quality Standards for Surface Waters of the State of Washington, Chapter 173-201A WAC. Olympia, WA: Washington Department of Ecology, Water Quality Program. Available at http://www.ecy.wa.gov/biblio/0610091.html

2 Quinault Indian Nation. 2013. Queets River Watershed Water Temperature Dataset, 2011-2013. Quinault Indian Nation.

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

4 WADNR. 2014a. Washington State DNR Managed Land Parcels. Olympia, WA: Washington Department of Natural Resources.

5 WADNR. 2014b. Washington State Non-DNR Major Public Lands (NDMPL) Polygons. Olympia, WA: Washington Department of Natural Resources.

6 WADOT. 2013. Polygons depicting the boundaries of Tribal Lands in Washington State. Olympia, WA: Washington Department of Transportation.

7 WAECY. 2011a. 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.

Water Wells

1 Chehalis Basin Partnership. 2010. The Chehalis Basin Salmon Habitat Restoration and Preservation Strategy for WRIA 22 and 23. The Chehalis Basin Partnership, Habitat Work Group.

2 Ibid.

3 Smith, C. & J. Caldwell. 2001. Salmon and Steelhead Habitat Limiting Factors in the Washington Coastal Streams of WRIA 21. Lacey, WA: Washington State Conservation Commission.

4 Washington Administrative Code 173-522-050

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

6 WADOT. 2012. Linear representation of Washington State Routes (GIS Feature Class SR500kLRSSPS). Olympia, WA: Washington Department of Transportation.

7 WAECY. 2011a. 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.

8 WAECY. 2015. Water Well Logs Points. Olympia, WA: Washington Department of Ecology.